



**THE 5TH AFRICAN
ORGANIC
CONFERENCE
KIGALI, RWANDA**

DECEMBER 12 - 15, 2023

Theme :

Strengthening Resilient and Sustainable Food Systems in Africa through Organic Agriculture

Scientific Track Proceedings of the 5th African Organic Conference
December 12 – 15, 2023 in Marriott Hotel, Kigali-Rwanda



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AfrONet
African Organic Network

NOARA
Network of Organic Agriculture Researchers in Africa
شبكة الباحثين في الزراعة العضوية بـ إفريقيا

ISO FAR

International Society of Organic Agriculture Research



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– Network of Organic Agriculture Researchers in Africa (NOARA).

This publication has been edited externally.

ISBN: 978-978-60736-5-1 (Prints)

978-978-60736-0-6 (Online)

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NOARA

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



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 (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.

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Projet « Centre de Connaissances de l'Agriculture Biologique » Knowledge Centre for Organic Agriculture and Agroecology in Africa (KCOA) Knowledge Hub for Organic Agriculture and Agroecology in Africa (KHWA)

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Key information about the KCOA

The project is being implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

The project is based on the observation that the main actors in agricultural production, processing and marketing do not have easy and sufficient access to practical knowledge to implement and disseminate organic farming practices. In this sense, KCOA's approach is to help bridge the knowledge gap and create a continental network of Knowledge Hubs as an innovative strategy to promote organic agriculture in collaboration with stakeholders in the North, West, East, Central and Southern Africa regions.

GIZ is setting up 1 Knowledge Hub per region in partnership with African NGOs:

- **West Africa** : ENDA Pronat, Agrecol Africa, FENAB, NOAN, CNOP, Songhai Centre
- **East Africa**: Biovision Africa Trust
- **Southern Africa**: Sustainability Institute
- **North Africa**: SEKEM

Overall, the objective is that knowledge hub actors and their networks, in the regions of East, Southern Africa, West Africa, North Africa and Central Africa, **be strengthened in their role in promoting organic agriculture and agroecology.**

Introducing the KHWA

The *Knowledge Centre for Organic Agriculture and Agroecology in Africa (KHWA)* project supports the establishment of knowledge Hubs in organic farming and agroecology (AE) in the West, Eastern, Southern, Northern and Central African regions. The objective of the Network of Regional Knowledge Hubs for Organic Farming in Africa is to better integrate and promote local organic farming approaches and practices in agricultural systems.

For the West Africa Knowledge Hub (KHWA), activities revolve around three (3) fields of action, each coordinated by an organization, namely:

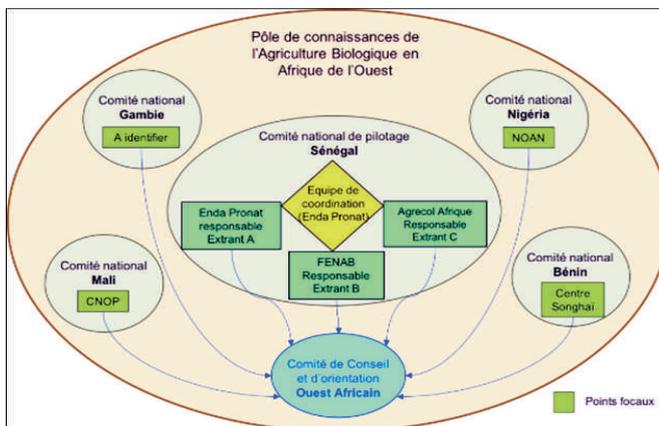
Enda Pronat, Head of Coordination of the Hub and Output A: The access of the actors of the knowledge hubs and their networks to technical and methodological knowledge for the promotion of organic agriculture and agroecology is improved.

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FENAB, Output B Manager: The skills of multipliers for the dissemination of OA/AE knowledge, concepts and good practices are strengthened.

AGRECOL Africa, Responsible for Output C The networking of AB and AE actors is strengthened. The technical implementation of activities in other KHWA countries is ensured by three (3) Institutional Focal Points (IFPs), namely: Songhai Center in Benin, CNOP in Mali and NOAN in Nigeria. For The Gambia, activities are implemented by output managers with the support of a local consultant.



Activities of Output A: Access to technical and methodological knowledge for the promotion of organic farming and agroecology for the promotion of organic farming and agroecology is improved for the actors of the knowledge hubs and their networks

Documented scientific knowledge

This is scientific and codified knowledge. The national knowledge managers, under the supervision of the regional manager, collect according to the identified needs: pest control, soil health, marketing options, organic certification and financing, and the specific needs of women in relation to organic agriculture and agroecology.

This will involve:

Identify the sources of collection in relation to these needs: these are the documents to be collected at the level of research, training and extension institutions, universities, NGOs, farmers' organizations, financing structures, resource persons (researchers, extension agents, production and processing companies, traders, etc.), carry out collection missions with these structures: Present the project, look for dynamics and synergies with the structure for a long-term partnership, Materialize the membership of the cluster. Understand internal knowledge validation procedures.

Traditional knowledge unknown to a large number of users, capitalized

In each country, the collection of endogenous knowledge from communities will be carried out by a collection team composed of an interviewer and a relay farmer. The interviewer is responsible for administering the guide (after having received training on the elaborate guide) and for finding avenues for further study if necessary, and the role of the relay farmer will be to facilitate contact and communication with the knowledge bearers (translation, confidence-building).

All this knowledge, after validation by a committee (composed of researchers and/or practitioners with a lot of experience in organic farming and agroecology) will be translated into knowledge products adapted (videos, technical sheets, podcasts...) for dissemination.



Output B Activities: Multipliers' skills for disseminating OA/AE knowledge, concepts and good practices are strengthened.

FENAB's concept of skills building and knowledge dissemination extends over the duration of the KCOA's Project. It is composed of 6 strategic areas of implementation.

This mechanism focuses on building the capacity of multipliers and disseminating knowledge through appropriate activities combining different approaches.

The multipliers (who are the target group of the project) include all those who have been selected during the mapping workshops and registered in the West African Multipliers database. They participate in the dissemination of recognized and validated knowledge on organic farming to farmers, farmers' associations, processors and consumers. Multipliers are trainers, well-trained farmer leaders, farmer facilitators, women processors, young organic entrepreneurs, extension agents, independent agro-ecological centre agents, young bloggers who are interested in organic farming, GSP controllers who do organic certification, etc. and that operate in the different organic ecological value chains.

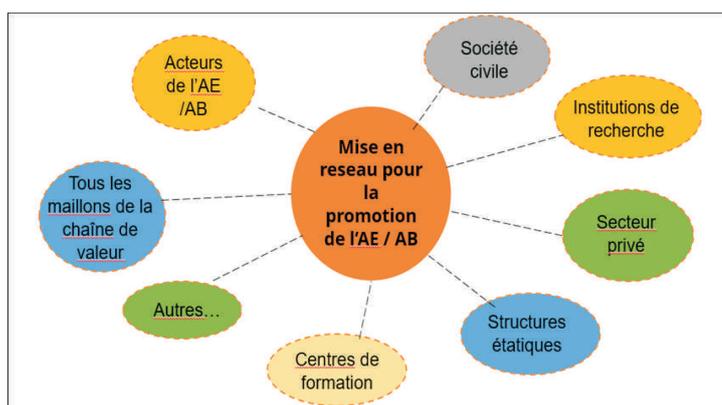


Activities of Output C: The networking of OA and AE actors is strengthened

This involves the establishment of local and/or national networks of actors in organic value chains in the 5 countries (Benin, Gambia, Mali, Nigeria and Senegal). To this end, the results of the studies/diagnoses carried out in all countries during the first phase of the project will be exploited... Based on the studies carried out, at least 1 key and priority organic product (value chain) will be targeted in each country.

Thus, the overall objective is to bring together the actors of these value chains (producers, processors, traders, consumers) in order to develop/strengthen these sectors.

The members of these networks will also facilitate the collection of endogenous knowledge, participate in its validation and sharing within their respective networks. (Outputs A and B).



Major activities of the KHWA

Output A: Access to Knowledge

- Community surveys to collect traditional knowledge
- Community feedback workshops to discuss the traditional knowledge collected
- Validation of knowledge
- Adapted Broadcast Media Productions



Output B: Knowledge Dissemination

- Training of Master Trainers
- Site Visits/Exchange Visits
- Capacity Building Workshops
- Scaling up training sessions
- Farmers' field schools
- Raising awareness among users through dissemination

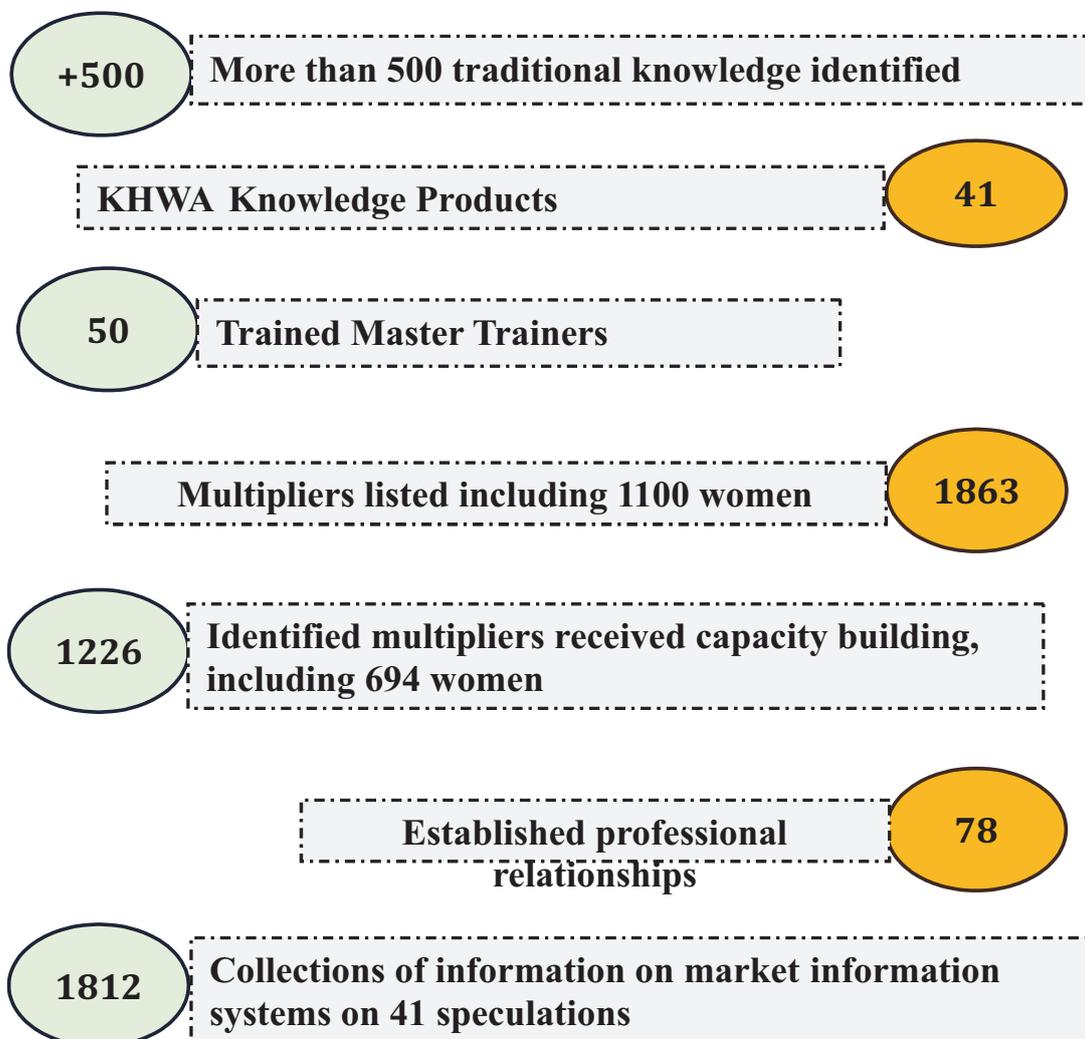


Output C: Networking of OA and AE actors

- Networking workshop for value chain actors
- Organic Weekend
- Support for PGS certification
- Participation in OA and AE promotion events



KHWA in figures







Promotion of Organic Market through Sales Promotion Strategy: An initiative of Ibadan Go Organic Multipurpose Cooperative Society, Nigeria

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Keywords:

Awareness,
Buy-two-get-one-free,
organic consumers,
promotion of organic products,
sales promotion.

Abstract

Organic agriculture, viz-a-viz the produce and products, as a recent innovation requires more awareness to attract patronage, therefore, the need to explore different kinds of strategies to achieve this. Ibadan Go organic Multipurpose Cooperative Society, Nigeria, dived into the use of sales promotion as a strategy to attract more people to organic produce /products, and it is hoped the experience could benefit other organic outfits across the continent. Good and catching fliers and posters were designed and hard copies produced to publicise the sales promotion widely. The soft posters and handbills were circulated on-line while hard copies were pasted in strategic places to sensitize the general public including the existing customers of organic produce about the organic promotion. This was done a week before the commencement of the sales promotion which ran for two weeks between December 14th and 31st, 2022 across all the sales outlets of Ibadan Go Organic Multipurpose Cooperative Society in Ibadan. The strategy was for customers to buy any two (2) produce/products and get one (1) for free. The free portion was made possible courtesy of Ecological Organic Agriculture Initiative. The sales promotion also features sensitization on the benefits of food grown using organic standards. The total number of customers patronizing the Ibadan Go Organic MCS market rose by 71% at the end of the promotion and the customers sustained months after the promo. It could therefore be concluded that floating a sales promotion for organic produce/products could attract more consumers.

Promotion du marché biologique grâce à une stratégie de promotion des ventes : une initiative de la société coopérative polyvalente Ibadan Go Organic, Nigeria

Résumé

L'agriculture biologique, à savoir les produits et les produits, en tant qu'innovation récente, nécessite une plus grande sensibilisation pour attirer le mécénat, d'où la nécessité d'explorer différents types de stratégies pour y parvenir. La société coopérative polyvalente biologique Ibadan Go, au Nigeria, s'est lancée dans l'utilisation de la promotion des ventes comme stratégie pour attirer davantage de personnes vers les produits biologiques, et on espère que l'expérience pourra profiter à d'autres entreprises biologiques à travers le continent. Des dépliants et des affiches attrayants et attrayants ont été conçus et des copies papier ont été produites pour faire connaître largement la promotion des ventes. Les affiches souples et les prospectus ont été diffusés en ligne tandis que des copies papier ont été collées à des endroits stratégiques pour

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Mots clés :

Sensibilisation,
Achetez-en deux,
obtenez-en un gratuit,
consommateurs bio,
promotion des produits biologiques,
promotion des ventes.

sensibiliser le grand public, y compris les clients existants de produits biologiques, à la promotion du bio. Cela a été fait une semaine avant le début de la promotion des ventes qui s'est déroulée pendant deux semaines entre le 14 et le 31 décembre 2022 dans tous les points de vente de la société coopérative polyvalente Ibadan Go Organic à Ibadan. La stratégie consistait pour les clients à acheter deux (2) produits/produits et à en obtenir un (1) gratuitement. La portion gratuite a été rendue possible grâce à l'Initiative pour l'agriculture biologique écologique. La promotion des ventes comprend également une sensibilisation aux avantages des aliments cultivés selon des normes biologiques. Le nombre total de clients fréquentant le marché Ibadan Go Organic MCS a augmenté de 71 % à la fin de la promotion et le nombre de clients s'est maintenu des mois après la promotion. On pourrait donc en conclure qu'une promotion des ventes de produits biologiques pourrait attirer davantage de consommateurs.

Introduction

Organic Agriculture has continued to gain ground due to its benefits of making healthy food available to people while also prioritizing environmental and biodiversity conservation (Adenle *et al.*, 2018). Organic Agriculture has been adjudged as the fastest growing agricultural system which is premised on its acceptability due to its benefits to man and the environment (FiBL, 2022). However, despite these huge benefits, the percentage of people that are aware and by extension patronize organic produce and products is still very low especially in the developing countries, therefore the need to promote awareness in order to increase the demand. One of the ways by which increased awareness and demand of a product could be achieved is by engaging on sales promotion (Hermiyenti and Wardi, 2018). Promotion has been considered as the set of marketing techniques or practices, marketing action, form of communication, aiming at increasing the volume of sales by securing the attention of potential buyers (Alexandrescu and Milandru, 2018). According to Gordon-Hecker (2020), promotion deals are the most widely used strategies to attract consumers (Bogomolova *et al.*, 2015).

One of the main promotional elements used in developing a firm's promotional program is sales promotion which is expected to increase purchasing decisions because it could have a significant influence on purchase satisfaction (Cuellar-Healey, 2013; Hermiyenti and Wardi, 2018). The findings of Brata *et al.* (2017) showed a strong positive correlation between promotion of a product and purchase decision of customers. It is possible for a good product to receive low demand because the consumers do not get information about it (Mothersbaugh *et al.*, 2007).

Some of the popularly known sales promotion tactics used are "Buy one, get one free" called BOGOF, or "Buy two and get the third free". These campaigns are useful when one needs to sell several products at once (Cuellar-Healey, 2013).

Ibadan Go Organic Multipurpose Cooperative Society is a group of organic agriculture value chain actors aiming at making healthy food available for the people in order to reduce the health challenges associated with chemical reduces inherent in food obtained from conventional agricultural as well as other integral environmental ordeal (Erhunmwunse, 2012). The Cooperative currently has different six sales point within Ibadan metropolis but patronage is still very low, therefore the need for promotion of organic products using the concept of sales promotion. The rational of this initiative is to attract much more people to organic produce and products. It is hoped that why the sales promotion attracts more people to the organic market the quality of the produce and products can keep them and make them regular consumers thereby increase the demand for organic agricultural produce/products.

Methodology

Good and catching fliers and posters were designed and hard copies produced to publicise the sales promotion events widely. The soft posters and handbills were circulated on-line while hard copies were pasted in strategic places to sensitize the general public including the existing customers of organic produce about the organic sales promotion. This was done a week before the commencement of the exercise.

The promo ran from December 14 to 31 across all the sales outlets of Ibadan Go Organic Multipurpose Cooperative Society in Ibadan. The strategy was for customers to buy any two (2) of our produce/products and get one (1) for free. Every consumer that purchases two of any organic produce / product was given one for free, courtesy of Ecological Organic Agriculture Initiative in Nigeria.

The produce / products that were involved in the promotion activity were jute mallow, celosia, amaranth, pineapple, plantain, ginger, radish, pawpaw, palm oil, chicken, cocoyam, potato, cucumber, catfish, turmeric, watermelon, mushroom and garri. These were supplied by different members of the Cooperative. In the course of the sales promotion exercise, there was continuous sensitization on the benefits of organic foods to man and also to the environment.

Results

A total number of 180 people participated in the sales promotion with 92 as new customers. The total number of customers patronizing the Ibadan Go Organic MCS market through the different outlets before the promotion was 158 while the total number of the customers rose to 270 at the end of the promo, giving rise to 71% increase in the number of customers (Figure 1). The analysis of the customers that patronised during the promo by gender and age is shown in Figure 2. The result shows that there are more female customers than the male while there more adults (>36 years of age) than youths. The more female could be because female are more involved in the preparation of food for the family. More adults being involved could also be because they have families to cater for. This is in line with the findings of Crane (2019) that females are more involved in purchase of food stuffs than male.

The new members have been added to the online (WhatsApp) market platform of the Ibadan Go Organic MCS, where they can access regular information on the organic market and place their order from time to time. The analysis of the organic produce and products sold within the promotion period is shown in Figure 3. These ranges from leaf vegetables, fruits, spices, palm oil to starch. The total volume of produce sold during the time of the promotion exercise worth USD 1,196 (Figure 4). The average sale per month in October and November was USD 215. Thus, the sales increased by 499% in December by the reason of the sales promotion. This is in line with the report of Hermiyenti and Wardi (2018) that promotion affects the purchase decision of customers. It also confirmed the submission of Bogomolova *et al.* (2015) that promotional deals are widely used strategies to lure customers into higher and more frequent purchases.

Post sales promotion experience: The analysis of the customers attracted by sales promotion exercise that still patronise the organic markets after the exercise is shown in Figure 5. About 50 % of the people who were drawn into the organic market through the sales promotion exercise still patronized the organic market. This suggests that the benefits derived from the organic produce and products gotten during the sales promotion exercise was worthwhile and hence attracted the consumers to the products. This is in line with the report of Basha *et al.* (2015) that organic food products possess high quality: better taste, increased shelf live, etc (Gopalakrishnan, R. (2019). The new customers still staying with the organic products could also have been influenced by the continuous awareness done during the sales promotion exercise.

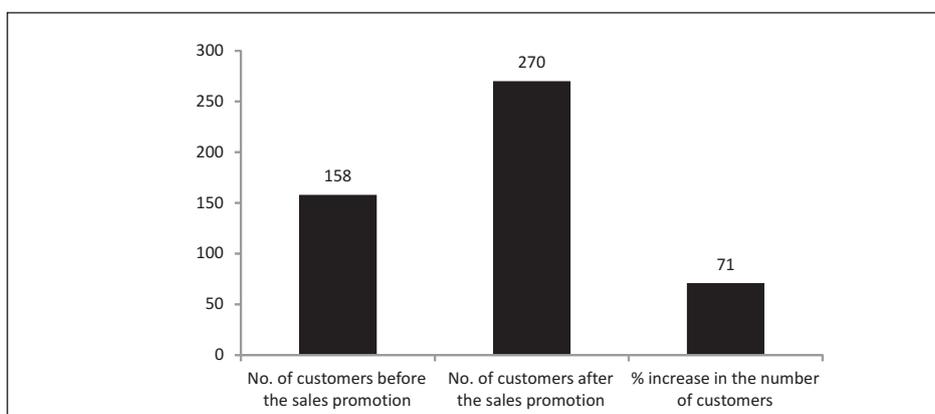


Figure 1: Percentage increase in the number of customers after the sales promotion

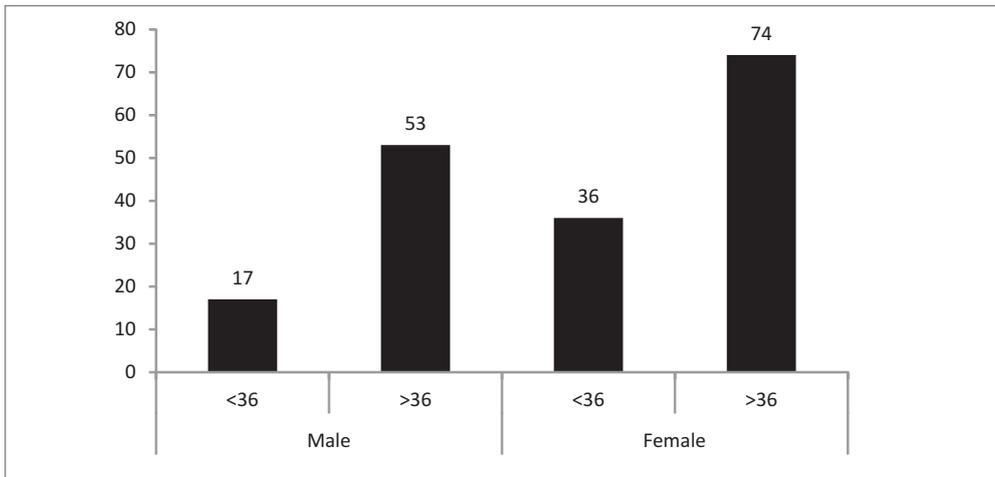


Figure 2: The analysis of the customers that patronised the organic markets during the sales promotion disaggregated by gender and age

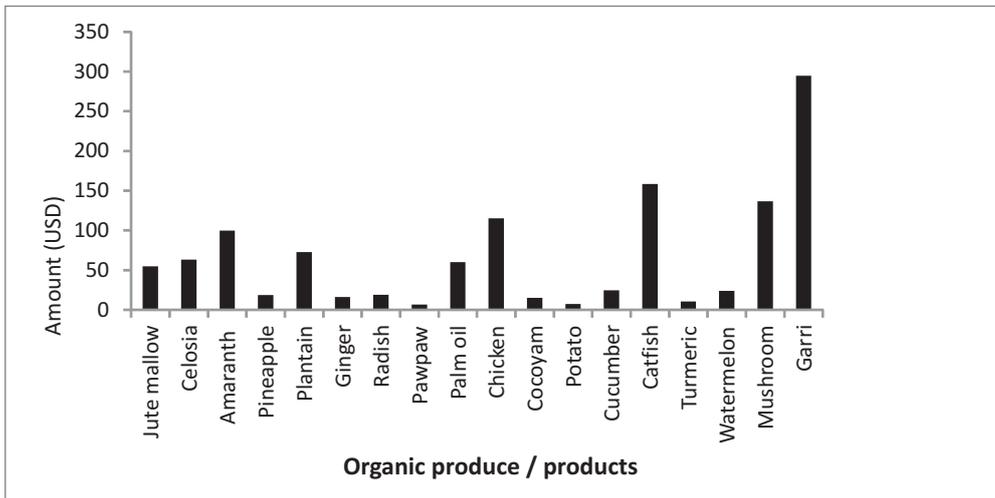


Figure 3: The analysis of the sales made within the sales promotion period

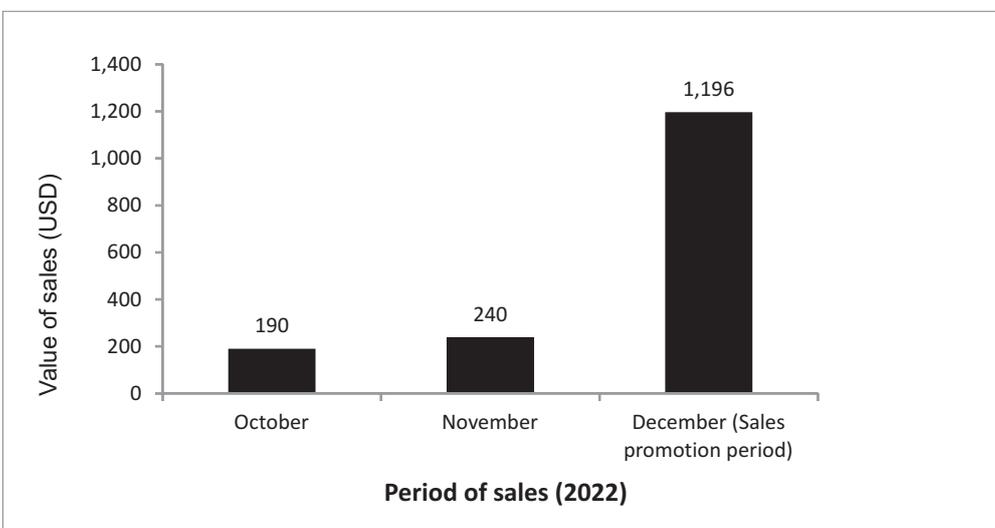


Figure 4: Sales report from October to December, 2022

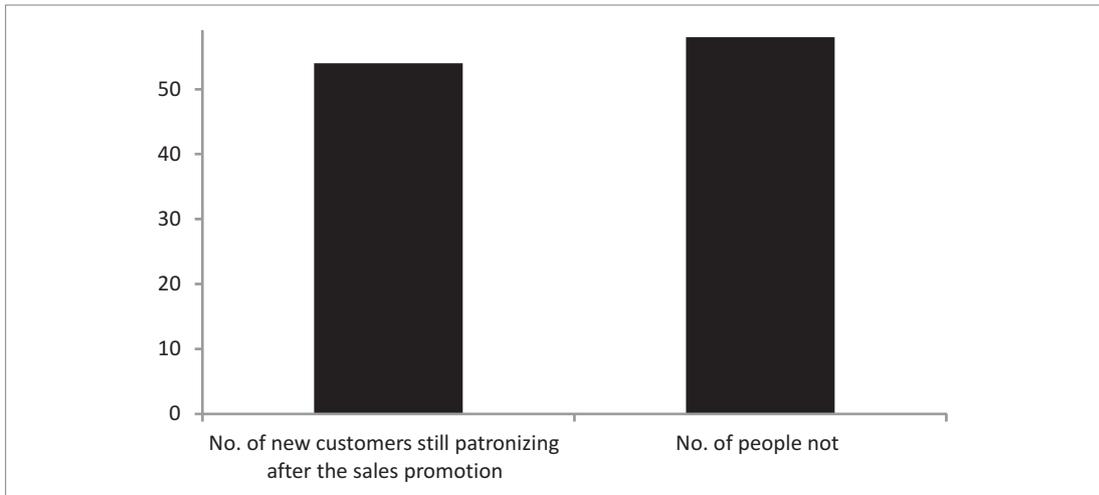


Figure 5: The analysis of the customers attracted by sales promotion exercise that still patronise the organic markets after the exercise

The poster features a top banner with images of various organic products including bananas, lemons, watermelon, a bag of flour, a jar of jam, and leafy greens. Below the banner, the text reads 'Ibadan Organic Multipurpose Cooperative Society'. The main promotion is 'DECEMBER ORGANIC PROMO' with a 'BUY 2 GET 1 FREE' offer. The dates are 'Wed., 14TH to Wed., 28TH, DECEMBER, 2022' and the time is '10am Daily'. The venues listed are: University Health Services Centre (Jaja), UI (Wednesdays and Fridays); University of Ibadan Community Market, Teaching and Research Farm Outlet, Abadina (Thursdays); Oyo State Ministry of Agric, Secretariat Agodi Ibadan (Thursdays); and Barth Road, Beside Saint Anne's Hostel, UI. (Tuesdays and Fridays). A red circular badge states 'OFFER VALID while stocks last T&C Apply'. A list of available products includes Vegetables, Fruits, and Garri. Contact information includes email: ibadangoorganic@gmail.com, Twitter: [ibadangoorganic](https://twitter.com/ibadangoorganic), and Instagram: [ibadangoorganic](https://www.instagram.com/ibadangoorganic).

Posters for the organic sales promotion

Conclusion

The need to raise awareness on the organic market especially in the developing countries cannot be overemphasized because the sector is still evolving. This led to Ibadan Go Organic MCS, Ibadan Nigeria exploring the potential of sales promotion strategy to stimulate people to know and patronage organic products. The result of the sales promotion exercise shows an increase in the number of customers patronising organic produce and products and by extension in the volume of sales. Thus, sales promotion strategy could be recommended for other organic market outfits to increase the visibility of organic market.

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Published by:





Acceptability of Carrot-fortified and Vanilla flavoured Cakes among Visitors in Botanical Garden, University of Ibadan

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Keywords:

Acceptability,
Cake,
Carrot fortified,
Organoleptic,
Vanilla flavoured

Abstract

This study investigated the awareness and acceptability of Carrot-fortified Cake in comparison with the popular Vanilla flavoured Cake among visitors in the Botanical Garden, University of Ibadan. *Carrot cake* is made from wheat flour fortified with Carrot rich in Vitamin A, there is low awareness on the product, the nutritional composition and its health benefits. Artificial additives and preservatives are commonly used in the preparation of food. Literatures showed that use of organic micronutrients has not been well utilized in the preparation of food especially in baking which is an aspect of cooking methods. This study provided information on the use of organic micronutrients for the acceptability and consumption preference by the consumers, which should be highly encouraged and promoted in food preparation. A hundred samples of structured sensory evaluation form were administered to respondents comprising of visitors in Botanical Garden, University of Ibadan to assess the organoleptic properties of carrot and vanilla cake and to determine the most preferred samples of the two snacks using purposive sampling. The findings showed that Carrot-fortified Cake was ranked higher in appearance 53%, taste 46%, aroma 46%, texture 43%, overall acceptability 40%, when compared to Vanilla flavoured Cake in appearance 44%, taste 34%, aroma 38%, texture 22%, and overall acceptability 18% based on the 7 hedonic scale rating. However, research should be carried out on the use of natural preservatives in food preparation.

Acceptabilité des gâteaux enrichis de carottes et aromatisés à la vanille parmi les visiteurs du jardin botanique de l'Université d'Ibadan

Résumé

Cette étude a examiné la notoriété et l'acceptabilité du gâteau enrichi aux carottes par rapport au gâteau aromatisé à la vanille populaire parmi les visiteurs du jardin botanique de l'Université d'Ibadan. Le gâteau aux carottes est fabriqué à partir de farine de blé enrichie en carottes riches en vitamine A, il y a une faible sensibilisation. sur le produit, la composition nutritionnelle et ses bienfaits pour la santé. Les additifs artificiels et les conservateurs sont couramment utilisés dans la préparation des aliments. La littérature a montré que l'utilisation de micronutriments organiques n'a pas été bien utilisée dans la préparation des aliments, en particulier dans la pâtisserie, qui constitue un aspect des méthodes de cuisson. Cette étude a fourni des informations sur l'utilisation de micronutriments organiques pour l'acceptabilité et la préférence de consommation des consommateurs, qui devraient être fortement encouragées et promues dans la préparation des aliments. Une centaine

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Mots clés :

Acceptabilité,
Gâteau,
Carotte enrichie,
Organoleptique,
Arôme vanille

d'échantillons de formulaires d'évaluation sensorielle structurée ont été administrés aux répondants comprenant des visiteurs du jardin botanique de l'université. d'Ibadan pour évaluer les propriétés organoleptiques du gâteau aux carottes et à la vanille et pour déterminer les échantillons les plus préférés des deux collations à l'aide d'un échantillonnage raisonné. Les résultats ont montré que le gâteau enrichi aux carottes était mieux classé en termes d'apparence 53 %, de goût 46 %, d'arôme 46 %, de texture 43 % et d'acceptabilité globale 40 %, par rapport au gâteau aromatisé à la vanille en termes d'apparence 44 %, de goût 34 %, d'arôme 38 %. texture 22 % et acceptabilité globale 18 % sur la base de l'échelle hédonique 7. Cependant, des recherches devraient être menées sur l'utilisation de conservateurs naturels dans la préparation des aliments.

Introduction

Carrot (*Daucus carota* L.) can be eaten raw, chopped, grated, or included to salads for colour or texture. Carrots are commonly chopped and boiled, or steamed, and cooked in soups and stews, as well as refined infant nourishments and a few pet nourishments (Van *et al.*, 2012). Carrot juice is also widely consumed, especially as a health drink, either blended alone or with other fruits and vegetables (Abid and Javed, 2018).

Cakes are high in sugar and rich in carbohydrates and fat but low in other nutrients, including protein, minerals, and vitamins (Roni *et al.*, 2021). The World Health Organization (WHO) reported snacks with high sugar and fat content as unhealthy. The demand for functional food with higher nutrients and minerals has led to the fortification of cake using organic nutritionally rich root vegetable (carrot) to enhance the micronutrient content of cakes.

The organoleptic characteristics of food/products are perceived through human sense organs. *Carrot cake* is made from wheat flour fortified with Carrot rich in Vitamin A. However, it has not gained a high level of acceptance from the public compared to other snacks (such as vanilla cake, red velvet cake, chin-chin etc.), hence, low awareness about the snack, the nutritional composition and its health benefits (Sowmiya and Narayanan, 2013). There is dearth of studies on carrot-fortified cake. Therefore, it was considered important to undertake this study. The study investigates the awareness and acceptability of Carrot-fortified Cake and Vanilla flavoured Cake.

Objective of the study

The general objective of this study was to investigate the awareness and acceptability of Carrot-fortified Cake and Vanilla flavoured Cake among visitors in the Botanical Garden, University of Ibadan, Ibadan, Oyo state, Nigeria. Specifically, the study determined:

1. awareness of Carrot-fortified Cake among visitors in Botanical Garden.
2. the consumption preference of the samples.
3. overall acceptability of carrot cakes among visitors in the Botanical Garden, University of Ibadan.

Materials and Methods

Study area: This research was carried out in Botanical Garden, located within the University of Ibadan campus which was founded in 1948 and situated 6 kilometres to the North of the city of Ibadan (7°26'N and 3°54'E) covering a total land area of 1,032 hectares (over 2,550 acres of land).

Materials: The ingredients used to produce samples include wheat flour, carrots, vanilla extract and others were purchased from Bodija market, Ibadan, Oyo State.

Preparation of carrot cake:

Ingredients and measurements

- 1000 grams of all-purpose flour
- 2 teaspoons baking powder
- ¼ teaspoon ground nutmeg
- ½ teaspoon salt
- 10 large eggs, room temperature
- ½ (100 grams) cup granulated sugar
- 1 teaspoon pure vanilla extract
- 300 grams of grated carrots.

Recipe: The *carrot cake* samples were prepared using the method described by Olubunmi et al., (2017) with slight modifications:

1. In a large mixing bowl, the dry ingredients; flour, baking powder, nutmeg, and salt were measured and mixed until well combined and then set aside.
2. Margarine or Butter and sugar were measured into a bowl and mixed using mixer until it is thoroughly mixed and fluffy.
3. In a separate mixing bowl, eggs were whisked together, and vanilla extract was added.
4. The fresh carrots were then grated using grater and squeezed out using hands to remove the water content. Then the grated carrot was added into the wet ingredients and mix until well combined.
5. Thereafter, bit by bit the wet ingredients were added to the mixed butter and sugar.
6. The dry ingredients and wet ingredients were then mixed with a whisk or rubber spatula until just combined to form a batter, making sure not to over mix the batter.
7. The oven was preheated at 180° C.
8. The cake pans were then well greased with margarine or butter to make it non-stick and set aside.
9. The cake batter was evenly poured into the prepared cake pans and baked in the oven for 40-45 minutes until the tops of the cakes are set, and a toothpick was inserted into the center to check the inside.
10. It was then removed from the oven and allowed to cool in the pans for about 20-25 minutes.
11. Once the cake was cooled, it was removed from the pans and the cake was allowed to finish cooling.
12. After cooling it was then cut into a square shape and packaged

Sensory Evaluation

Selection of panel of judges: The organoleptic analysis was conducted using a hundred consumers panel of judges made up of visitors within the Botanical Garden, University of Ibadan. Hundred (100) copies of structured questionnaires and sensory evaluation forms were administered to the respondents using purposive sampling techniques. The organoleptic evaluation involves the use of respondents' sense organs to assess the appearance, colour, taste, flavour, aroma, and texture of both samples using the 7-point hedonic scale of measure where 1 and 7 represent dislike extremely and like extremely respectively to rate the samples. Respondents were selected to rate the food items and whether they meet food standards and requirements.

Results and Discussion

Awareness of carrot-fortified cake among visitors in Botanical Garden:

From table 1, a larger percentage of the visitors to botanical garden like carrots (94%) and only few don't (6%), this corresponds to the research by Aruna and Sowmiya, (2014) that carrot is a generally acceptable food which can be serve as fruits or vegetables. While 17% preferred it added to food, 30% preferred it raw and 53% preferred it in both ways. Also, showed the level of awareness of carrot cake by respondents, most of the respondents were not aware of carrot cake (68%) while 32% were aware, and 78% of the respondents have not taken carrot cake before while 22% have tried it before. Out of the 22% that has taken it, it was recorded that 15% took it occasionally and 7% took it rarely. The table also shows that 86% knew what carrot cake are made from while 14% weren't sure.

Table 1: Distribution by respondents' awareness of carrot-fortified cake

Variable	Frequency	Percentage %
Do you like carrots?		
Yes	94	94
No	6	6
Total	100	100
How do you prefer to eat carrots?		
Boiled (Added to food)	17	17
Raw	30	30
Both	53	53
Total	100	100
Are you aware of carrot cake		
Yes	32	32
No	68	68
Total	100	100
Have you ever eaten carrot cake		
Yes	22	22
No	78	78
Total	100	100
If yes, how often do you eat it		
Occasionally	15	15
Rarely	7	7
No response	78	78
Total	100	100
Do you know what Carrot Cake is made from?		
Yes	86	86
No	0	0
Not Sure	14	14
Total	100	100

Consumption preferences of the samples: Figure 1 shows the distribution by respondents' consumption preference and price worth for carrot-fortified and vanilla-flavoured cakes.

For vanilla-flavoured consumption preference, 11% of the respondents will consume 1 piece, 43% will consume 2 Pieces, 2% will consume 3 pieces, 4% will consume 4 pieces, 37% will consume more than 5 pieces and 3% won't consume at all.

For carrot-fortified consumption preference, 7% will consume 2 Pieces, 17% will consume 3 pieces, 13% will consume 4 pieces and 63% will consume more than 5 pieces. The high level of consumption preference of carrot cake is determined by the organoleptic properties – appearance, taste, aroma, texture. The organoleptic attributes are key factors in determining food acceptability since consumers seek food with certain organoleptic properties. In addition, organoleptic properties of food have distinct and influential effects on food acceptability and consumption preference (Juliana, 2018), influencing the decision to either accept or reject a product (Kostyra *et al.*, 2016).

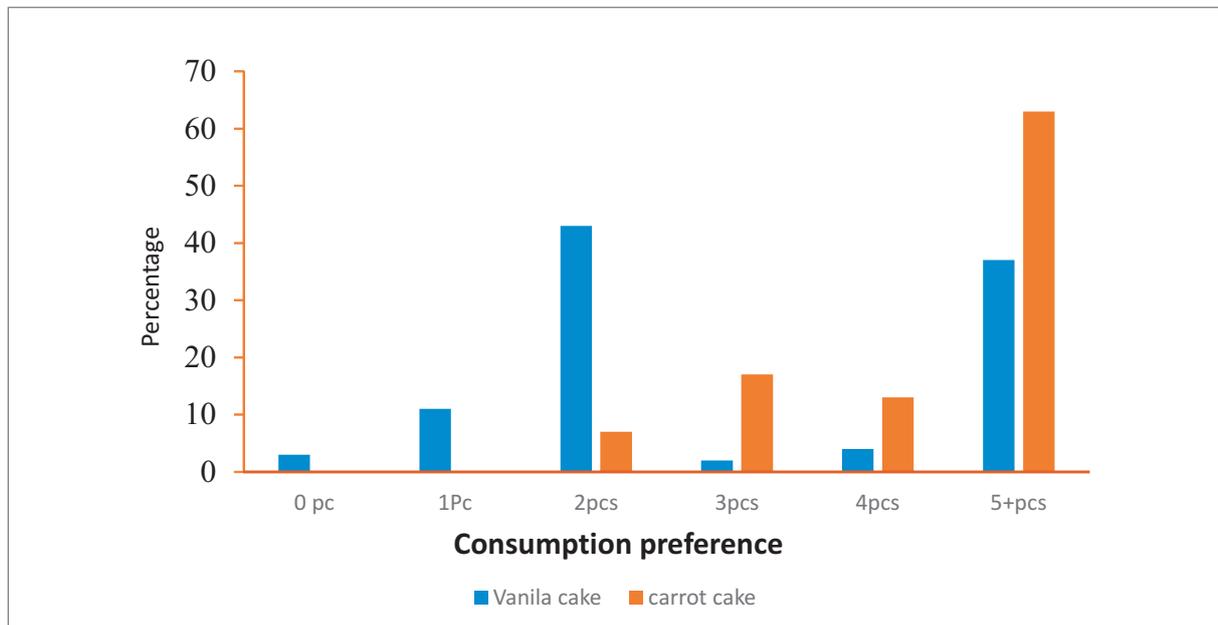


Figure 1: Percentage distribution of Respondents' Consumption Preference

Overall acceptability of carrot-fortified and vanilla flavoured cake: The overall acceptability of carrot cake and vanilla was assessed, and it was observed that 40% preferred carrot cake to a very large extent, 41% large extent, 17% little extent and 2% do not prefer carrot cake at all. Also, for vanilla cake, 18% preferred to a very large extent, 41% large extent, 37% little extent, 3% very little extent and 1% do not prefer vanilla cake at all. This implies that a larger percentage choose carrot cake above vanilla cake, most based on the texture and appearance of the carrot cake. The carrot cake is reported to be fluffier because of the moisture content added from the carrot and the appearance was attractive to the respondents as the carrot was not visible (Abid and Javed, 2018).

In terms of appearance, the result shows that both products had a high level of rating on the 6th rank of the hedonic scale in which they were liked moderately at 53% for carrot cake and 44% for vanilla cake. Appearance is the first organoleptic attribute seen by consumers when consuming a product and its characteristics play an important role in the acceptance or rejection of products (Dias *et al.*, 2012). It can be concluded that when someone is interested in the appearance of the samples of study, it's most likely that the person will have high expectations of their taste (Spence, 2015).

The average respondent's assessment of the taste of the samples ranked high from 6 – 7 on the hedonic scale for like moderately: 44% - carrot cake, 39% - vanilla cake and like extremely: 46% - carrot cake, 34% - vanilla cake respectively. Juliana (2018) stated that people tend to accept and eat food that contains their preferred taste concentration. While a product can have an attractive colour or appearance and packaging, the actual participation and continual consumption of it depends on the taste (Apata *et al.*, 2021). It can be concluded that carrot cake was rated higher than vanilla cake in terms of taste.

Aroma is another organoleptic parameter used in denoting the sensations of odour. Aroma of the two samples was rated highest from scale 5 to 7 on the 7 hedonic scale for like slightly: 19% - carrot cake, 28% - vanilla cake; like moderately: 46% - carrot cake, 38% - vanilla cake; and like extremely: 27% - carrot cake, 26% - vanilla cake; respectively. Aroma can be referred to as volatile compounds perceived by the odour receptors of olfactory tissues of the nasal cavity and a pleasant smell makes food delicious (Mian *et al.*, 2017).

The texture for carrot cake and vanilla cake on the 7 hedonic scale was rated highest at scales 5 to 7 for like slightly: 18% - carrot cake, 36% - vanilla cake; like moderately: 37% - carrot cake, 33% - vanilla cake; and like extremely: 43% - carrot cake, 22% - vanilla cake; respectively. The texture of food is conceptualized in various ways such as fluffiness, thickness, crispiness, crunchiness, firmness, and smoothness as stated by and is a strong indicator of food quality and affects food acceptability (Juliana, 2017).

Packaging is also an important aspect of product attributes that improve consumers' perception to consumption which either attracts or repels the consumer (Apata et al., 2021). Two different packaging was used for each sample to know which of the packaging material is best and acceptable by the consumers. White sealable transparent nylon was used to package carrot cake and cling film for vanilla cake. From the research, in terms of packaging carrot cake which was ranked highest at the 6th (33%) is higher than vanilla cake which was ranked highest at the 5th (28%). It can then be concluded that the most preferred packaging material is white sealable transparent nylon.

Visitors are willing to consume carrot cake in larger proportion because it's healthy and its "ready-to-eat" nature. All age group accepted the carrot-fortified cake. Therefore, it can be concluded that *carrot cake* was highly accepted by the visitors in the botanical garden in comparison with *vanilla cake* according to this study.

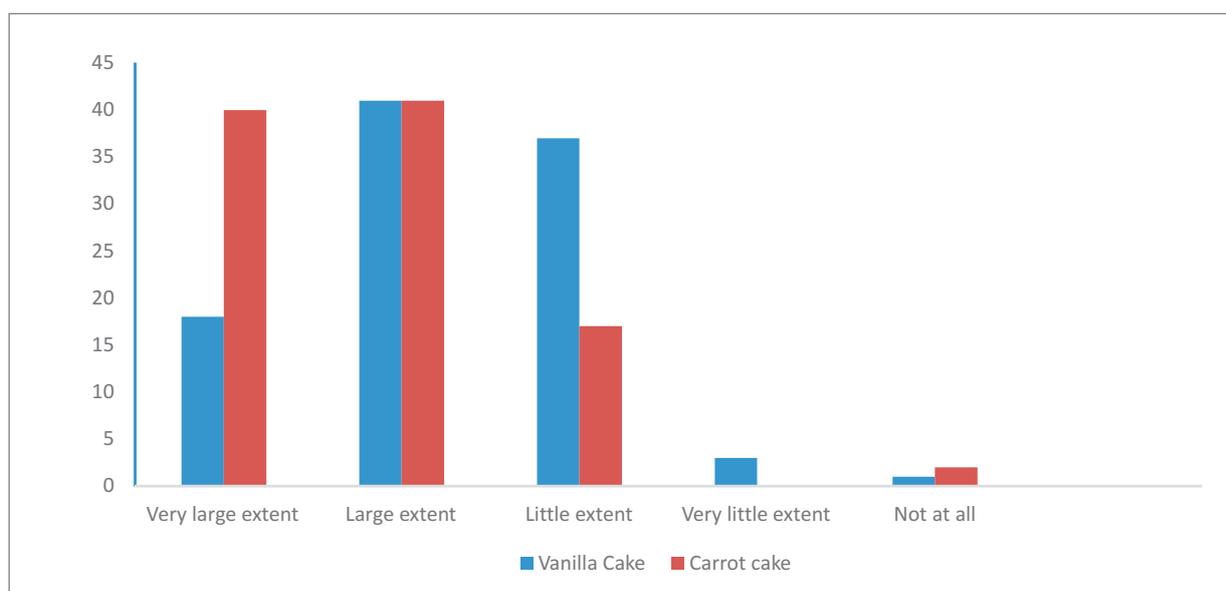


Figure 2: Percentage distribution of Respondents' Overall acceptability

Conclusion

The result from the study showed that carrot-fortified cake has high level of acceptability and consumption compared to vanilla-flavoured cake due to its appearance, taste, and texture, also there is low awareness on carrot-fortified cakes. Therefore, further study should be undertaken on the shelf life and mode of preservation without the use of artificial preservatives and natural preservatives such as vinegar, lemon and sea salt can be introduced at a recommended dosage.

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The Role of Agricultural Institutions in the Adoption of Organic Agriculture: A Case Study of the Federal College of Agriculture, Ibadan, Nigeria

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Keywords:

Adoption,
African Heads of States,
Agricultural institutions,
mainstreaming,
organic agriculture

Abstract

The need to embrace organic agriculture in Africa has been identified by the Heads of States and machineries have been put in place to mainstream Ecological Organic Agriculture (EOA) into national policies, strategies and programmes in Africa by an initiative called Ecological Organic Agriculture. This paper however presented the place of agricultural academic institutions in achieving this target with a case study of the Federal College of Agriculture, Ibadan, Nigeria. Academic institutions have been well positioned to share, promote and spread any new information or discovery. Thus, if agricultural institutions could play their role in promoting organic agriculture, their contribution could be so significant in achieving the set goal of the African Heads of States. The Federal College of Agriculture, Ibadan, Nigeria realizing the benefits of organic agriculture in the year 2020 seized the opportunity of the declaration by the African Heads of State and has been committed to the spreading of the good news in the country. The College established an organic farm, advocate for organic agricultural system and has a biweekly market through which many people now get to know about benefits of organic agriculture and patronize the market. The College is strategically positioned to run National Diploma in organic agriculture in the country by reason of the facilities and organic system already put in place. If all agricultural institutions in the continent could be practically involved in the campaign for organic agriculture in this manner, it will in no small way fast track the realization of the African Heads of States.

Le rôle des institutions agricoles dans l'adoption de l'agriculture biologique : une étude de cas du Collège fédéral d'agriculture, Ibadan, Nigeria

Résumé

La nécessité d'adopter l'agriculture biologique en Afrique a été identifiée par les chefs d'État et des mécanismes ont été mis en place pour intégrer l'agriculture biologique écologique (EOA) dans les politiques, stratégies et programmes nationaux en Afrique dans le cadre d'une initiative appelée agriculture biologique écologique. Cet article présente toutefois la place des établissements d'enseignement agricole dans la réalisation de cet objectif, avec une étude de cas du Collège fédéral d'agriculture d'Ibadan, au Nigeria. Les institutions académiques sont bien placées pour partager, promouvoir et diffuser toute nouvelle information ou découverte. Ainsi, si les institutions agricoles pouvaient jouer leur rôle dans la promotion de l'agriculture biologique, leur contribution pourrait être significative dans la réalisation de

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Mots clés :

Adoption,
chefs d'Étatafricains,
institutions agricoles,
intégration,
agriculture biologique

l'objectif fixé par les chefs d'Étatafricains. Le Collège fédéral d'agriculture d'Ibadan, au Nigeria, qui a pris conscience des avantages de l'agriculture biologique il y a trois ans, s'est rallié à la déclaration des chefs d'Étatafricains et s'est engagé à diffuser la bonne nouvelle dans le pays. L'université a créé une ferme biologique, milité en faveur de l'agriculture biologique et organise un marché hebdomadaire qui permet à de nombreuses personnes de connaître les avantages de l'agriculture biologique et de fréquenter le marché. L'école est stratégiquement positionnée pour dispenser le diplôme national d'agriculture biologique dans le pays en raison des installations et du système biologique déjà mis en place. Si toutes les institutions agricoles du continent pouvaient impliquer concrètement dans la campagne en faveur de l'agriculture biologique de cette manière, cela permettrait d'accélérer la réalisation des objectifs fixés par les chefs d'État africains en matière d'agriculture biologique.

Introduction

Importance of organic agriculture

The necessity for organically grown agricultural produce is based on the potential danger of possible contamination with synthetic chemicals (pesticides, herbicides, mineral fertilizers, etc) associated with those grown conventionally. Research has shown that the chemical residues from agricultural produce and products could be carcinogenic and little wonder cases of cancer is very alarming in the recent times (Zarean and Poursafa, 2019; Budreviciute *et al.*, 2020; WHO, 2022; Patel *et al.*, 2023).

Some unmonitored produce available around us could also be GMOs (genetically modified organisms) which could be injurious to our body and result into health problems (Erhunmwunse, 2012). It is against this background that there is a global campaign for 'organic produce', where use of synthetic chemicals is discouraged and a set of standards are followed in growing the produce with quality assurance system called certification to ensure that the farmers really abide by the four principles of organic agriculture (IFOAM, 2005; AyanfeOluwa *et al.* 2019). The aim is to provide 'safe food' for consumers, preserve the lives of farmers while conserving the ecology (Adenle *et al.*, 2018).

The decision of African Heads of States and the relevance of Agricultural Institutions in the achievement

Earlier in 2010, the African Heads of States and Governments made a positive decision on organic farming [EX.CL/Dec. 621(XVII)] (FAO, 2013; FAO & AUC. 2018). This decision led to the evolution of Ecological Organic Agriculture (EOA) Initiative in the continent since 2011 (AdeOluwa *et al.*, 2017). Ecological Organic Agriculture is defined as a holistic system that sustains the health of ecosystems and relies on functional cycles adapted to local conditions, rather than the use of synthetic inputs which have adverse effects on total health (human, animal, plant and environmental). It is however worthy of note that tertiary institutions of agriculture have the potential to play a major role in achieving this feat.

This is because the educational and research institutions have the capacity to extend any new knowledge or discoveries to people leveraging on their established platforms.

The Federal College of Agriculture, Ibadan, Nigeria as a case study

Currently, only a very few Institution in Nigeria has an Organic Farm. Thus, the Federal College of Agriculture, Ibadan establishing an Organic Farm is a major achievement. The objectives are to make safe food available to the staff of the College, sister institutions as well as the neighbouring towns while serving as a training center for middle level manpower. In addition, the College provides produce and services for the organic industry and farmers (through vocational training), thereby facilitating the advocacy for and subsequent adoption of organic practices by many to serve the organic industry.

The beginning, the progress and the future

The development of the Farm

The vision for an Organic Farm was conceived by the Provost of the College; Dr. Mrs. Elizabeth O. Augustus towards the end of 2020. A suitable land in the College was then identified and designated for the farmwhere activities commenced by December 2020. In 2022, the College through the Farm Demonstration Capital project of the year 2021 fenced the College Organic Farm to ensure the security of the produce on the farm.

One of the major limiting factors of production in the tropics is water. Rain-fed agriculture is no longer reliable due to climate change; there were situations where long drought could be experienced during the usual rainy season. This necessitates irrigation facilities to ensure reliable crop production. In view of this, the College embarked on installation of irrigation facilities to the capacity of one acre of land to ensure adequate water supply for all- year-round crop production.

Production

The Farm operations started in 2021 with the cultivation of some crops; maize and leaf vegetables in small quantities. In 2022, the scale of production increased and more crops were planted. The crops planted were radish, watermelon, cucumber, garden egg and maize. Of note was the success made in the successful cultivation of water melon using organic principles and resulting in big fruits weighing as much as 5 kg. Some knowledgeable people are afraid of eating water melon from the open market because of the likely heavy dose of synthetic chemicals that could have been involved in the production, as a crop that is susceptible to many insect and diseases attacks. Higher yield of water melon and cucumber would have been realized but for lack of irrigation facility to sustain the crop water requirement when the natural rain stopped. This necessitated the approval of irrigation facility for an acre of land. The field operations activities are shown in Figures 1 to 6.

Organic screen house crop production

The College acquired two units of screen house for organic crop production. This has boosted the volume of organic production by the College while also serving as a training facility for the College students, students on industrial training and those on internship from universities and other colleges (Figures7 and 8).

Establishment of the College organic market

The College Organic Market was commissioned in the year 2022 by the representative of the Honourable Minister of Agriculture and Rural Development. This was imperative to create means of regular public access to the organic produce and products. Many people have been sensitized and aware of the superiority of organic products but had no access to them. The market now serves the College Organic Farm and is made open to other organic farmers in order to make an array of produce and products available to consumers. The market runs twice a week and the number of consumers has continued to grow by the day (Figures9 and 10).



Figure 1: A one acre irrigation facility



Figure 2: Cucumber field



Figure 3: Maize field



Figure 4: Okra field



Figure 5: Mango ginger field



Figure 6: Water melon fruits at harvest



Figure 7: Organic cucumber production in the screen house



Figure 8: Organic tomatoes production in the screen house



Figure 9: Commissioning of the Federal College of Agriculture Organic Market by the Honourable Minister, Federal Ministry of Agriculture, Nigeria.



Figure 10: FCA Organic Market in progress

Impacts so far

- The College has been able to come up with natural inputs to deal with insect and pathogenic attacks of some specific crops over time.
- So many households now have access to organic produce and products through the College Organic Market which holds twice a week.
- The market conducts advocacy talk from time to time to new customers to enlighten them about the difference between organic and the conventional farming. Thus, more people through this medium now understand the importance and benefits of organic agriculture.
- The College can now conduct vocational training and short courses in organic Agriculture.
- The College is now strategically positioned to be accredited for the National Diploma in Organic Agriculture, with the facilities in place. Thus, the College shall be able to produce Diplomates (manpower) in organic agriculture OA, who shall serve the sector at both government and private levels.
- Organic production system challenges driven research is being conducted to address the limitations facing the organic producers.

Challenges

- The need to expand the scope of production to be able to meet demand
- The need for more facilities to enable the required expansion
- The need for research funding to explore and validate some possible solutions
- The need for diversification into organic livestock production

Conclusion

This paper x-rayed the potential of the agricultural institutions in achieving the goals of the African Heads of States in mainstreaming organic agriculture into the national policy, using an agricultural educational institution; Federal College of Agriculture, Ibadan, Nigeria as a case study. The adoption of the Organic agricultural system by the College has aided advocacy among students of agriculture, farmers and consumers in the environment, leading to increase in awareness as well as the demand for the produce. This shows that if several agricultural educational and research institutions across Africa shall play their roles in this dimension, the awareness of the importance of organic agriculture can easily spread in the continent. This shall in turn aid the demand for national policy to drive the sector thereby facilitating the achievement of the goals of the African Heads of States in mainstreaming organic agriculture into the national policy across the continent.

Appreciation

The Government of the Federal Republic of Nigeria
The Federal Ministry of Agriculture and Rural Development, Nigeria
Ecological Organic Agriculture Initiative of Nigeria
Ibadan Go Organic Multipurpose Cooperative Society

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Comparative Effects of Water Hyacinth Compost and Tea with Mineral Fertilizer NPK on Growth and Yield of Lettuce (*Lactuca sativa* L.) under Hydroponic Condition

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Keywords:

Lettuce,
Hydroponics,
water hyacinth compost,
Water hyacinth tea,
NPK 15:15:15 fertilizer

Abstract

Alternative means of food security for people is urgently needed due to the negative impact of global recession. Vertical farming techniques such as hydroponics that maximize output and minimize the use of resources emerged as the alternative way in addressing the problem of increase in demand for fresh vegetables in human diet led to innovative idea that can boost crop productivity, hence need for alternative nutrient solutions as fertilizer to enhance production of crops in hydroponics systems. Therefore, the need to evaluate the effects of different fertilizers materials on the growth and yield of lettuce in hydroponics system. Experiment was conducted at the greenhouse of Department of Soil Resources Management, University of Ibadan, Nigeria, June 2022 with deep water culture hydroponic system. Experiment was laid out in a Completely Randomized Designed with four treatments: 20% water hyacinth based-compost, 20% water hyacinth tea, 20% NPK mineral fertilizer and the control (water). Data were collected on number of leaves, plant height, chlorophyll content and fresh weight. Data collected were subjected to Analysis of variance using GENSTAT 4th Edition and the significantly different means were separated using LSD and error bars at probability level of 5%. Result revealed that water hyacinth based-compost nutrient solution had the highest number of leaves, plant heights, chlorophyll content and overall fresh mean weight yield for lettuce production under hydroponic condition. It is therefore concluded that water hyacinth based-compost support growing of lettuce in hydroponic media.

Effets comparatifs du compost et du thé de jacinthe d'eau avec l'engrais minéral NPK sur la croissance et le rendement de la laitue l'engrais minéral npk sur la croissance et le rendement de la laitue (*Lactuca sativa* L.) en condition hydroponique

Résumé

Il est urgent de trouver d'autres moyens d'assurer la sécurité alimentaire des populations en raison de l'impact négatif de la récession mondiale. Les techniques d'agriculture verticale, telles que la culture hydroponique, qui maximisent le rendement et minimisent l'utilisation des ressources, sont apparues comme un moyen alternatif de résoudre le problème de l'augmentation de la demande de légumes frais dans l'alimentation humaine. Elles ont donné lieu à des idées novatrices susceptibles de stimuler la productivité des cultures. Il existe donc des solutions nutritives alternatives, comme les engrais, qui permettent d'améliorer la production des cultures dans

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les systèmes hydroponiques. Il est donc nécessaire d'évaluer les effets de différentes matières fertilisantes sur la croissance et le rendement de la laitue dans un système hydroponique.

L'expérience a été menée à la maison-écran du département de gestion des ressources en sol de l'université d'Ibadan, au Nigeria, en juin 2022, avec un système de culture hydroponique en eau profonde. L'expérience a été conçue de manière complètement aléatoire avec quatre traitements : 20 % de compost à base de jacinthe d'eau, 20 % de thé de jacinthe d'eau, 20 % d'engrais minéral NPK et le contrôle (eau). Des données ont été collectées sur le nombre de feuilles, la hauteur des plantes, la teneur en chlorophylle et le poids frais. Les données collectées ont été soumises à une analyse de variance à l'aide de GENSTAT 4^e édition, et les moyennes significativement différentes ont été séparées à l'aide de LSD et de barres d'erreur à un niveau de probabilité de 5 %.

Les résultats ont révélé que la solution nutritive à base de compost de jacinthe d'eau présentait le plus grand nombre de feuilles, de hauteurs de plantes, de teneur en chlorophylle et de rendement global en poids frais moyen pour la production de laitue en conditions hydroponiques.

On peut donc conclure que le compost à base de jacinthe d'eau favorise la culture de la laitue en milieu hydroponique.

Mots-clés:

Laitue,
hydroponie,
compost de jacinthe d'eau,
thé de jacinthe d'eau,
engrais NPK 15:15:15

Introduction

Recently, over 820 million people do not have access to sufficient food, with more than one in every five children under the age of five years being malnourished and stunted (United Nations 2019). Our food systems are failing, and the outbreak of COVID-19 pandemic is making things worse: UN Secretary-General Antonio Guterres said on 9 June 2020 "that the world is on the brink of its worst food crisis in 50 years" (The Guardian 2020). Alternative means of food security for people is urgently needed as the impending recession following the COVID-19 pandemic puts basic nutrition beyond their reach. This has led to the global food industry searching for more sustainable and accessible systems for the production of healthy food, particularly fresh vegetables and fruit.

Vertical farming techniques such as hydroponics and aquaponics that maximize output and minimize the use of resources (space, soil, air, water and nutrient) emerged as the alternative way in addressing this problem. Hydroponics is a systematic approach of growing crops in a complete nutrient solution without soil (Chatelier, 2003). Hydroponic allows a more efficient use of water and fertilizers, as well as a better control of climate and pest infestation, increases the crop quality and productivity, which results in higher competitiveness of the product and economic incomes (Florez, 2012). Lettuce can be successfully grown in nutrient film techniques system and deepwater culture. Crops in hydroponic system are not influenced by climate change therefore, can be cultivated year-round and considered as off season produce (Manzocco *et al.*, 2011).

Therefore, the reason to compare fertilizer quality of water hyacinth tea, compost with mineral fertilizer NPK.

The objective

The objective of this study is to:

Evaluate the effects of different fertilizer materials on the growth and yield of lettuce in a hydroponic system.

Materials and Methods

Description of the experimental site

This experiment was carried out at the screen house of Soil Resources Management, Agronomy Building, Faculty of Agriculture, University of Ibadan, Nigeria (latitude 7° 26' N and longitude 3° 55' E) between and April-June 2022. It is located in the derived savannah of Southwest Nigeria.

Materials and their sources

The compost was obtained from the organic section of Teaching and Research Farm University of Ibadan. And crisp head variety of lettuce seeds were purchased from seed store in Ogunpa, Ibadan.

Experimental Treatment and Design

The different rates of each treatment were based on the calculation of the composition of Nitrogen in the water hyacinth at the recommended application rate of 100 kg N/ha for lettuce. The experimental design was laid in a complete randomized design (CRD) with 4 treatment replicated 3 time per fertilizer treatment with a total of 36 pot used, treatments include:

Water (Control) water hyacinth tea, water hyacinth compost and NPK 15:15:15. The size of each experimental container was 0.5 litres for good germination and proper crop growth.

Agronomic Practices and Statistical analysis

Sand was put into a perforated seedling tray and the seed was broadcasted evenly on the soil inside the tray, watering was done regularly, the germination took place between 3-5 days after sowing. Transplanting was done at three weeks after planting. Harvesting was carried on 21st June, 2022 seven weeks after transplanting.

Collection of data was on weekly bases after transplanting, data collected are; Number of Leaves, Plant Height, Chlorophyll Content of the leaf. The data collected were subjected to analysis of variance using GENSTAT 4th Edition and the significantly different means were separated using LSD and error bars at probability level of 5%.

Results

Table 1: Pre-Planting Chemical Properties of the Nutrient Solutions used for the experiment

Parameters	Compost	Water Hyacinth Tea
pH (1:1, H ₂ O)	6.8	6.5
Nitrogen (g/kg)	1.54	1.2
Phosphorous (mg/kg)	1.20	1.60
Basic Cation (g/kg)		
Potassium	0.48	0.12
Calcium	0.00	0.00
Magnesium	0.20	0.20
Sodium	0.1	0.04
Micronutrients (mg/kg)		
Manganese	1.10	0.04
Iron	4.74	0.16
Copper	0.3	0.00
Zinc	0.14	0.00

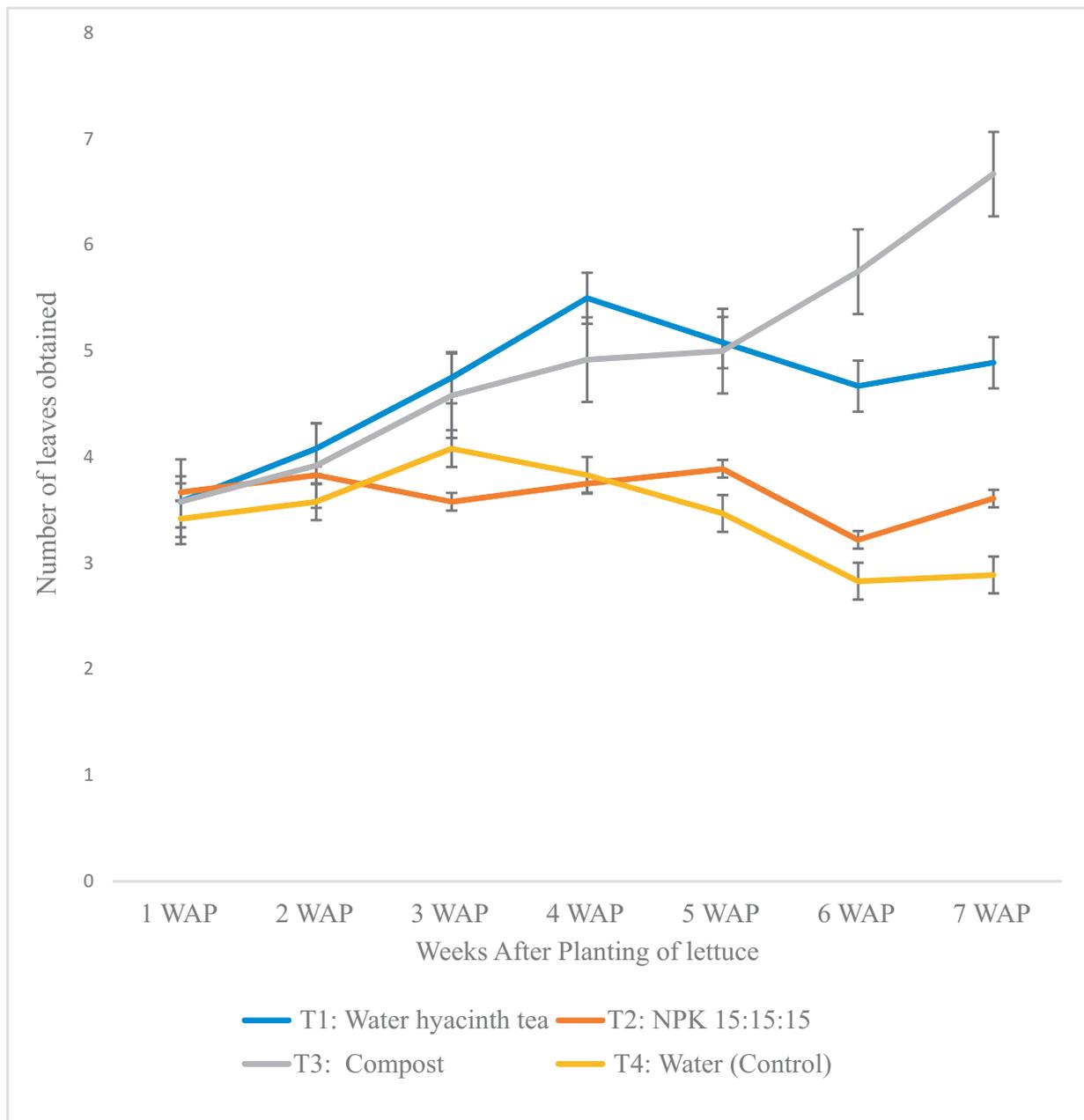


Figure 1: Influence of different fertilizers treatments on the number of leaves of lettuce on a weekly basis
*Error bars indicate standard error of mean

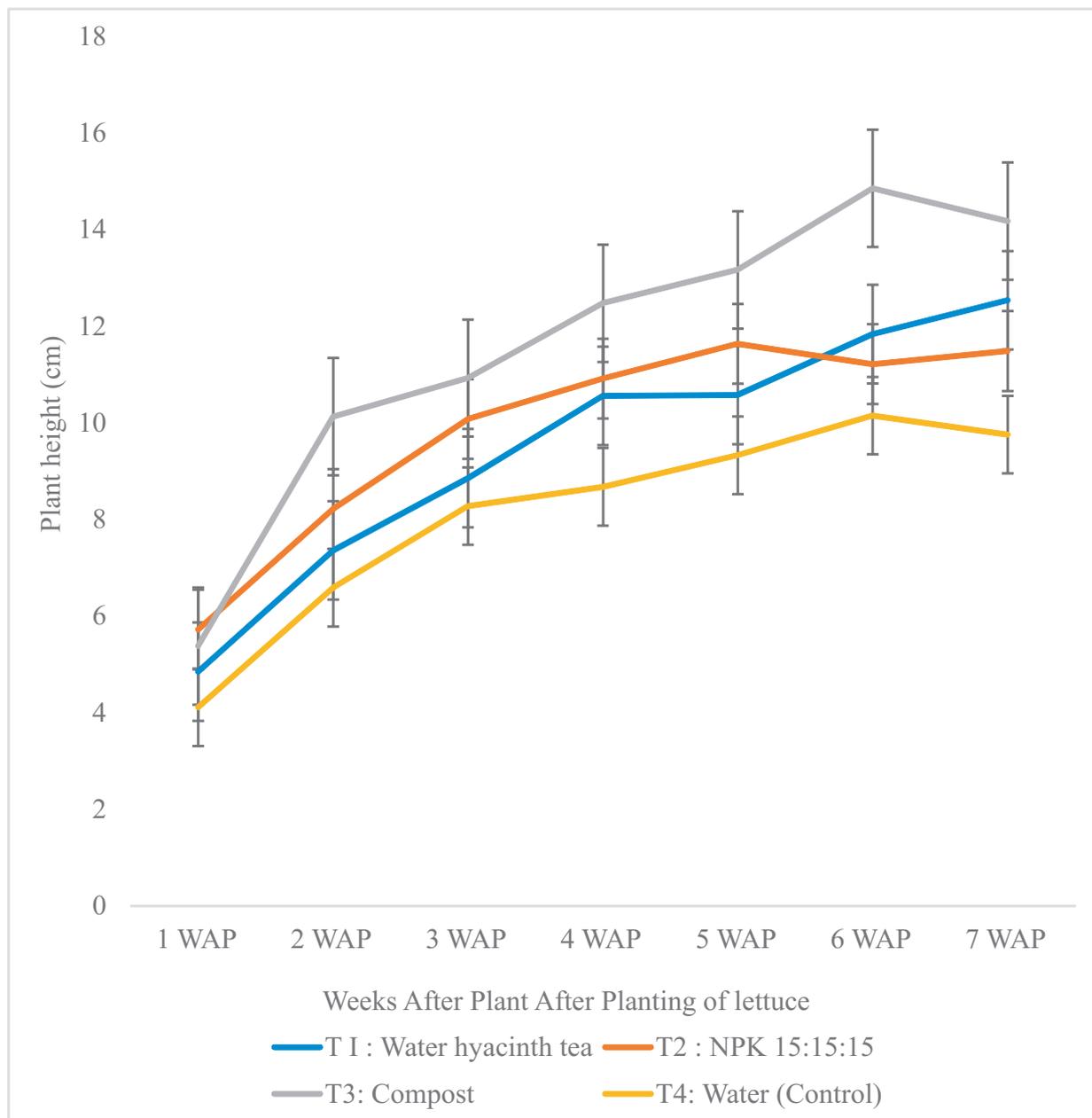


Figure 2: Influence of different fertilizers treatments on the plant height of lettuce on weekly basis
*Error bars indicate standard error of mean

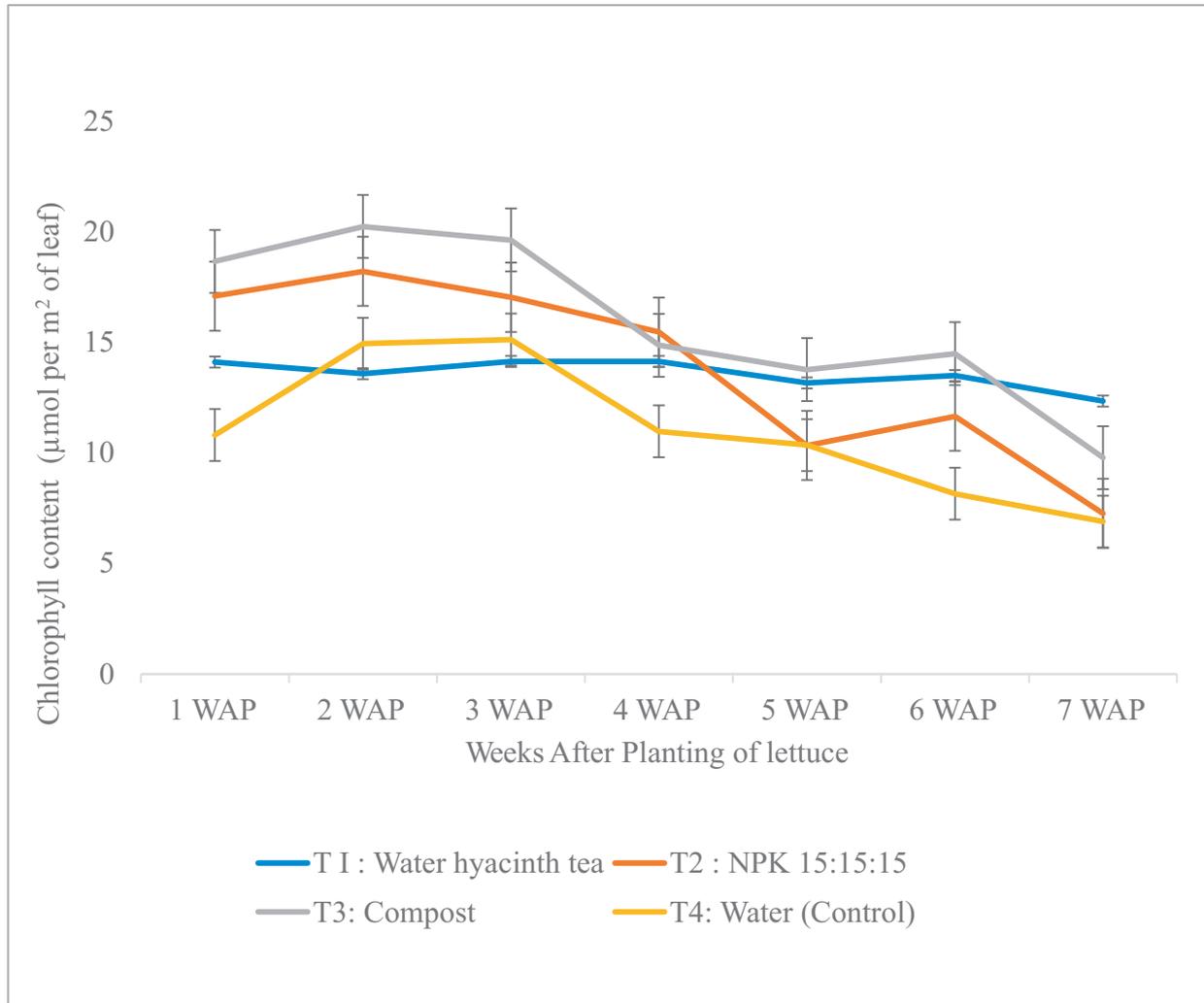


Figure 3: Influence of different fertilizers treatments on the chlorophyll content of lettuce on weekly basis

*Error bars indicate standard error of mean

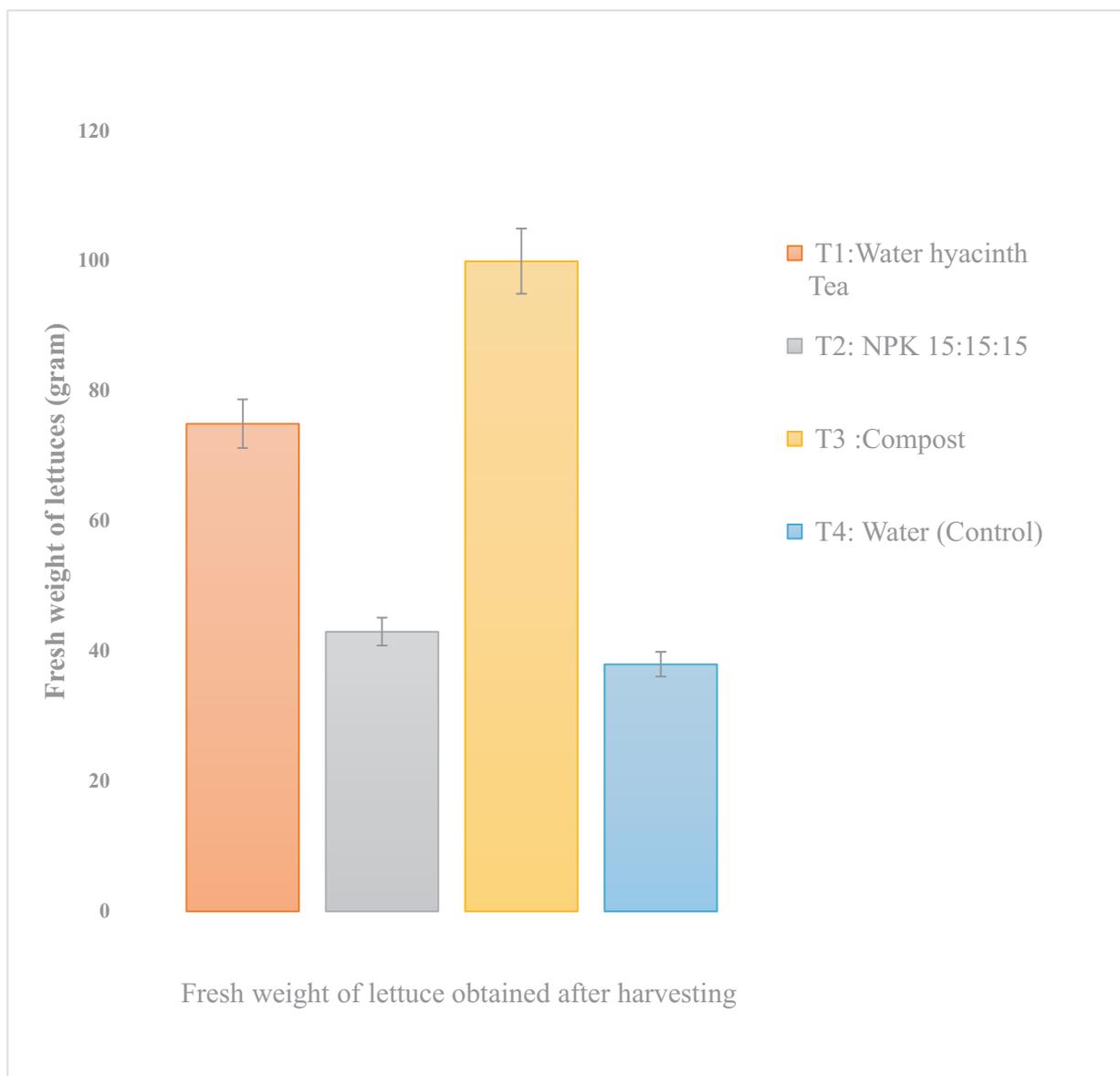


Figure 4: Effect of different fertilizers materials on fresh weight of lettuce after harvesting
*Error bars indicate standard error of mean

Discussion

The result of this study reveals that different fertilizers materials influence the growth and yield of lettuce used in this experiment. The study of water hyacinth as organic fertilizer revealed that the incorporation of water hyacinth into cropping system increased the yield performance of lettuce. Different rates of water hyacinth tea (WHT), different rates of water hyacinth based-compost (WHBC) and different rate of NPK 15:15:15 used in this study were found to be more effective at 20% for the growth and yield of the test crop over 100% application rate which implies that the treatment application of 40% to 100% of (WHT) has a toxic effect on the growth and yield of lettuce. This indicated that there will not be availability of nutrient element for crops leading to toxicity of nutrient to the plant and retarding crop growth. This finding is in agreement with the assertion of (Asao et al., 2014) who reported that if certain nutrients are present in excessive quantities, solutions may become toxic to the plant and reduce growing rates. Increase in plant growth and

yield as a result of application of water hyacinth based-compost is expected in that compost contained and released considerable amount of appropriate nutrients for the development of lettuce.

The result of this study is in agreement with previous report of Peterson (2006) who reported that using composted water hyacinth material could serve as quality manure for improving soil fertility conditions and thus crop yields on the whole. The highest number of leaves, plant height, chlorophyll content recorded with water hyacinth based-compost solution in this study is in consonance with the study by (Xu et al., 2005) who reported that vegetables grown with moderate levels of organic manures grew better and resulted in a final higher total yield than those grown on higher concentration together with those grown using synthetic fertilizers.

Conclusion

At the end of the experiment, the result obtained indicated that the effect of different fertilizer materials on growth and yield of lettuce in hydroponics system as well as the percentage of water hyacinth tea and water hyacinth based-compost that can be used as organic fertilizer for growing lettuce in hydroponic medium. Lettuce yield was more improved by water hyacinth-based compost compared to other applied fertilizer treatment, with the highest fresh weight of lettuce obtained from water hyacinth based-compost (100 gram) while 20 % of water hyacinth based-compost and water hyacinth tea was better than other concentrations.

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Published by:





Resilience of *pfumvudza* Farming Method to Climate Shocks and its Potential for Scaling in Africa

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Keywords:

Assets, dryland, climate change, replication, vulnerability, *pfumvudza*, Zimbabwe

Abstract

Food shortage and nutrition insecurity are becoming prevalent in most African households due to frequent droughts, rising costs of inputs and shortage of draught power. This is prevalent in small-scale farming lands. In order to improve food security, governments are promoting and supporting sustainable farming practices. In 2019, the government of Zimbabwe implemented the *pfumvudza* method, a form of conservation agriculture to address food insecurity in the country. However, not much had been done to explore and evaluate its resilience to drought conditions affecting communal farming areas. Against this backdrop, this study applied the resilience theory to examine how *pfumvudza* farming addresses the climate change stresses, adversities, and its sustainability as a mediating process. The south eastern lowveld of Zimbabwe was taken as a case study area. It also highlights the potential for scaling up the method in other similar African countries Data were collected from focus group discussions and key informant interviews. Research findings reveal that the south eastern lowveld is characterised by climate shocks and seasonality induced adversities. *Pfumvudza* principles are cost effective had increased the resilience of livelihood assets to shocks and adversities. The human, social, physical and natural capital assets engraved in the *pfumvudza* capacitate the smallholder farmers to reduce their vulnerabilities from climate shocks in dryland landscapes. The bonding and bridging capital, transformative productivity of the method through knowledge, attitudes, skills, and competencies have also increased resilience of smallholder farmers in the region. Therefore, the method has enabled vulnerable smallholder farmers to cope with the vagaries of weather and enhanced their livelihood strategies. In this regard, it can be implemented in other African countries experiencing climate stresses.

Résilience de la méthode de culture du *pfumvudza* aux chocs climatiques et son potentiel de mise à l'échelle en Afrique

Résumé

La pénurie alimentaire et l'insécurité nutritionnelle deviennent prévalentes dans la plupart des ménages africains en raison des sécheresses fréquentes, de l'augmentation des coûts des intrants et de la pénurie de force de traction. Cette situation est prévalente dans les petites exploitations agricoles. Afin d'améliorer la sécurité alimentaire, les gouvernements encouragent et soutiennent les pratiques agricoles durables. En 2019, le gouvernement du Zimbabwe a mis en œuvre la méthode *pfumvudza*, une forme d'agriculture de conservation, pour lutter contre l'insécurité alimentaire dans le pays.

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Cependant, peu de choses ont été faites pour explorer et évaluer sa résilience aux conditions de sécheresse affectant les zones agricoles communales. Dans ce contexte, cette étude a appliqué la théorie de la résilience pour examiner comment l'agriculture *pfumvudza* fait face aux stress du changement climatique, aux adversités et à sa durabilité en tant que processus médiateur. Le sud-est du lowveld du Zimbabwe a été pris comme zone d'étude de cas. Les données ont été recueillies lors de discussions de groupe et d'entretiens avec des informateurs clés. Les résultats de la recherche révèlent que le sud-est du Lowveld est caractérisé par des chocs climatiques et des adversités induites par la saisonnalité. Les principes du *Pfumvudza* sont rentables et ont augmenté la résilience des moyens de subsistance face aux chocs et aux adversités. Les actifs humains, sociaux, physiques et naturels gravés dans le *pfumvudza* permettent aux petits exploitants agricoles de réduire leur vulnérabilité face aux chocs climatiques dans les paysages arides. Le capital de liaison et de rapprochement, la productivité transformatrice de la méthode à travers les connaissances, les attitudes, les aptitudes et les compétences ont également renforcé la résilience des petits exploitants agricoles de la région. Par conséquent, la méthode a permis aux petits exploitants vulnérables de faire face aux aléas climatiques et d'améliorer leurs stratégies de subsistance. À cet égard, elle peut être mise en œuvre dans d'autres pays africains confrontés à des stress climatiques.

Mots clés:

Actifs, zones arides, changement climatique, reproduction, vulnérabilité, *pfumvudza*, Zimbabwe

Introduction

In arid and semi-arid regions, household food availability and nutrition security are adversely affected by climate change and variability, reduced water availability, soil quality deterioration together with increased pest and disease infestations. In Africa, there are an estimated 33 million smallholder farmers contributing up to 70% of the food supply (Abrams et al., 2017). With greater investment in smallholder agriculture, many countries have the potential to increase food production and reduce poverty (Shikuku, 2019; Shikuku et al., 2017). Low yields and production levels, and a lack of access to quality seeds combined with changing weather patterns are contributing to rural poverty and hunger. These challenges cause hunger and malnutrition among vulnerable communities in most dryland regions of the continent (Sear, 1995; Tomlow et al., 2006; Venkateswarlu and Shanker, 2012).

There is a growing drive to produce more food without degrading the soil, cutting down trees and encroaching into environmentally sensitive areas by adopting sustainable farming practices at local, national, regional and global scales (Shilomboleni et al., 2019). Sustainable farming techniques that improve food security and environmental sustainability include climate smart agriculture, agroecology, organic agriculture, regenerative agriculture, permaculture, conservation agriculture, and natural farming among others (Jena, 2019; FAO, 2021). Judicious adoption of these innovations strengthen resilience and adaptive capacity of food systems among smallholder farmers. This requires a better understanding of inherent problems so that they can be addressed and combated effectively (Zim VAC, 2020). Most national programmes in Africa fail due to lack of political capital.

Africa's agricultural landscape is diverse and rich, yet, despite progress, it still grapples with challenges, especially given that agriculture employs 65% of our workforce. Although agriculture remains a mainstay for the majority of Africa's workforce, its growth is yet to eradicate hunger and malnutrition. Scaling agricultural innovations or practices requires a budget to increase the scale by employing more people and doing the same thing in more places. It involves capacity building as a vital component, testing the innovation with a few participants within a limited geographic area and then apply it to a broader scale to create more impact (Kirina et al., 2022). Scaling agricultural practices provides opportunities for sustainability and a public/policy-driven strategy (Shikuku, 2019). For example, through presidential decrees, acts of parliament, or a practice adopted from the internationally accepted best practice. Also, research and development are vital as the adoption of an innovation involves interactions of partnerships, farmer field schools and institutions (Groot et al., 2019; Kirina et al., 2022). However, the path towards scaling farming is fraught with

challenges. Scaling takes time, and it suffers from transitional challenges associated with the context of innovations, new spatial spaces with heterogeneous biophysical and socio-economic conditions.

Pfumvudza farming

In Zimbabwe, almost 30% of the population is food insecure. The government implemented the *pfumvudza* farming during the 2020/21 farming season to increase the resilience of agriculture to droughts. It was also intended to improve conservation of water, soil and biodiversity in crop lands (Venkateswarlu and Shanker, 2012). The term *pfumvudza* literally means to bloom during the new season. It refers to the spring time when foliar of deciduous trees begin to reshoot before the rainy season (Mujere, 2022). *Pfumvudza* was implemented to improve food security at household level. It is a form of conservation farming having three pillars namely: minimum soil disturbance by digging holes for planting; permanent soil cover using organic mulch; and, crop rotation and intercropping with cover crops. Zenda (2020) commented:

Conservation agriculture which is now locally known as pfumvudza has been in existence for decades but was more aggressively promoted by the Government of Zimbabwe during the 2020-2021 cropping season. Thus, making it more popular and widely adopted. For several years, local and international non-governmental organisations (NGOs) tried to popularise it, but fell short in terms of reach and promotion. But when the Government adopted it and promoted it in a big way, it was widely accepted and adopted as a critical tool for response to the impact of climate change and successive droughts which had led to poor harvests in past seasons. Conservation agriculture integrates a set of soil management practices aimed at minimising soil disturbance and maintaining a constant soil cover. This large- scale promotion of low input sustainable agriculture approach to enhance household food and nutrition security in the country, was made possible thanks to political will and the willingness of smallholder farmers at the grassroots to heed calls from the Government.

A standard *pfumvudza* plot is a rectangular land measuring 16m by 39m, which represents an area of 624m² (Figure 1). Three maize seeds evenly placed in each of the 1,459 planting basins. A planting station measures 15cm deep, 15cm wide and 15cm long (Oldreive, 2006, Mujere, 2022). Each row, 56 maize cobs are harvested. The cobs are shelled, ground and fill a 20 kg bucket of mealie meal adequate to produce local staple food, sadza, thick porridge to feed a household of six members (the average household size in the country) for a week. If the plot is well managed, it produce a tonne of maize grain enough to feed a six-member household for one year (Thierfelder and Wall, 2009). Each *pfumvudza* plot requires 12 kg of agricultural lime. 16 kg of basal fertilizer, 2kg of maize seed and 16 kg of top-dressing fertilizer.

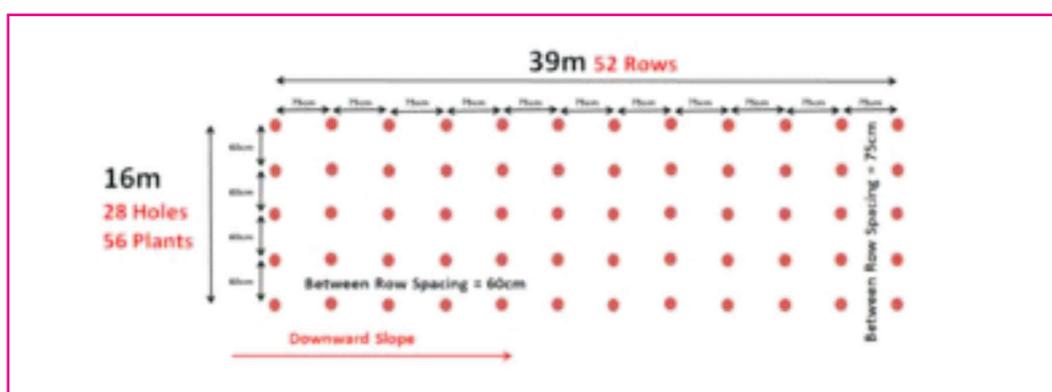


Figure 1: Layout of a *pfumvudza* plot
Source: Edwards (2013:4)

In order to ensure its success of the *pfumvudza* farming practice, there is need for adequate farmer training and timely availability of inputs. Its success lies not only in wide adoption by small-scale farmers but also at the extent to which the vulnerable groups are included (Mujere, 2022). The method has the potential to improve food security of rural households, provide reasonable return to investment and is an effective way of utilising resources (ZimVac, 2020). Since the countrywide inception of *pfumvudza*, its adaptive capacity to climate shocks and adversities are still somewhat understudied. This study assesses the resilience of *pfumvudzain* addressing adversities and enhancing sustainability among smallholder households in the south eastern lowveld of Zimbabwe. It also assesses its potential for replication in other African countries.

Materials and methods

Study area

The southeastern lowveld (i.e., a parcel of land below an altitude of 600 m) is an undulating terrain stretching to Zimbabwe's border with South African and follows the Limpopo River to the border with Mozambique (Figure 2). It comprises a national park, safari area, communal areas and large-scale commercial farms (Manyanga et al, 2000; Wolmer, 2005; Cooper et al., 2008). The region is one of the driest parts of the country receiving an average annual rainfall of 450 mm. Rainfall is erratic and unreliable for dryland farming, making supplementary irrigation necessary for successful crop production (UNDP, 2008; 2018).

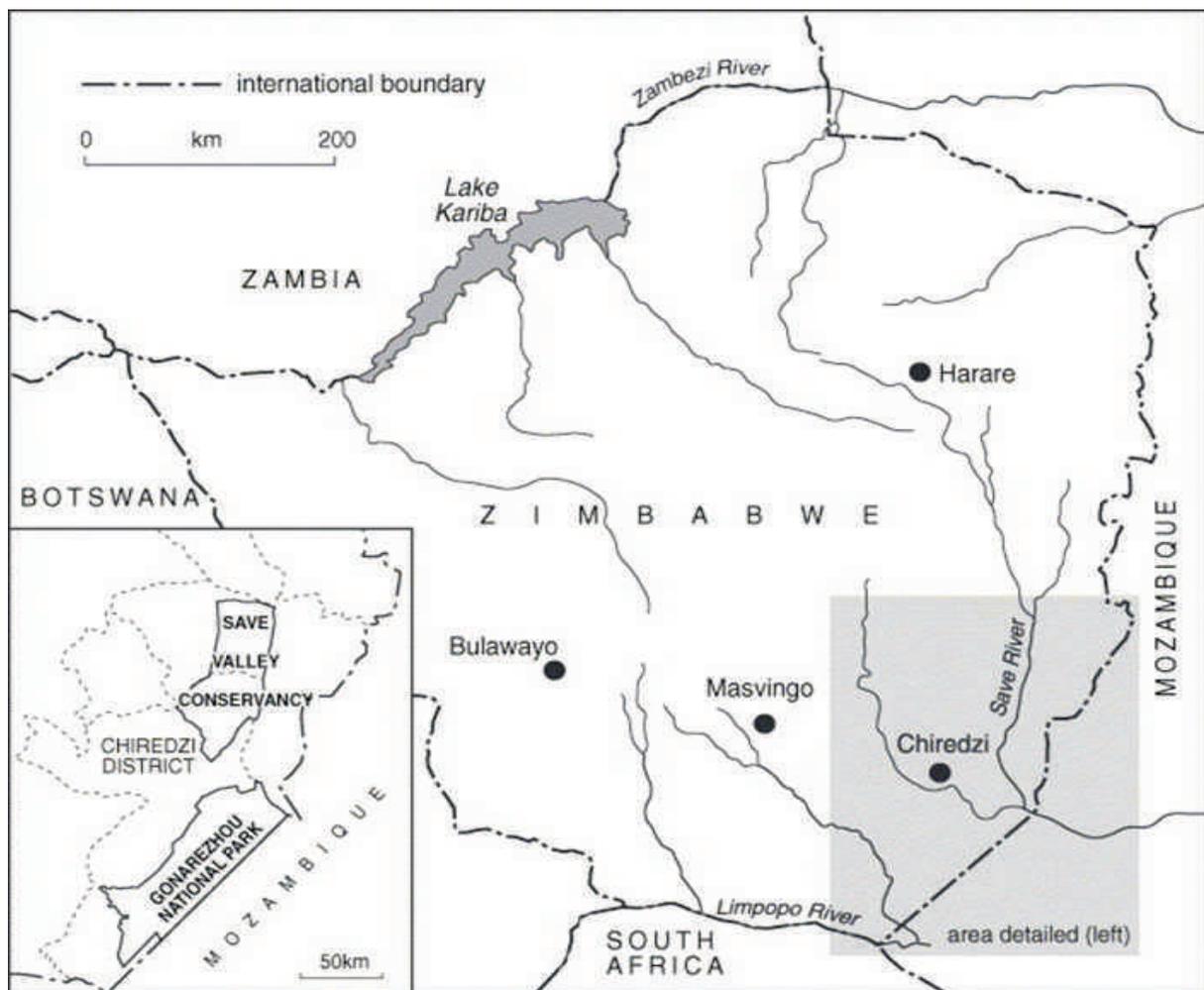


Figure 2: Location of the south eastern lowveld (dark rectangle) of Zimbabwe
Source: Wolmer (2005)

Data collection

The study was conducted in 2022, during the second year of countrywide adoption of *pfumvudza* farming. Qualitative data were collected from four focused group discussions (FGDs) with dryland farmers. Each FGD had an average of 15 participants comprising men, women and the youths. Extension officers from the Department of Agriculture Technical and Extension Services (AGRITEX) and traditional leaders took part in the survey as key informants. The discussions sought to collect information regarding participant perceptions and views on the resilience of *pfumvudza* as a mediating process, how it averts adversities and its positive livelihood outcomes.

Ethical considerations

The study observed ethical standards as provided by Great Zimbabwe University. Ethical conduct towards participant's information as well as honest reporting of the results is critical in research (Flicker et al., 2007; Richards et al., 2002). Before starting field work, the researchers sought an ethics clearance certificate from Great Zimbabwe University Ethics Committee. In the field, the researchers observed the following ethics; prior informed consent of participants, debriefing of research purpose, voluntary participation, privacy, confidentiality, anonymity when reporting data, and freedom of participants to withdraw from the research.

Conceptual framework

The study adopted the resilience framework which involves three connected components namely: adversity, mediating factors and outcomes (Figure 3).

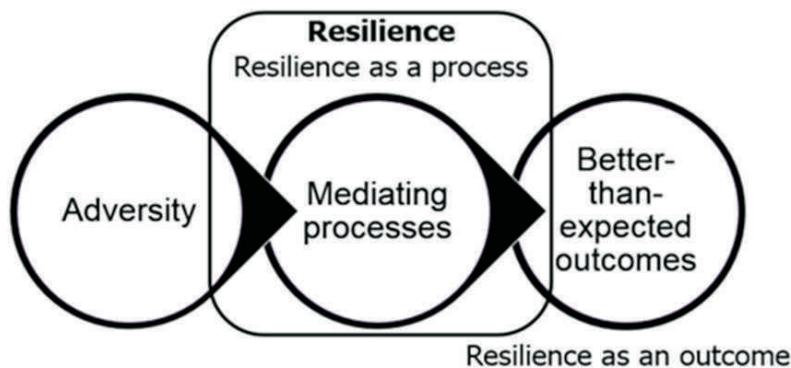


Figure 3: Resilience as a process and outcome
Adapted from van Breda (2018:6)

Resilience is the capacity of people to deal with external shocks such as conflicts, illnesses, floods, storms, droughts, pests, diseases and seasonality. It is a multilevel process that leads to positive outcomes in the face of chronic or acute adversity (Bonanno and Diminich, 2013). Resilience to acute adversity involves recovering after the shock has ended. Whereas, resilience to chronic adversity involves recovering in the face of on-going shocks (Bonanno and Diminich, 2013). Persistent drought is a form of adversity and resilient to it depends on the vulnerability of a community.

Mediating processes refer to coping mechanisms that are influenced by access to human, social, financial, physical and natural assets. They result in positive livelihood outcomes when supported by appropriate laws, policies, legislations, culture and institutions. Realised positive livelihood outcomes comprise sustainable use of natural resources, increased income, well-being, and food security (Van Breda, 2018).

Results

Adversity in drylands agriculture

Focused group discussions and key informant interviews revealed that the south eastern lowveld experiences shocks from floods, drought and epidemics. Crop harvests were low, food prices were increasing and health was compromised.

Most vulnerable households lacked assets and insecurity as a result of poor subsistence. Civil conflicts were also other sources adversities.

Pfumvudza as a mediating process

Human capital

Pfumvudza training and awareness by extension staff enhanced skills and knowledge of participants in decision making. Land preparation in winter reduces labour costs since weeds will be immature. Households with people living with disabilities are assisted to prepare land by able bodied community members especially during sacred days occurring once a week. The extension staff member commented that:

For pfumvudza to be successful, we need to support smallholder farmers so that they can stay in agriculture and see farming as a business while using good agricultural practices. This allows farmers to increase production without causing large-scale deforestation.

A farmer during a FGD added that:

Training has empowered us smallholder dryland farmers. The support we received from NGOs and AGRITEX in terms of cultivating traditional grains, has enhanced farmers' health for them to dig planting basins in their plots. The level of loyalty and punctuality by pfumvudza adopters establish building blocks for dryland farmers' resilience. Farmers would arrange for a day to assist those who cannot afford to do manual tasks so that no one is left behind.

Social capital

Kerr (2018) alludes, that social capital is a strong predictor of a community's post disaster recovery. During FGDs it was highlighted that *pfumvudza* bring communities together during field demonstrations and field days. At these occasions farmers network and share experiences and skills. They reciprocate, build trust and identify opportunities and constraints of *pfumvudza*. They have also established relations with informal institutions, neighbouring wards and villages and non- state actors from which they are getting complimentary inputs such as traditional grains. A FGD participants alluded:

Networking with other farmers, civil societies and government builds trust and reciprocates good behaviour and practices. Communal farming under pfumvudza involves mediating blocks and processes that enhance positive outcomes in agriculture.

Physical capital

Some farmers had benefitted from hoes and reaper tines provided by non-governmental organisations. The reaper tines facilitate mechanized *pfumvudza* farming for farmers living with disabilities, chronically ill patients and child headed household farmers. Hoes and reaper tines mediated and averted challenges of draught power in the region.

Natural capital

Dryland farmers in the south eastern lowveld possess large pieces of land. The region has the country's largest and second largest inland water reservoirs, TugwiMukosi dam and Lake Mutirikwi respectively. Farmers obtain organic manure from nearby forests and pastures. Fertile soils and seasonal rainfall enhance crop productivity for farmers practicing *pfumvudza*. One youth member has this to say:

From the land we have on farm and off farm livelihoods activities such crops, fruit and wildlife harvesting. These livelihoods options avert shocks, stresses, and seasonality. Using compost manure yields good harvest thereby achieving a better-than-expected outcome.

Political capital

Key informant interviews with traditional leaders highlighted that *pfumvudza* requires stable land ownership and political buy in. Lack of political will, supportive agricultural policies, and investment, coupled with a focus on short-term development solutions, leave large tracts of agricultural land underutilized, smallholder farmers poor and food insecure. Consequently, politicians earn public goodwill, and trust for supporting the initiative. A female participant commented:

Since *pfumvudza* is a government supported initiative, politicians are behind its implementation to ensure food security in their constituencies. Furthermore, this creates confidence in dryland farmers as they adopt *pfumvudza* as a promising method that is reliable, sustainable and achievable.

Better outcomes from *pfumvudza*

Group discussions revealed that maintenance of the same planting basin under *pfumvudza* makes tilling of the land easy. There is limited disturbance of the soil structure thus averting erosion. Runoff and erosion are significantly reduced as a result of mulching has improved moisture retention capacity. Use of the same planting basin every season has led to suppression of weed growth.

Despite dry spells experienced in the region, crop productivity has relatively improved compared to the conventional farming. Knowledge, skills and competencies have also improved as a result of capacity building programmes offered by AGRITEX and NGOs. Living standards, food availability and nutrition security were improved as households became more resilient to climate stresses and environmental degradation.

Potential for scaling organic *pfumvudza* in Africa

African economy is agro-based. Agriculture is responsible for food security to feed over 1.5 billion citizens (World Bank, 2022). It enhances exports, substitute imports, supplies raw materials for agro-industry parks and creates jobs for men, youth and women. Despite its vast resources, Africa grapples with the triple burden of malnutrition, overpopulation and economic meltdown affecting its present and future generations. At least one in five Africans have inadequate food and an estimated 140 million people face acute food insecurity (World Bank, 2022). *Pfumvudza* farming can be implemented continent-wide because there is a progressive increase in climate action and financing towards sustainable agricultural production options.

African countries and regional bodies have developed policies and frameworks to promote and scale climate smart agricultural practices. For example, the African Union's Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods in 2014 prioritised resilient agriculture as a development agenda. During the same summit, Vision 25*25 was launched targeting at least 25 million farm households practicing climate smart agriculture by 2025 (African Union, 2014). Also, the Union's Comprehensive Africa Agriculture Development Programme (CAADP) requires each country to allocate at least 10% of its national budget towards agriculture and rural development, and to achieve agricultural growth rates of at least 6% per annum. CAADP is an Agenda 2063 continental initiative that aims to help African countries eliminate hunger, malnutrition and reduce poverty by raising economic growth through agriculture-led development. Improved budgetary allocation for farming allows for input support to smallholder farmers (African Union, 2021). Improving the sustainability of agricultural production and use of natural resources is critical for the success of *pfumvudza* farming.

Eradication of hunger and food insecurity is the ultimate goal of family farming. Inclusion of stakeholders including poor men, women and youths in agriculture is vital for empowerment and job creation. Heightened collaboration among governments, civil society, and private sectors is critical to ensure that smallholder farmers receive appropriate training and inputs in time. Lack of mechanization for draft power means farmers can use simple tools such as hoes to dig planting basins.

Smallholder African farmers possess livestock such as cattle, donkeys and goats from which they get manure (Call et al., 2019). Livestock are generally seen as one the most important sources of livelihood for rural households, and serve a number of different forms of capital namely: physical (labour and consumption), natural (organic fertilizer), financial (security, savings account), and social (adding value to community members).

Conclusion

The study assesses the resilience of *pfumvudza* method in dryland farming in the south eastern lowveld of Zimbabwe. Key informant interviews and focused group discussions revealed that south eastern lowveld is characterized by shocks, stresses, risks and uncertainties, seasonality and policy-institution and process induced adversities. Institutionally, *pfumvudza*'s principles are cost effective. The human, social, physical, natural, and political capital assets engraved in the *pfumvudza* program capacitate the capability of smallholder farmers to recover from vulnerabilities of dryland landscape. The bonding and bridging capital, transformative productivity of the method through knowledge, attitude, skills, and competencies have reduced vulnerability by averting shocks, stresses and seasonality among smallholder farmers in the south eastern lowveld.

Pfumvudza as a low input sustainable farming approach can be adopted in other African countries to enhance smallholder farmer's food and nutrition security. It creates a conducive political environment, adapts and mitigate the vagaries of climate change as one elder farmer commented:

When the drought hit, my crops did not have enough water. I had low yields and a shortage of food. Farmers in Africa need more support. We need plows, fertilizers and good quality seeds. Before pfumvudza, conventional farming was very laborious, and seeds were too expensive. We never had enough to eat. I could not afford to send all my children to school. The older ones went, but the smaller ones were left out. The support we get in pfumvudza is vital for the success of smallholder dryland agriculture.

Data availability statement

Inquiries are directed to the corresponding author for original contributions presented in the study.

Acknowledgments

Many thanks also go to the survey participants for their valuable inputs.

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Perspective of Nigerian Students on Choosing Organic Agriculture as a Course of Study in Tertiary Institutions

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Keywords:

Students,
Higher Institution,
Study,
Organic Agriculture

Abstract

Over the last decade, the global production and trade in Organic Agriculture have been expanding exponentially. However, insufficient skilled personnel as workforce in the organic agriculture sector of many developing countries is a major limitation to development of sector. This study investigated the interest of agricultural students of tertiary institutions of Nigeria in studying organic agriculture as a course. The study made use of quantitative research approach to obtain information from respondents. A structured e-questionnaire was used to elicit information from respondents for data collection. Data for the survey were collected on respondents' socio-economic characteristics, awareness on organic agriculture as a course of study, interest of agricultural students in studying organic agriculture and motivation to studying organic agriculture as a course. Data collection was done electronically with kobotoolbox. The study revealed that a major reason by the respondents for choosing organic agriculture as a course is opportunities for further studies within or outside Nigeria. Majority of the respondents also preferred to study organic agriculture at the First-Degree level (University). This overwhelming interest of the students in studying organic agriculture as a course also came with demand of what would be their motivation of choices of institutions where they would like to study the course. The study recommends that there must be a comprehensive curriculum in place covering essential aspects of organic agriculture practices, including sustainable farming practices, soil health, and organic certification processes and as well as establishment of standard organic farms for research and practical activities.

Point de Vue des Etudiants Nigeriens sur le Choix de L'agriculture Biologique Comme Programme D'etude Dans les Etablissements D'enseignement Superieur

Résumé

Au cours de la dernière décennie, la production et le commerce mondiaux de l'agriculture biologique ont connu une croissance exponentielle. Cependant, l'insuffisance de personnel qualifié dans le secteur de l'agriculture biologique de nombreux pays en développement est un obstacle majeur au développement de ce secteur. Cette étude s'est intéressée à l'intérêt des étudiants en agriculture des établissements d'enseignement supérieur du Nigéria pour l'étude de l'agriculture biologique en tant que cours. L'étude a utilisé une approche de recherche quantitative pour obtenir des informations auprès des personnes interrogées. Les données de l'enquête ont été collectées sur les caractéristiques socio-économiques des répondants, leur connaissance de l'agriculture

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Mots clés:

étudiants,
établissement supérieur,
étude,
agriculture biologique

biologique en tant que filière d'études, l'intérêt des étudiants en agriculture pour l'étude de l'agriculture biologique et leur motivation à étudier l'agriculture biologique en tant que filière d'études. La collecte des données a été effectuée électroniquement à l'aide de kobotoolbox. L'étude a révélé que l'une des principales raisons pour lesquelles les personnes interrogées ont choisi l'agriculture biologique comme cours est la possibilité de poursuivre des études à l'intérieur ou à l'extérieur du Nigéria. La majorité des personnes interrogées préfèrent également étudier l'agriculture biologique au niveau du premier diplôme (université). Cet intérêt massif des étudiants pour l'agriculture biologique s'est accompagné d'une demande de motivation quant au choix des établissements dans lesquels ils souhaitent étudier cette discipline. L'étude recommande la mise en place d'un programme complet couvrant les aspects essentiels des pratiques d'agriculture biologique, y compris les pratiques agricoles durables, la santé des sols et les processus de certification biologique, ainsi que la création de fermes biologiques standard pour la recherche et les activités pratiques.

Introduction

Over the last decade, the global production and trade in Organic Agriculture have been expanding exponentially(Ref.) However, the practice of organic agriculture in an organized manner is still an evolving issue in Nigeria with no institution presently training skilled personnel in organic agriculture. This is partly due to tertiary institutions in the country lacking appropriate curricula to teach organic agriculture. This situation contributes to other factors hindering the development of organic agricultural sector in the country. Although, land under organic agriculture in Nigeria (as an important country indicator of status of organic agriculture) has increased from 3,154 ha in 2007 (FiBL and IFOAM, 2009) to 54,995 ha in 2019 (FiBL and IFOAM-Organics International, 2022), the number of producers in the sector (about 1,000) is still very low compared to the potential of the country blessed with diverse agroecology favourable to organic agricultural production, as well as manpower. One of the ways of improving the situation is to equip tertiary institutions training students in agriculture with curricula on organic agriculture.

The unfolding market opportunities globally, especially in the developed countries of Europe and North America, reveal a shift in consumers' preferences towards safe and hazard free organic foods. This situation provides Nigeria with opportunities to tap into the growing global organic agriculture business worth Eur 106.4 billion and organic agricultural land of 72.3 million hectares (FiBL, 2021). However, without corresponding skilled workers to support development of organic agriculture in the country, this would be difficult to achieve.

The importance of agriculture as a requirement for self-sufficiency, employment, and food supply to the individual, nation and the world at large cannot be over emphasized. Agriculture plays important role as the base of economic growth and development and revenue source for many countries, including Nigeria. One of the ingredients for accelerating agricultural development is the provision of adequate knowledge through education in the sector (Onu and Ikehi, 2013). Academic institutions are responsible for training skilled workers. Currently, there is no known institution of higher learning in Nigeria offering organic agriculture as a field of study. This among others has limited development of the country's organic sector. As a starting point for training of skilled personnel in organic agriculture in Nigeria, the National Board for Technical Education (NBTE) has developed a curriculum for National Diploma in Organic Agriculture Technology. However, there is a need to investigate opinion of agricultural students in the country on studying organic agriculture as a course. A positive result from this process should be a green light to adoption of the current curriculum on organic agriculture developed by the NBTE or other.

Organic agriculture has several benefits for the environment and human health. According to the Food and Agriculture Organization (FAO), Organic agriculture reduces non-renewable energy use by decreasing agrochemical needs, which require high quantities of fossil fuel to be produced. Organic agriculture also contributes to mitigating the greenhouse effect and global warming through its ability to sequester carbon in the soil (Crowder, 2023).

Organic farming practices promote soil health, carbon storage, and water conservation. They also reduce the use of chemical pesticides, synthetic fertilizers, and greenhouse gas emissions that harm the soil, water, and climate. Organic foods are rich in minerals and vitamins. Organic agriculture encounters several challenges. These include ecological justice, animal welfare, fair trade, supply chain development, productivity limitations, in addition to regional adaptation and global harmonization for standards (IFOAM, 2021).

Ohaji, (2009), identified that poor attitude of the students towards agricultural programme is associated with migration from rural areas (which are the main center of agricultural production) to urban due to the fact that they have not been adequately motivated towards agriculture. Therefore, apparent growth in interest, attitude and aspiration toward agriculture would come about only when there is real effort by the government to improve agriculture. Nwanko, (2015) in a similar study identified that students' perception affects their interest in agricultural Programmes, which enables them develop an interest in knowing more about a particular thing. The factors influencing the choice of agricultural science in universities in Nigeria are numerous including family and friends influence, profession and job considerations (Leven, 2007).

Objectives of the Study

1. Determine respondents' socio-economic characteristics
2. Discover respondents' awareness on organic agriculture as a course of study
3. Evaluate interest of agricultural students in studying organic agriculture as course
4. Identify respondents' motivating factors to choosing agriculture related careers in tertiary institutions or otherwise

Methodology

Study Population and location

Study Population: The respondents for the study comprised of different categories of students including secondary, post-secondary, undergraduates and post graduate students in the study area.

Research approach

The study made use of quantitative research approach to obtain information from respondents. A structured e-questionnaire was used to elicit information from respondents for data collection.

Data Collection Technique

Data for the survey were collected on respondents' socio-economic characteristics (including their institution, location, age, sex, religious affiliation, institution ownership category, etc.), awareness on organic agriculture as a course of study, etc. Data collection was done electronically with kobotoolbox for the online questionnaire.

Data Analysis

Data collected through e-questionnaire were sorted, coded and analysed using the statistical package for the social sciences (SPSS) software. Descriptive analysis was done including charts, frequency, percentages, means and weighted scores to draw conclusions and recommendations for the study.

Results and Discussion

A total of four hundred and sixty-one (461) respondents were sampled for the study from twenty secondary and tertiary institutions. The sampled respondents were selected from both private and government owned institutions across the six geo political zones of Nigeria students ranging from secondary to post graduate level in Nigerian tertiary institutions.

Sex of Respondents

Result from the study as shown in Figure 1 reflects that the majority of sampled respondents (58.0%) were female. This is an indication that there could be more female students studying agriculture in Nigerian tertiary institutions. This result is contrary to Adebo (2013)'s claim that there are more male students studying agriculture as a course in Nigeria tertiary institutions.

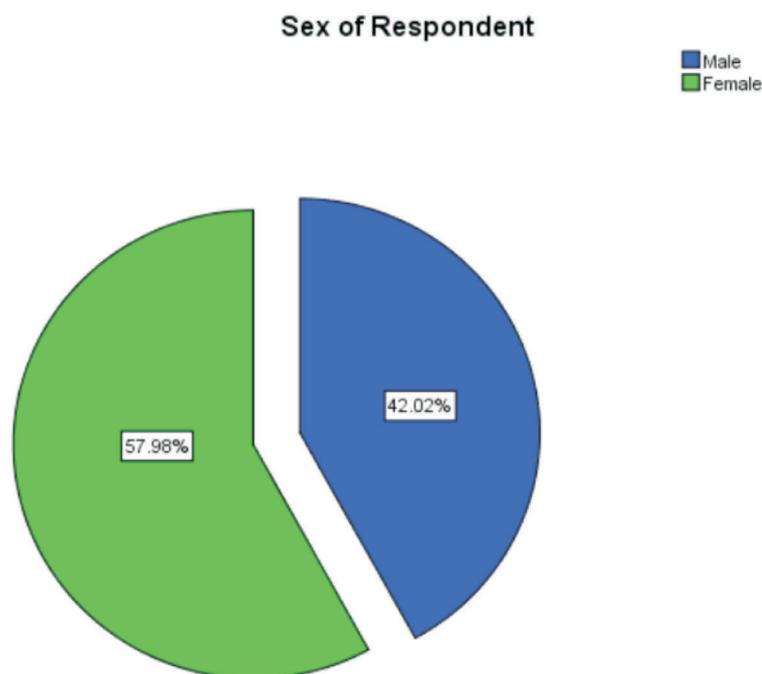


Figure 1: Respondents' Sex

Age of Respondents

Results as shown on Table 1 indicated that majority (59.7%) of the respondents were within the age range of 15-25 years, 14.3% were within the age range of 26-35 years while few (1.7%) were within the age range of 36-45 years. The mean age of respondents was 23.49. This is to confirm the claim that the sampled respondents were mostly undergraduates, single and in their youthful age with strength to execute practical aspect of organic agriculture as a course of study.

Table 1: Age of Respondents

Age Range	Frequency	Percent	Mean
15-25	275	59.7	23.49
26-35	66	14.3	
36-45	8	1.7	
46-55	3	.6	
>55	1	.2	
No response	108	23.5	
	461	100.0	

Category of Respondents

Result as indicated in Table 2 shows that majority (85.2) of the sampled respondents were undergraduates of tertiary institutions in Nigeria. Other categories of respondents included postgraduate students (14.2), post-secondary and secondary school students (0.3) respectively.

Table 2: Category of Respondents

Category of Respondent	Frequency	Percent
Secondary	1	0.3
Post-Secondary	1	0.3
Undergraduate	317	85.2
Postgraduate	53	14.2
Total	372	100.0

Marital Status of Respondents

As indicated in Figure 2, majority (93.6%) of the respondents were single while few (6.4%) of the respondents were married. This indicated that more of the sampled respondents were undergraduates in tertiary institutions and the result is in tandem with Onu and Ikehi (2013) that young and single students have more time to study agriculture in tertiary institutions due to the practical and sometimes rigorous aspect of the course.

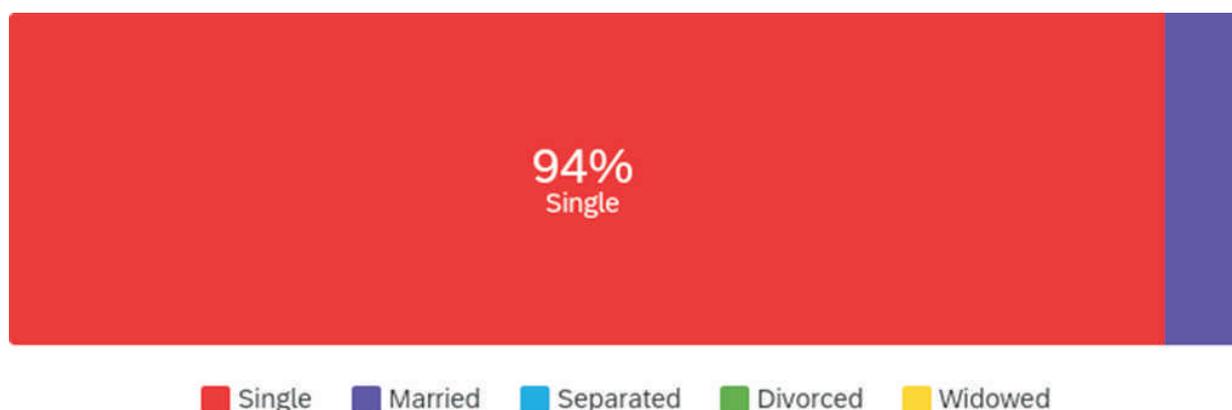


Figure 2: Marital Status of respondents

Location of Respondents

Results from the study as indicated in Table 3 shows that respondents were sampled from 21 States of the Federation covering the six geo-political zones of Nigeria. A total of 64.9% of the sampled respondents were from the South Western part of Nigeria, 6.7% from South East, 3.2% from South-South, 2.0% from North East, 4.3% from the North Central and 0.8% of the sampled respondents were from the North Western part of Nigeria. This result confirm the claim of Adebo and Sekumade (2013) that there are more educated youths from the Southwestern region of Nigeria due to their high enrollment in Nigerian tertiary institutions across the country.

Table 3: Location of Respondents

Location of Institution	Frequency	Percent
Abia	3	0.8
Adamawa	1	0.3
Akwabom	5	1.3
Anambra	8	2.1
Bayelsa	2	.5
Benue	2	.5
Cross River	1	.3
Delta	6	1.6
Ebonyi	1	.3
Edo	10	2.7
Ekiti	10	2.7
Enugu	1	.3
Imo	5	1.3
Kogi	6	1.6
Kwara	10	2.7
Lagos	37	9.8
Niger	3	.8
Ogun	35	9.3
Ondo	12	3.2
Osun	31	8.2
Oyo	187	49.7
No response	85	18.4
Total	376	100.0

Represented Institutions

The study revealed in Table 4 that about 5% of the sampled institutions were Secondary while 95% were tertiary Institutions. It further revealed that about 17% of the sampled tertiary institutions were Monotechnics and Polytechnics while 64% were Universities offering Agriculture as a course of study.

Table 4: Respondents’ Institutions

Names of Institution	Frequency	Percent
Akanulbiam Federal Polytechnic Unwana	1	0.2
Ambrose Alli University	1	0.2
Ekiti State University, Ado-Ekiti,Ekiti State.	1	0.2
Federal University of Agriculture, Abeokuta	1	0.2
Federal University Oye-Ekiti	1	0.2
Ibrahim Badamasi Babangida University Lapai	3	0.7
Iganmu Senior High School	1	0.2
Institute of Agricultural Research and Training	1	0.2
Joseph Sarwuantarka University Makurdi, Benue State	1	0.2
Michael Okpara University of Agriculture Umudike Umuahia	1	0.2
Niger Delta University, Bayelsa State	1	0.2
Oxford Model College	3	0.7
Oyo State College of Agriculture and Technology Igboora	1	0.2
Royal Prince and Princess College	1	0.2
The Polytechnic, Ibadan	1	0.2
University of Ibadan	283	61.4
University of Uyo	1	0.2
WahabFolawiyo Senior High School	1	0.2
Yaba College of Education	2	0.4
Yaba College of Technology	72	15.5
Total	461	100.0

Source: E-Survey, 2023

Ownership of Institution

The study reveals in Figure 3 that majority (96.5%) of the sampled institutions were Federal Government owned Institutions, 2.1% were State owned while less than 2% of the sampled Institutions were private owned. This is an indication that Agricultural related courses are offered more in Government owned than Private owned tertiary institutions in Nigeria.

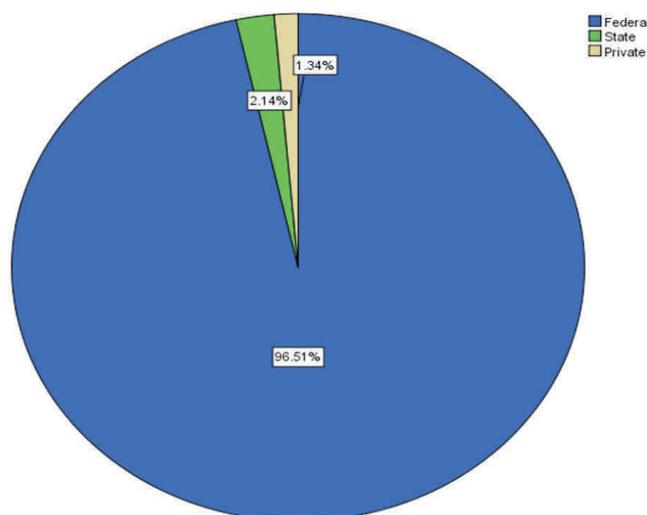


Figure 3: Ownership of Institutions

Interest to Study Organic Agriculture as a Course

Results obtained from the study (Figure 4) revealed that majority (84.3%) of the sampled respondents were interested in studying organic agriculture as a course in their various tertiary institutions while 10.9% of the respondents were not sure of their interest in studying organic agriculture as a course while few (4.8%) of the sampled respondents were not interested in studying organic agriculture as a course of study in their various institutions. Deji et al (2021) in a similar study supported this claim that agricultural students' in Nigerian tertiary institutions should be motivated by providing conducive environment and relevant facilities.

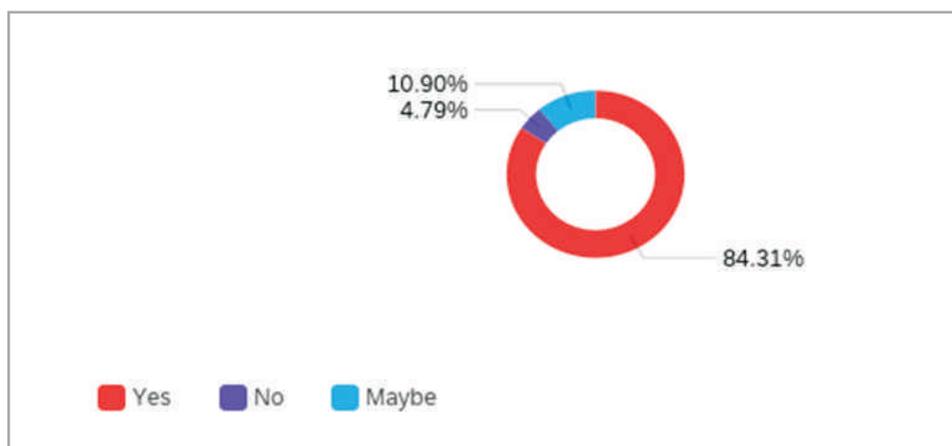


Figure 4: Interest to study organic agriculture as a course

Motivation for desiring to study Organic Agriculture as Course of Study in Tertiary Institutions

Results as revealed on Table 5 shows that respondent' interests to study organic agriculture as a course of study in tertiary institutions were due to certain motivating factors which included: Opportunities for further studies within or outside Nigeria (30.2%), Interest in practicing organic farming (29.1%), Seeking more knowledge on Organic Agriculture and Agroecology practices (24.3%), Passion for ecosystem sustainability (22.3%) and secured job opportunities (16.3%). Other motivating factors included access to information materials on Organic Agriculture and Agroecology (10.6%) and Influence of social media information (3.0%).

Table 5: Motivating factors for desiring to study organic agriculture as a course of study

Motivation for desiring to study Organic Agriculture as a course	Frequency	Percent
Secured job opportunities	75	16.3
Opportunities for further studies within or outside Nigeria	139	30.2
Interest in practicing organic farming	134	29.1
Passion for ecosystem sustainability	103	22.3
Seeking more knowledge on Organic Agriculture and Agroecology practices	112	24.3
Access to information materials on Organic Agriculture and Agroecology	49	10.6
Influence of social media information	14	3.0
Other factors (pls signify)	16	3.5

Awareness of Tertiary Institutions offering Organic Agriculture as a Course

The survey revealed in Table 6 that majority (57.3%) of the sampled respondents were not aware of tertiary institutions offering organic agriculture as a course while few (23.4%) of the respondents were aware of such. This implies that most tertiary institutions offering agricultural courses in the country are yet to incorporate organic agriculture into their curricula.

Table 6: Awareness of tertiary institutions offering organic agriculture as a course

Awareness of any tertiary institutions offering Organic Agriculture as a course	Frequency	Percent
Yes	108	23.4
No	264	57.3
No response	89	19.3
Total	461	100.0

Interest in studying Organic Agriculture as a course in Tertiary Institutions

As revealed on Table 7, many of the sampled respondents (52.3%) showed interest in studying organic agriculture as a course in their respective tertiary institutions, 16.9% of the respondents were not sure of their interest in studying organic agriculture as a course, while 11.5% of the sampled respondents were not interested in studying organic agriculture as a course in their various tertiary institutions.

Table 7: Interest in studying organic agriculture as a course in Nigerian tertiary institutions

Interest in Studying Organic Agriculture in Nigeria	Frequency	Percent
Yes	241	52.3
No	53	11.5
May be	78	16.9
No response	89	19.3
Total	461	100.0

Conclusions and Recommendations

The growing organic agriculture industry is one of the ways of generating employment in Nigeria. However, the personnel to be employed would have to be properly trained in organic production system through appropriate educational institutions. This study therefore investigated the interest of agricultural students of tertiary institutions of Nigeria in studying organic agriculture as a course.

The study revealed that majority of the respondents, although not having information on tertiary institutions offering organic agriculture but indicate interest in study the course in tertiary institutions. A major reason by the respondents in choosing organic agriculture as a course is opportunities for further studies within or outside Nigeria. Majority of the respondents also preferred to study organic agriculture at the First-Degree level (University). This overwhelming interest of the students in studying organic agriculture as a course also came with demand of what would be their motivation of choices of institutions where they would like to study the course. This is an indication that the current National Diploma programme in Organic Agriculture Technology by the National Board for Technical Education should be of interest to a good number of youths in Nigeria as they stand the opportunity of being trained in organic production system to either improve their chances for further studies or employment in the organic agriculture sector.

The study recommends that:

- i. Higher institutions should be capable of providing high-quality education and training in organic agriculture
- ii. There must be a comprehensive curriculum in place covering essential aspects of organic agriculture practices, including sustainable farming practices, soil health, and organic certification processes.
- iii. The institutions should have the right facilities to train the students in both practical and theoretical aspects of organic agriculture.

- iv. The institutions should have personnel that are well trained on at least principles and practices of organic agriculture.
- v. The institutions should have well equipped laboratories and libraries for training the students.
- vi. Such institutions should have standard organic farms for research and practical activities.
- vii. Establishment of standard organic farms for research and practical activities.
- viii. Entrepreneurial aspect of organic agriculture should be given priority in the training services provided by such institutions.
- ix. Availability of necessary inputs (organic seeds, feed, fertilizers, pesticides, etc.) for training the students.
- x. The institutions should incorporate exploration of all the aspects of organic agriculture to build the careers of their students.
- xi. Networking opportunities with professionals and organizations in the field should be available, in addition to support services, access to updated knowledge, and an alignment with ethical and environmental values.

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Published by:





Chemical Composition of Essential Oils of Aromatic Plants used to Control Bean Bruchids in the Republic of Congo

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Keywords:

Biopesticide,
monoterpene,
legume,
pest

Abstract

In Congo, with seed losses in storage approaching 60%, bruchid control has become a priority. The traditional method is to use the leaves or rhizomes of *Lippia multiflora*, *Cymbopogon citratus*, *Chenopodium ambrosioides*, *Ocimum gratissimum* and *Zingiber officinale*. The aim of this study is to analyze the chromatography of the essential oils of five aromatic plants used by growers to control bean and pigeon pea bruchids. These oils are extracted by hydrodistillation from fresh or dried leaves or rhizomes. After derivatization of the essential oil, the chemical composition is determined by gas chromatography-mass spectrometry (GC-MS). Variability in the chemical composition of essential oil extracted from the organ is noted in both fresh and dry states. A predominance of α -citral (40.5%) and thymol (52.6%) for *C. ambrosioides*. With *C. citratus*, it is 53.7% α -citral and 44.6% (2Z)-2-(3,3-Dimethylcyclohexylidene) ethanol. An occurrence of α -citral (47.1%) and thymol (21.9%) for *L. multiflora*. With *Z. officinale*, α -curcumene is the major constituent with 18.7% and 5.9%. Thymol accounts for 92.6% and 93.7% of *O. gratissimum* essential oils. These molecules contribute to the efficacy of these extracted oils in controlling bean pests in the field and in seed storage.

Composition chimique des huiles essentielles des plantes aromatiques utilisées dans la lutte contre les bruches de haricots en République du Congo

Résumé

Au Congo, avec des pertes des graines en stockage qui avoisinent 60 %, la lutte contre les bruches est devenue une priorité. La méthode traditionnelle préconisée est l'utilisation des feuilles ou de rhizomes de *Lippia multiflora*, *Cymbopogon citratus*, *Chenopodium ambrosioides*, *Ocimum gratissimum* et *Zingiber officinale*. Cette étude vise à analyser la chromatographie des huiles essentielles de cinq plantes aromatiques utilisées par les producteurs pour lutter contre les bruches haricots et de pois cajan. Ces huiles sont extraites par hydrodistillation sur les feuilles ou les rhizomes à l'état frais ou sec. Après la dérivatisation de l'huile essentielle, la composition chimique est déterminée par la chromatographie en phase gazeuse couplée à la spectrométrie de masse (CG-SM). Il est noté une variabilité de la composition chimique d'huile essentielle extraite de l'organe à l'état frais et sec. Une prédominance de α -citral (40,5%) et le thymol (52,6%) pour *C. ambrosioides*. Avec *C. citratus*, elle est de 53,7% de α -citral et de 44,6% de (2Z)-2-(3,3-Diméthylcyclohexylidène) éthanol. Une occurrence de α -citral (47,1%) et de thymol (21,9%) pour *L. multiflora*. Avec *Z. officinale*, le α -curcumène est constituant majeur avec

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légumineuse,
déprédateur

18,7% et 5,9%. Le thymol représente à 92,6 % et 93,7% dans les huiles essentielles *O. gratissimum*. Ces molécules contribuent à l'efficacité de ces huiles extraites dans la lutte contre les bioagresseurs de haricot en champ et en conservation des graines.

Introduction

Les plantes aromatiques connaissent un regain d'intérêts économiques ces deux dernières décennies par les usages multiples en industries agro-alimentaire, parfumerie, cosmétique et pharmaceutique. Les parties aériennes et souterraines sont souvent utilisées pour l'obtention des extraits bruts et des huiles essentielles, nécessaires en médecine traditionnelle humaine, en médecine vétérinaire, en alimentation humaine ainsi qu'en protection des plantes cultivées contre les bio agresseurs. En médecine humaine, outre les extraits des plantes, les huiles essentielles possèdent des propriétés anti-dépressives, anti-pyrétiques, antimicrobiennes (Chaumont et al, 2001 ; Kpodekon et al, 2013 ; Sharma et al, 2016 ; Melo et al, 2019 ; Valková et al, 2022), anti inflammatoire (Abena et al., 2003 ; Ouadja et al, 2021), antibactériennes (Matasyoh et al, 2007 ; Owolabi et al. 2009 ; Chekem et al, 2010 ; Saliu et al. 2011 ; Silva et al. 2016 ; Samba et al, 2020 ; Ouadja et al, 2021), antiseptiques, antalgiques (Abena et al., 2007), antistress (Etou-Ossibi et al., 2016), fongicides (Abena et al., 2002 ; Pino et al. 2018), sédatives (Skaria et al., 2012) et même des activités anticancéreuses (Koba et al, 2009 ; Avoseh et al., 2015 ; Shameem et al, 2019 ; Ngan et al, 2020) et antioxydantes (Agnaniet et al. 2005 ; Kumar et al, 2007 ; Khadri et al. 2008 ; Hammoudi et al, 2015 ; Santiago et al, 2016 ; Kpadonou et al, 2019 ; Barbosa et al, 2021). Elles sont ainsi utilisées pour guérir les affections respiratoires, les bronchites, la tuberculose, le rhumatisme, le paludisme, les affections cutanées et les affections parasitaires causées par les champignons, les bactéries et les vers parasites. L'usage des huiles essentielles s'est avéré en médecine vétérinaire pour lutter contre les tiques, les vers intestinaux et les punaises (Monteiro et al, 2017 ; Lemoufouet et al, 2018 ; Hounnimassoun et al, 2020). En agro alimentation, il est prouvé leur efficacité dans la stabilisation du lait frais de vache au Sud du Bénin (Degnon et al, 2016), l'assaisonnement des menus (Abegaz et al, 1993 ; Likibi et al, 2019) et la préservation des aliments (Hyldgaard et al, 2012 ; Prakash et al., 2015 ; Dwivedy et al, 2016 ; Adeogun et al, 2017 ; Majewska et al, 2019).

Quant à la protection des plantes cultivées, il est connu qu'au champ et en post récolte, les bio agresseurs occasionnent plus de 70 % des pertes (Bouchikhi et al., 2010). Pour réduire ces pertes, la lutte chimique est couramment recommandée en utilisant les molécules de synthèse. Bien que ce type se soit révélé efficace, malheureusement, il pollue l'environnement, provoquant ainsi la perte de la biodiversité par son action sur les organismes non-cibles (Chemat et al., 2012). Pour les molécules chimiques largement utilisées, il est aussi signalé une recrudescence de la résistance des parasites et des insectes contre les matières actives. A ce jour, la méthode de lutte intégrée est préconisée contre les bio agresseurs des plantes cultivées. Elle est devenue une priorité en l'agriculture durable et respectueuse de l'environnement. Cette méthode inclue les volets de luttes agronomique, génétique et biologique. Dans le volet lutte biologique, outre l'usage des parasitoïdes ou des auxiliaires, des entomopathogènes et des hyperparasites, l'utilisation des huiles essentielles extraites des plantes aromatiques est devenue un axe majeur afin de réduire les impacts des bio agresseurs. Les huiles essentielles se sont montrées fongicides (Mohr et al, 2017 ; Langsi et al, 2018 ; Kassi et al, 2020, Adjovi et al, 2022), insecticides ou insectifuges (Tapondjou et al 2001 ; Tapondjou et al 2003 ; Pushpanathan et al, 2006 ; Ndomo et al, 2009 ; Ntonga et al, 2012 ; Bossou et al, 2013 ; Santiago et al, 2014 ; Pinto et al, 2015 ; Kanko et al, 2017 ; Kobenan et al, 2018 ; Langsi et al, 2018), larvicide (Bigoga et al, 2013) et acaricides (Pamo et al, 2008). Les propriétés de ces huiles extraites de plantes aromatiques conduisent à leur utilisation dans la lutte contre les maladies dues aux champignons et bactéries ainsi que contre les fléaux causés par les acariens et les déprédateurs en plein champ ou en post récolte. Au Congo, les déprédateurs du genre bruches causent des pertes des graines de pois cajan et de haricot dans les zones productrices. Pour lutter contre ces bruches, les producteurs font couramment recours aux méthodes traditionnelles parmi lesquelles l'utilisation des ingrédients de feuilles, de fruits et de rhizomes des plantes aromatiques. Ces organes sont issus des plantes de *Lippia multiflora* L., *Cymbopogon citratus* Steud., *Chenopodium ambrosioides* L., *Ocimum gratissimum* L., *Capsicum annum* L et de *Zingiber officinale* Rosc (Messaudene et Mouhou, 2017). Les

effets de ces organes sur les bruches manquent de preuves scientifiques pour expliquer leur efficacité et leur innocuité. Les producteurs ou utilisateurs ne s'appuient que sur les connaissances empiriques. Ces plantes ou ses organes (feuilles ou rhizomes) sont couramment associés à la culture d'haricot ou introduits dans les récipients de stockage de leurs graines (Delobel et Malonga, 1987). Ces organes, à l'état frais ou sec contiendraient des huiles essentielles ayant des activités insecticides ou/et insectifuges sur les bruches de haricots et pois cajan. Mais, la composition chimique des huiles essentielles extraites des feuilles et les rhizomes de cinq plantes aromatiques étudiées est encore mal connue. Les constituants de ces huiles pourraient expliquer l'effet insecticide ou insectifuge observé.

Ainsi, l'objet de cette étude est de déterminer les composés chimiques des huiles essentielles des cinq plantes aromatiques utilisées par les producteurs pour lutter contre les bruches haricots et de pois cajan.

Matériel et méthodes

Matériel végétal

Le matériel végétal est constitué des feuilles de *Lippia multiflora* L., *Cymbopogon citratus* Steud., *Chenopodium ambrosioides* L. et *Ocimum gratissimum* L. ainsi que les rhizomes de *Zingiber officinale* Rosc. Les cinq plantes aromatiques sont identifiées comme ingrédients dans les méthodes traditionnelles de lutte contre les bruches dans les régions productrices de haricots au Congo (Delobel et Malonga, 1987). Pour l'extraction de ces huiles testées au cours de cette étude, les feuilles sont récoltées à 10 heures, en novembre 2019 à Agri-Congo de Mayanga dans les zones périurbaines de Brazzaville, Les rhizomes de *Zingiber officinale* sont achetés au marché de Bacongo, arrondissement 2 de Brazzaville.

Méthodes

Extraction des huiles essentielles

Les huiles essentielles sont extraites des feuilles de *L. multiflora* L., *C. citratus* Steud, *C. ambrosioides* L. et *O. gratissimum* L ainsi que des rhizomes de *Z. officinale* Rosc. Avant leurs extractions, les organes végétaux récoltés ou achetés, sont nettoyés puis rincés, deux fois à l'eau de robinet au laboratoire, pour enlever les débris inertes et vivants (poussières, fourmis, etc.). Ils sont ensuite repartis en deux lots. Le premier lot est gardé à l'état frais. Le second est séché à l'abri de la lumière pendant 10 jours. Pour ces deux lots, l'extraction est faite par hydro distillation sur un extracteur de type Clevenger (Clevenger, 1908). Ainsi, 500 g de l'organe frais ou sec d'une espèce végétale sont introduits dans un ballon de 6 litres avec 2 litres d'eau. Le mélange est ensuite porté à ébullition pendant 3 h 30 minutes (soit 1 h 30 minutes pour le chauffage du ballon et 2 h pour l'extraction). La vapeur émise monte jusqu'à un condensateur, et le condensat retombe dans la petite burette. L'huile flotte sur l'eau, qui est pour sa part progressivement renvoyée dans le ballon chauffé par le conduit en diagonale. Après 2 h d'extraction, l'huile essentielle est ensuite récupérée avec de l'éther diéthylique pour favoriser le flottage de l'huile sur l'eau grâce à une micropipette. Pour sécher toutes les traces d'eau contenues dans l'huile recueillie, il est utilisé le sulfate de magnésium anhydre MgSO₄. L'huile essentielle extraite est conservée dans un flacon hermétiquement fermé à 4°C au réfrigérateur avant la caractérisation moléculaire au laboratoire de chimie de la Petroci.

Détermination des composés chimiques des huiles essentielles

Pour déterminer les composés chimiques, 10 mg d'échantillon d'huile essentielle sont dérivatisés par addition de 250 µl de N, O-Bis (trimethylsilyl) trifluoroacetamide, Trimethylchlorosilane (BSTFA + TMCS, 99 :1) et de 250µl de pyridine. Le mélange est agité au vortex pendant 2 mn puis porté à 70 °C à l'étuve pendant 30 min. Ainsi, 1µl de la solution obtenue est injecté au GC-MS pour l'analyse. L'analyse par GC-MS est réalisée sur un appareil de marque Perkin Elmer, modèle Clarus 680GC 600C MS doté d'une colonne Restek Rtx-5ms de 60 m de longueur, d'un diamètre intérieur de 0,25 mm et d'une épaisseur de film de la phase stationnaire de 0,25 µm. L'hélium est employé comme gaz vecteur à débit fixe de 1 ml/mn. Le programme de température du four est de 50°C pendant 5 mn, puis un gradient de 3°C/min est appliqué jusqu'à 250°C. Cette dernière température est maintenue pendant 28 mn, soit une durée totale d'analyse de 100 mn. La température de l'injecteur est fixée à 250°C. L'injection est réalisée en mode split avec un ratio de 1 :50. Le spectromètre de masse est paramétré en mode impact électronique avec une température de source

d'ionisation de 200°C, une énergie d'électrons de 70 eV, une vitesse de balayage de 200 scans/mn et une plage de balayage comprise entre 50 et 600 m/z.

Résultats

1. Teneur en composés chimiques des huiles essentielles des feuilles de *Chenopodium ambrosioides*

L'abondance relative des composés chimiques des huiles essentielles des feuilles fraîches et sèches de *Chenopodium ambrosioides* est consignée dans le Tableau 1. Les résultats révèlent une variabilité de la composition et l'abondance des composés chimiques des huiles essentielles issues des feuilles fraîches et sèches de *C. ambrosioides*. Avec l'huile essentielle des feuilles fraîches, il est identifié 16 molécules discriminantes de celles des feuilles séchées. Pour ces molécules, la forte occurrence de 40,5 % est notée avec la molécule de α -citral. Il est enregistré la proportion de 27,8% et 24,2% respectivement pour les molécules de thymol et β -citral. Les autres molécules expriment une faible abondance ayant un taux inférieur à 0,6% dans l'huile essentielle. Pour les feuilles sèches, sur les 10 molécules discriminantes, le thymol est plus abondant. Cette molécule représente 52,6 % de l'huile essentielle des feuilles sèches. Outre le thymol, il est identifié les molécules de α -cymène et 2-bornène avec les proportions de 17,4% et 13,9%. Dans l'huile de *C. ambrosioides*, les molécules α -cymène, β -terpinène, α -citral et thymol sont communes à des proportions différentes des feuilles fraîches et sèches. Excepté le Patchoulane à temps de rétention élevé (50,31 min), les poids moléculaires plus importants sont notés sur l'huile essentielle des feuilles sèches de *C. ambrosioides*. Il est observé le temps de rétention compris entre 47,08 à 48,21 min avec la molécule d'exo-Norbornanol et 3-Méthylbenzenethiol (Tableau 1).

Tableau 1: Molécules chimiques contenues dans l'huile essentielle de *Chenopodium ambrosioides*

Nom de constituants	Temps de rétention (min)		Surface (mV. s)		Surface (%)	
	Frais	Sec	Frais	Sec	Frais	Sec
3-Thujene C10H16	7,68	-	9727014,31	-	0,2	
6-Methyl-5-heptene-2-one	10,63	-	9884635,05	-	0,2	
α -Phellandrene	-	11,57	-	47452696,77		0,2
β -Myrcene	12,08		6499149,49		0,1	
o-Cymene	14,41	18,07	181569429,35	5375063258,56	3,2	17,4
β -Terpinen	17,14	17,76	28809711,29	1043363784,43	0,5	3,4
5-Aminotetrazole	18,27		6565112,34		0,1	
Linalol	19,69		12931130,03		0,2	
Gamma Terpinene		20,52		107161099,13		0,3
7-Methyl-3,4-Octadiene	24,84		13408536,90		0,2	
4-Terpineol	25,28		12355437,89		0,2	
β -Citral	28,83		1388121229,59		24,2	
α -Citral	30,71	33,10	2324399649,90	574758627,99	40,5	1,9
Kemitracin-50	31,00		18815948,45		0,3	
2-Carene		31,47		1466031331,18		4,7
2-Bornene		31,64		4296919211,27		13,9
Thymol	32,41	37,11	1593906900,42	16274014005,52	27,8	52,6
1-Adamantylacetic acid	32,95		13120899,10		0,2	
2,7-Dimethyl-2,7-octanediol	34,34		7429275,35		0,1	
Nona-3,5-dien-2-ol		35,42		721931468,19		2,3
2-Ethylcyclohexanol	36,42		14356275,66		0,3	
Formic acid	37,79		7518943,79		0,1	
Nerolidol	45,39		29269747,74		0,5	
(Z,E)- α -Farnesene	46,22		22746538,29		0,4	
exo-Norbornanol		47,08		255700022,66		0,8
3-Methyl-1-cyclohexene		47,33		78791702,11		0,3
2-Méthylbenzenethiol		47,58		380055061,03		1,2
β -Bisabolene		47,86		72388245,30		0,2
3-Méthylbenzenethiol		48,21		250043289,86		0,8
Patchoulane	50,31		36531162,88		0,6	

2. Teneur en composés chimiques des huiles essentielles extraites des feuilles de *Cymbopogon citratus*

Dans l'huile essentielle des feuilles sèches de *Cymbopogon citratus*, il est identifié 19 molécules avec une proportion variable (Tableau 2). Sur les 19 molécules, il est noté une forte occurrence de 44,6% avec la molécule (2Z) - 2-(3,3-Dimethylcyclohexylidene) éthanol et 30% pour α -citral. La molécule 3-methylbenzenethiol est représentée à 5,7%. La proportion de 4,9% et 4,5 % est observée avec exo-norbornanol et o-cymene. Sur l'huile essentielle des feuilles fraîches de *C. citratus*, le α -citral est la molécule plus abondante sur 13 identifiées. Elle est présente à 53,7%. Avec le β -citral, ce taux est de 32,6%. Ces taux sont plus importants comparé à 5,1% observé avec trans, trans-Farnesol. Les molécules α -citral et decanoic acid sont identifiées des huiles essentielles fraîches et sèches de de *C. citratus*. Le decanoic acid a un poids moléculaire élevé se traduisant par le temps de rétention de 70,86 min et 64,85 min avec l'huile essentielle des feuilles sèches. Pour l'huile essentielle des feuilles fraîches de *C. citratus*, le stearic acid exprime un temps de rétention de 71,57 min (Tableau 2).

Tableau 2: Molécules chimiques contenues dans l'huile essentielle de *Cymbopogon citratus*

Nom de constituants	Temps de rétention (min)		Surface (mV. s)		Surface (%)	
	Frais	Sec	Frais	Sec	Frais	Sec
6-Methyl-5-heptene-2-one	9,76		34191308,27		0,2	
4-Methyl-3-(1-methylethylidene) -1-cyclohexene		12,20		242056625,01		0,9
o-Cymene		12,45		1234045322,38		4,5
2-Propylcyclohexanone		17,21		106749948,90		0,4
1,3-Hexadiene, 2,3,5-trimethyl		20,19		34376878,83		0,1
(2Z) -2-(3,3-Dimethylcyclohexylidene) ethanol		25,73		12193333573,06		44,6
β -Citral	26,12		6289041438,40		32,6	
α -Citral	27,82	27,44	10352068404,28	8196704019,94	53,7	30,0
Nona-3,5-dien-2-ol		29,43		504012143,98		1,8
Thymol		30,85		98670929,62		0,4
2.7-dimethyl-2.7-Octanediol	30,86		145348428,65		0,8	
2-(6-Octynyl) -1,3-dioxolane		32,19		62212944,75		0,2
3,3,6-Trimethyl-1,4-heptadien-6-ol	32,74		267244781,28		1,4	
Geraniol		33,71		71058211,02		0,3
α -Pinene, 3-trimethylsilyloxy		34,14		87372632,28		0,3
3-Methyl-Cyclopentene	34,31		109701274,88		0,6	
Linalol oxide	37,22		259248774,46		1,3	
3-Methyl-crotonic acid		38,23		476805963,87		1,7
Trans, trans-Farnesol	38,33		976209555,83		5,1	
Exo-Norbornanol		40,69		1348407970,31		4,9
Citral diethyl acetal	40,72		97669184,84		0,5	
3-Methylbenzenethiol		41,16		1552463370,43		5,7
2-Methylbenzenethiol		41,75		702886949,70		2,6
Bomeole	41,82		108922825,71		0,6	
Maleic acid	43,65		244112783,21	\	1,3	
Isopulegol acetate		63,49		112985744,83		0,4
Neric acid	66,99		75285176,51		0,4	
4,8-Decadienal, 5,9-dimethyl	67,35		52506079,22		0,3	
Phytol		70,17		63585662,57		0,2
Stearic acid, trimethylsilyl ester		72,33		186393994,91		0,7
Decanoic acid	70,52	64,95	48445080,69	50421235,91	0,3	0,2
Stearic acid	71,57		213794570,42		1,1	

3. Teneur en composés chimiques des huiles essentielles extraites des feuilles de *Lippia multiflora*

Pour *Lippia multiflora*, il est identifié 19 molécules contenues dans des huiles essentielles des feuilles fraîches et sèches (Tableau 3). Avec l'huile essentielle des feuilles fraîches, sur les 19 molécules identifiées, le α -citral et β -citral sont plus représentatives. Pour ces molécules, il est enregistré les proportions de 47,1 % et 26,2%. L'occurrence de 3,5%, 6,2% et

7,7% est notée respectivement pour la molécule trans trans-farnesol, stearic acid et thymol. Cette dernière molécule, elle est la plus abondante dans l'huile essentielle des feuilles sèches de *L. multiflora*. A un taux de 21,9 % le thymol est plus important comparé à 16,9% obtenu avec 1-Imidazol-1-yl-2,2-diméthylpropan-1-one. Les molécules D-carvone et 2,4-Ditert-butyl-2,4-adamantanediol expriment la même proportion de 10,9%. Avec le temps de rétention de 72,75 min et 73,03 min, le stearic acid a le poids moléculaire plus élevé des composants des huiles essentielles des feuilles fraîches et sèches de *L. multiflora*. Outre le stearic acid, avec les occurrences variables, les molécules o-cymene et thymol sont identifiées dans les huiles essentielles des feuilles fraîches et sèches de *L. multiflora* (Tableau 3).

Tableau 3: Molécules chimiques contenues dans l'huile essentielle de *Lippia multiflora*

Nom de constituants	Temps de rétention (min)		Surface (mV. s)		Surface (%)	
	Frais	Sec	Frais	Sec	Frais	Sec
o-Cymene	12,15	25,22	23417464,61	2399878413,77	0,3	4,9
β-Pinene		23,49		317135934,56		0,6
β-Citral	25,51		2139176442,12		26,2	
Limonene		25,71		1265018286,46		2,6
γ-Terpinene		27,14		141384185,93		0,3
α-Citral	27,25		3845318963,93		47,1	
1-Imidazol-1-yl-2,2-diméthylpropan-1-one		28,20		8341997838,37		16,9
Thymol	30,83	39,99	627227430,30	10807473595,76	7,7	21,9
2-[2-(2-Méthyl-1-propenyl) cyclopropyl]-2-propanol	32,45		41162422,54		0,5	
2-(6-Octynyl) -1,3-dioxolane	34,13		60170680,83		0,7	
D-Carvone		35,85		5390547115,65		10,9
Cyclohexan-1,2-diol	36,01		46827270,78		0,6	
Linalool		36,60		628207696,22		1,3
2-méthyl-3-octen-1-ol	36,70		55857547,98		0,7	
Linalol oxide	37,13		79591694,97		1,0	
Trans, trans-Farnesol	38,26		287979902,53		3,5	
Exo-Norbornanol	40,70		24677564,43		0,3	
O-Acetylthymol		40,83		3128293993,54		6,3
Borneol	41,90		29685329,59		0,4	
Maleic acid	43,79		64912743,71		0,8	
β-Caryophyllene		45,05		2689247433,44		5,4
Patchoulane	45,21		32272111,97		0,4	
β-Farnesene		46,00		1947185047,11		3,9
α-Caryophyllene		46,37		316309441,45		0,6
β-Caryophyllene oxide		51,28		653595991,96		1,3
4βH,5α-Eremophil-1(10) -ene		57,57		232194675,63		0,5
3,7,11-Triméthyl-3-hydroxy-6,10-dodecadien-1-yl acetate	64,40		42143389,22		0,5	
1S,4R)-p-Mentha-2,8-diene, 1-hydroperoxide	65,29		112644053,81		1,4	
Valeric acid, 4-cyanophenyl ester		66,61		1013724118,77		2,1
Nerolidol	67,08		26385397,47		0,3	
Cycloisolongifolene, 8-hydroxy-, endo		67,78		2811218520,86		5,7
4,8-Decadienal, 5,9-diméthyl	68,35		19800621,50		0,2	
2-(7-Heptadecynyloxy) tetrahydro-2H-pyran		68,99		375442425,03		0,8
4-Méthyl-1-phenyl-2-pentanone		69,91		1003105964,34		2,0
Oleic acid	71,66		99210971,37		1,2	
2,4-Ditert-butyl-2,4-adamantanediol		72,06		5382755486,31		10,9
Stearic acid	72,75	73,03	503926251,44	501374036,69	6,2	1,0

4. Teneur en composés chimiques des huiles essentielles extraites des feuilles de *Ocimum gratissimum*

Le tableau 4 consigne l'abondance relative des molécules des huiles essentielles des feuilles fraîches et sèches d'*Ocimum gratissimum*. Sur ces feuilles, le thymol est la molécule plus abondante. Sur cette molécule, la proportion de 92,6% et 93,7% est notée sur l'huile essentielle des feuilles fraîches et sèches. Ces proportions sont inférieures à 3% et

2,4% observées avec la molécule o-cymene. Pour l'*Ocimum gratissimum*, il est noté 10 molécules identifiées communes aux deux huiles essentielles des feuilles fraîches et sèches. La molécule caryophyllene oxide, stearic acid et α -ergostenol à poids moléculaire élevé n'est présente dans de l'huile essentielle des feuilles fraîches. Pour ces trois molécules, il est observé une durée de l'injection dans la colonne jusqu'à détecter au niveau du détecteur de 45,71 min, 72,53 min et 73,67 min (Tableau 4).

Tableau 4: Molécules chimiques constitutives d'huile essentielle de *Ocimum gratissimum*

Nom de constituants	Temps de rétention (min)		Surface (mV. s)		Surface (%)	
	Frais	Sec	Frais	Sec	Frais	Sec
β -Pinene	11,45	13,94	144512283,35	76675719,27	0,2	0,2
o-Cymene	13,56	15,87	1909406140,39	971346259,19	3,0	2,4
γ -Terpinene	15,99	18,11	771909234,04	376479400,48	1,2	0,9
α ,4-Dimethylstyrene	17,58	19,58	106607700,01	55413545,95	0,2	0,1
Nerol	25,94	27,28	218404096,70	241036707,82	0,3	0,6
Linalool	30,45	31,40	452416658,32	230814537,65	0,7	0,6
Thymol	32,03	32,81	58405434337,46	38089437912,85	92,6	93,7
Caryophyllene	37,97	38,32	97593106,20	113716710,44	0,2	0,3
α -Selinene	41,31	41,38	243844043,41	132855199,92	0,4	0,3
β -Bisabolene	42,06	42,09	339624172,38	345097266,93	0,5	0,8
Caryophyllene oxide	45,71		91892899,71		0,1	
Stearic acid	72,53		93532808,88		0,1	
α -Ergostenol	73,67		217446925,46		0,3	

5. Teneur en composés chimiques des huiles essentielles extraites des rhizomes de *Zingiber officinale*

Pour *Zingiber officinale*, 20 et 24 molécules sont constitutives des huiles essentielles des rhizomes frais et secs (Tableau 5). Avec les rhizomes secs, le thymol est la molécule la plus abondante. Elle représente 71,1% sur les 24 molécules identifiées. Il est noté une proportion de 5,9% de la molécule de zingiberene et 3% pour le α -curcumene. Sur les 20 molécules identifiées, la zingiberene est la plus importante avec 18,7% des huiles essentielles des rhizomes secs de *Z. officinale*. La tert-Butyl (2E) -3,7-dimethyl-2,6-octadienoyl, β -Sesquiphellandrene et α -Curcumene est présente respectivement à 12,3%, 11,8% et 10,9% sur 20 molécules identifiées. La molécule β -Bisabolene et Borneol sont représentées à la même proportion de 6,2%. Avec *Z. officinale*, 17 molécules identifiées sont communes aux huiles essentielles des rhizomes frais et secs. Les molécules de α -Thujene, β -Pinene, γ -Terpinen, Nerol, Maleic acid, Myrtenol et Linalol oxide ne sont présentes des huiles essentielles des rhizomes secs de *Z. officinale*. Pour *Z. officinale*, la tert-Butyl(2E) -3,7-dimethyl-2,6-octadienoyl est la molécule plus lourde avec un temps de rétention de 62,66 min et 62,86 min des huiles essentielles extraites des rhizomes frais et secs (Tableau 5).

Tableau 5: Molécules chimiques constitutives d'huile essentielle de *Zingiber officinale*

Nom de constituants	Temps de rétention (min)		Surface (mV. s)		Surface (%)	
	Frais	Sec	Frais	Sec	Frais	Sec
Camphene	9,99	12,33	208820279,74	115177930,79	0,9	0,3
α -Thujene		10,93		56569916,39		0,1
<i>o</i> -Cymene	14,72	16,89	183607243,84	1107048402,67	0,8	2,7
β -Pinene		14,82		75304122,95		0,2
Eucalyptol	15,26	17,38	533876455,16	475241185,32	2,3	1,1
?-Terpinen		19,26		140960018,12		0,3
Nerol		29,04		131044700,22		0,3
β -Citral	27,86	29,45	457976515,30	292936752,76	2,0	0,7
Borneol	28,79	30,34	1412081949,34	721694154,95	6,1	1,7
Linalool	29,13	30,69	430657261,16	302002417,18	1,9	0,7
α -Citral	29,57	31,07	803113980,47	454492143,96	3,5	1,1
Thymol	33,23	34,88	187659666,87	29408057124,14	0,8	71,1
β -Citronellol	33,52		188156709,36		0,8	
1-méthyl-1-(4-méthyl-3-cyclohexen-1-yl) éthoxy	34,24		515265025,98		2,2	
α -Curcumene	42,34	43,35	2529653630,96	1244399564,21	10,9	3,0
Zingiberene	43,20	44,16	4329791961,80	2445254046,50	18,7	5,9
α -Farnesene	43,55	44,49	1137782164,88	442148331,96	4,9	1,1
β -Bisabolene	43,92	44,86	1425320076,88	772046239,60	6,2	1,9
β -Sesquiphellandrene	44,68	45,57	2721098065,11	1161661369,26	11,8	2,8
Maleic acid		47,02		80791948,42		0,2
β -Eudesmol	50,54	51,26	314719045,08	132233144,76	1,4	0,3
Trans, trans-Farnesol	52,57	53,20	740832015,28	283455572,34	3,2	0,7
4 β H,5 α -Eremophil-1(10)-ene	53,59	54,18	579811289,51	279360864,04	2,5	0,7
Farnesol, tert-butyl dimethylsilyl ether	54,40		681877920,40		2,9	
Bicyclo[5.3.0]decan-2-one, 9-méthylène	55,26		510170411,59		2,2	
(2E,6E)-3,7,11-Triméthyl-2,6,10-dodecatriène	60,11		392389936,91		1,7	
Myrtenol		54,95		301731941,34		0,7
Linalol oxide		56,14		258235570,19		0,6
tert-Butyl(2E)-3,7-diméthyl-2,6-octadiénol	62,66	62,86	2843400256,00	694614842,97	12,3	1,7

6. Composés chimiques identifiées des huiles essentielles des cinq plantes aromatiques

Pour cinq plantes aromatiques, excepté *Cymbopogon citratus*, le thymole et *o*-cymene sont des molécules identifiées dans toutes les huiles essentielles (Tableau 6). Le thymol est représenté à plus de 90% dans les huiles essentielles de *Ocimum gratissimum* extraites sur les feuilles à l'état frais ou sec. Les proportions de 71,1% et 52,6% du thymol sont enregistrées dans l'huile de *Zingiber officinale* extraite des rhizomes à l'état sec et de *Chenopodium ambrosioides* extraite des feuilles séchées.

Le *o*-cymene est représenté à 17,4% dans l'huile essentielle de *C. ambrosioides* extraite des feuilles séchées. Avec une proportion inférieure à 5%, le *o*-cymene est présent dans toutes les autres huiles testées. Outre *O. gratissimum*, les composés β -citral et α -citral sont identifiés dans les huiles essentielles de quatre autres plantes. Mais, le β -citral est absent dans les huiles essentielles extraites des feuilles à l'état sec de *C. ambrosioides* et *C. citratus*. Avec ce composé, l'occurrence de 32,6% observée dans l'huile essentielle de *C. citratus* est plus importantes à 24,2 et 26,2 % notée dans les huiles essentielles de *C. ambrosioides* et *Lippia multiflora*. Par ailleurs, excepté dans l'huile essentielle de *L. multiflora* extraite des feuilles à l'état sec, le α -citral est identifié dans toutes les huiles essentielles. Avec les feuilles à l'état frais, le α -citral est représenté respectivement à une forte proportion de 40,5%, 47,1% et 52,6% dans l'huile essentielle de *C. ambrosioides*, *L. multiflora* et *C. citratus*. Le (2Z)-2-(3,3-diméthylcyclohexylidène) n'est identifié à 44,6% dans l'huile de *C. citratus* extraite des feuilles séchées. Les composés 1-imidazol-1-yl-2,2-diméthylpropan-1-one, D-carvone et 2,4-ditert-butyl-2,4-adamantanediol sont identifiés dans l'huile essentielle de *L. multiflora*. Avec *Z. officinale*, sur les rhizomes à l'état sec et frais, il est identifié zingiberene, β -sesquiphellandrene et tert-butyl (2E)-3,7-diméthyl-2,6-octadiénol. Cependant, le constituant α -curcumene n'est identifié dans l'huile essentielle extraite de rhizomes à l'état sec. Toutes ces molécules ne sont présentes dans les huiles de *C. ambrosioides*, *C. citratus*, *L. multiflora* et *O. gratissimum* (Tableau 6).

Tableau 6: Composés majeurs des huiles essentielles de 5 plantes aromatiques extraite des organes à l'état frais et sec

Nom de constituants	<i>Chenopodium ambrosioides</i>		<i>Cymbopogon citratus</i>		<i>Lippia multiflora</i>		<i>Ocimum gratissimum</i>		<i>Zingiber officinale</i>	
	Frais	Sec	Frais	Sec	Frais	Sec	Frais	Sec	Frais	Sec
β-Citral	24,2	0	32,6	0	26,2	0	0	0	2,0	0,7
α-Citral	40,5	1,9	53,7	30,0	47,1	0	0	0	3,5	1,1
Thymol	27,8	52,6	0	0,4	7,7	21,9	92,6	93,7	0,8	71,1
o-Cymene	3,2	17,4	0	4,5	0,3	4,9	3,0	2,4	0,8	2,7
2-Bornene	0	13,9	0	0	0	0	0	0	0	0
(2Z)-2-(3,3-Dimethylcyclohexylidene) ethanol	0	0	0	44,6	0	0	0	0	0	0
1-Imidazol-1-yl-2,2-dimethylpropan-1-one	0	0	0	0	0	16,9	0	0	0	0
D-Carvone	0	0	0	0	0	10,9	0	0	0	0
2,4-Ditert-butyl-2,4-adamantediol	0	0	0	0	0	10,9	0	0	0	0
α-Curcumene	0	0	0	0	0	0	0	0	10,9	0
Zingiberene	0	0	0	0	0	0	0	0	18,7	5,9
β-Sesquiphellandrene	0	0	0	0	0	0	0	0	11,8	2,8
tert-Butyl(2E)-3,7-dimethyl-2,6-octadienoyl	0	0	0	0	0	0	0	0	12,3	1,7
Total identified compounds (%)	92,5	83,9	86,3	74,6	81	60,6	95,6	96,1	53,7	77

Discussion

Cette étude a permis d'identifier les constituants chimiques des huiles essentielles extraites de *Chenopodium ambrosioides*, *Cymbopogon citratus*, *Lippia multiflora*, *Ocimum gratissimum* et *Zingiber officinale*. Dans les zones productrices d'haricots et pois cajan, ces plantes aromatiques sont utilisées par les producteurs comme ingrédients pour lutter contre les bruches. Les organes à l'état sec ou frais de ces plantes couramment utilisés sont les feuilles et les rhizomes. Pour l'huile essentielle extraite des feuilles fraîches de *C. ambrosioides*, les constituants chimiques β-citral, thymol et α-citral représentent 92,5 % de 20 identifiés. Le α-citral est le constituant majeur avec 40,4% suivi du thymol (27,8%) et de β-citral (24,2%). La prédominance de α-citral dans cette huile est contraire à celles observées par Tapondjou et al (2002), Singh et al., (2008) et Cheken et al., (2010). Pour ces auteurs, il est noté une forte occurrence de p-cymene. Mais, ce constituant chimique est présent dans l'huile essentielle de *C. ambrosioides* avec une faible proportion de 3,2%. Cette différence serait due à l'origine du matériel végétal. Les composés (Z)-ascaridole, α-terpinene, 4-carene, terpenolene sont dominants dans l'huile essentielle de *C. ambrosioides* extraite des feuilles fraîches par Gupta et al., (2002) ; Owolabi et al., (2009) ; Monzote et al. (2011) ; Borges et al. (2012) ; Santiago et al. (2014) ; Santiago et al. (2016) ; Monteiro et al. (2017); Langsi et al. (2018) ; Shameen et al., (2019). Avec l'huile essentielle de *C. ambrosioides* extraite des feuilles sèches, le thymol (52,6%), o-cymene (17,4%) et 2-bornene (13,9%) sont les composés dominants de 14 identifiés. Cette huile essentielle est marquée par une forte occurrence du thymol. Cette prédominance est contraire à celle de Terpinene observée par Cheken et al. (2010), El-Idriss et al. (2016), Bigoga et al. (2013) et Jiao et al. (2020). Aussi, il est révélé une dominance des composés ascaridole (Cavalli et al., 2004 ; Koba et al., 2009 ; Al-Kaf et al., 2016), bornylene (Pan et al., 2007) et cis-ascaridole (Dembitsky et al., 2008). Le Thymol et le α-citral sont les constituants chimiques présents quel que soit l'état des feuilles de *C. ambrosioides*. L'absence de β-citral identifié dans l'huile essentielle de *C. ambrosioides* extraite de feuilles sèches expliquerait par sa nature volatile. Le 2-bornene serait néoformé sous l'effet du séchage des feuilles. La forte proportion de ce composé n'est observée dans l'huile essentielle de *C. ambrosioides* extraite de feuilles fraîches.

Avec *Cymbopogon citratus*, il est signalé une forte proportion de α-citral dans les huiles essentielles extraites des feuilles. Sur les molécules identifiées, α-citral représente 53,7% et 30% dans l'huile de *C. citratus* extraite des feuilles à l'état frais et sec. Il est noté une différence des molécules identifiées des huiles essentielles de *C. citratus* selon l'état des feuilles utilisées à l'extraction. Ces résultats sont similaires à ceux obtenus par Dutta et al. (2014). L'huile extraite des feuilles fraîches, le α-citral et β-citral sont les composés majeurs avec une occurrence de 53,7% et 32,6%. Ces deux composés représentent 86,3% de 15 molécules identifiées. Cette prédominance de ces deux composés est obtenue par Matashyoh et al (2011), Bossou et al. (2013), Pinto et al. (2015), Degnon et al. (2016), Kanko et al. (2017), Pinto et al et al. (2018), kpadonou et al. (2019) et valkova et al. (2022). Pour ces auteurs, le geranial (ou α-citral) et neral (ou β-citral) sont des constituants chimiques plus importants de l'huile essentielle de *C. citratus* extraite des feuilles fraîches. Avec les feuilles sèches à l'abri de la lumière, les molécules (2Z)-2-(3,3-Dimethylcyclohexylidene) ethanol (44,6%) et le α-

citral (30%) sont majeures de 19 composés identifiés dans l'huile essentielle de *C. citratus*. La prédominance de (2Z)-2-(3,3-Diméthylcyclohexylidène) ethanol n'est signalée de notre huile essentielle de *C. citratus* extraite des feuilles à l'état sec. Cette molécule est aussi néoformée sous l'effet du séchage des feuilles à l'abri de la lumière. Cette molécule est inexistante dans l'huile essentielle de *C. citratus* extraite des feuilles fraîches. Elle résulterait de β -citral. Par ailleurs, le composé α -citral est présent dans l'huile essentielle de *C. citratus* quel que soit l'état des feuilles à l'extraction. Sur l'huile extraite des feuilles séchées à l'ombre, l'occurrence de 30% est notée pour l' α -citral. Cette proportion est en deçà de celles obtenues par Andrate et al. (2009), Kobe et al. (2009), Silou et al. (2011), Bossou et al (2013) et Likibi et al. (2019).

Sur les 20 composés chimiques identifiés dans l'huile essentielle de *Lippia multiflora* extraite des feuilles fraîches, il est noté une proportion de 81% constituée de α -citral (47,1%), β -citral (26,2 %) et Thymol (7,7%). Par contre, il est observé l'absence des composés α -citral et β -citral dans l'huile essentielle de *L. multiflora* extraite des feuilles séchées. A l'abri de la lumière, le séchage rapide des feuilles de *L. multiflora* entraînerait l'absence de α -citral et β -citral, molécules volatiles de cette huile essentielle. Mais, ces composés sont signalés par Samba et al. (2021). Ces auteurs révèlent une forte proportion de citral, neral et limonène dans l'huile essentielle de de *L. multiflora* extraite des feuilles séchées à l'abri de la lumière. De nos résultats, le thymol représente à 21,9 % de 20 molécules identifiées. La prédominance du thymol est mise en exergue par julinia et al. (2008), Gouollaly et al. (2010), Soro et al. (2015) et Kunle and Egharevba (2012). Le composé thymol avec 1-imidazol-1-yl-2,2-diméthylpropan-1-one (16,9%), D-carvone (10,9%) et 2,4-ditert-butyl-2,4-adamantanediol (10,9%) constituent plus de 60,6 % des molécules chimiques identifiées de l'huile essentielle de *L. multiflora* extraite des feuilles séchées à l'abri de la lumière. Les composés 1-imidazol-1-yl-2,2-diméthylpropan-1-one (16,9%), D-carvone (10,9%) et 2,4-ditert-butyl-2,4-adamantanediol ne sont identifiés dans l'huile essentielle de *L. multiflora* extraite des feuilles fraîches. Ces molécules seraient néoformées sous l'effet du séchage à l'abri de la lumière. Par contre, dans cette huile essentielle, les travaux de Kanko et al. (2004) ; Owolabi et al. (2009) et Diomandé et al. (2014) mentionnent la présence de 1,8 cineole, sabinène, geranial, neral, terpénoïl, thymyl acetate, cymène, linalol, limonène et carvaerol. Ces composés identifiés sont inexistants ou représentés en faible quantité de notre huile essentielle de *L. multiflora* extraite des feuilles séchées à l'abri de la lumière.

Pour *Ocimum gratissimum*, le thymol est le constituant majeur avec une proportion de 92,6 % et 93,7 % de l'huile extraite des feuilles fraîches et séchées à l'abri de la lumière. Avec le o-cymène, ils constituent 95,6% et 96,1% de 13 et 10 molécules identifiées dans ces huiles essentielles de *O. gratissimum*. Avec l'huile essentielle de *O. gratissimum* extraite des feuilles fraîches, une occurrence de 92,6 % de thymol est plus importante comparée à celle observée par Kassi et al. (2020). Par ailleurs, la forte occurrence de thymol est contraire à l'eugénol identifiée dans l'huile essentielle de *O. gratissimum* par Matasyoh et al. (2007), Prablu et al. (2009), Saliu et al. (2011), Silva et al. (2016), Elhassan et al. (2016), Soshi et al. (2017) et Barbosa et al. (2021). Cette différence expliquerait par l'origine géographique des plantes de *O. gratissimum*. Dans l'huile essentielle d'*O. gratissimum* extraite des feuilles séchées à la lumière, la prépondérance de 24,57% et 31,57 % du thymol est montrée par Kobenan et al. (2018) et Chaumont et al. (2001). Ces proportions sont en dessous de 93,7% de thymol observé. Le o-cymène est représentée à moins de 4% des huiles essentielles d'*O. gratissimum* extraites sur les feuilles à l'état frais ou sec. Mais, le p-cymène s'est révélé un constituant chimique majeur dans l'huile essentielle d'*O. gratissimum* extraites sur les feuilles séchées à l'abri de la lumière (Kobenan et al., 2018). Il est signalé l'absence des caryophyllène oxide, stéaric acid et α -ergosténoïl dans l'huile essentielle d'*O. gratissimum* extraite des feuilles séchées à l'abris de la lumière. Ces trois seraient très volatiles.

Les constituants chimiques α -curcumène, zingibérène, β -sesquiphellandréne et tert-butyl(2E)-3,7-diméthyl-2,6-octadiénoyl sont majeurs dans l'huile essentielle de *Zingiber officinale* extraite des feuilles fraîches. Ces quatre molécules chimiques représentent 53,7 % de 22 molécules identifiées avec une occurrence de 18,7 % pour le zingibérène. La forte proportion de ce composé chimique est prouvée par Onyenekwe et al. (1999), Felipe et al (2008), Padalia et al. (2011), Sasidharan et al. (2012) et Sharma et al. (2016). Cette forte présence de zingibérène est contraire à celle observée par Gupta et al (2011). Pour cet auteur, le geraniol est le composé majeur. Avec l'huile essentielle de *Z. officinale* extraite des feuilles séchées à l'abri de la lumière, le zingibérène est représenté à 5,9%. Ce constituant chimique constitue avec le thymol 77% de 24 molécules identifiées. Le thymol reste le composé majeur avec 71,1%. Cette prédominance expliquerait par la transformation des composés pendant le séchage des feuilles à l'abri de la lumière. En effet, le thymol a une proportion de 0,8% dans l'huile essentielle de *Z. officinale* extraite des feuilles fraîches. Cette forte occurrence du thymol est contraire à celle enregistrée par Sasidharan et al. (2010) et Ugbabe et al.

(2019). Ces auteurs identifient ar-curcumene, verbenol et eucalyptol comme constituants majeurs. Pour *Z. officinale*, il est identifié 17 composés présents à des proportions différentes dans l'huile essentielle des feuilles fraîches et séchées dont camphène, o-cymène, β -citral, borneol, linalool, α -citral, α -farnesène, β -bisabolène, β -sesquiphellandrene et β -eudesmol.

Conclusion

L'étude révèle une forte variation quantitative et qualitative des composés chimiques des huiles essentielles de cinq plantes aromatiques utilisées par les producteurs pour lutter contre les bruches haricots et de pois cajan. Il est identifié au moins 10 constituants chimiques des huiles essentielles extraites des feuilles de *L. multiflora* L., *C. citratus* Steud, *C. ambrosioides* L. et *O. gratissimum* L ainsi que les rhizomes de *Z. officinale* Rosc. Ces constituants sont les monoterpènes, les diterpènes et esquiterpènes. Le β -citral, le α -citral, le thymol, le o-cymène, le α -curcumène, le zingibérène, le β -sesquiphellandrene et le tert-butyl(2E)-3,7-diméthyl-2,6-octadiénol sont les plus représentatives des molécules chimiques identifiées. Ces molécules contribuent à l'efficacité de ces huiles extraites dans la lutte contre les bioagresseurs de haricot en champ et en conservation des graines. Pour une plante aromatique, il existe une variabilité des molécules chimiques selon l'état frais ou sec de l'organe utilisé à l'extraction de l'huile essentielle.

Remerciements

Les auteurs remercient l'Agence Universitaire de la Francophonie (AUF) et le FAO-Congo pour le financement et co-financement de ce projet de recherche.

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Social Network Drivers of Agroecological Practices: Case of the Avocado Multi-Stakeholder Platform in Kenya

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Keywords:

Agroecology;
Avocado;
Multistakeholder platform;
Social network analysis;
Value chain

Abstract

Smallholder farmers are practicing agroecology to enhance productivity, efficiency, and market access while coping with market uncertainty, environmental threats, and financial instability. Risk management addresses agricultural climate vulnerabilities, but the role of social network drivers on farm resilience practices has not been explored. This study examined the social network drivers that support avocado agroecological practices among producers on a multistakeholder platform. It uses social network analysis to identify connections and centrality measures in production, market, and information exchange networks. The methodology consists of farmer interviews and focuses on promoting agroecological practices. A multiple linear regression model was then used to determine if network centrality metrics, farmers' sociodemographic factors, and farm attributes influence the adoption of avocado agroecological techniques. The study reveals that market centrality and information exchange networks significantly influence agroecological practices more than production networks. Adoption is highly influenced by farmers' age and education, but not by farm size, gender, or education level. The findings show the significance of multi-stakeholder strategies in addressing societal issues, especially in the avocado sector. The study supports local initiatives involving farmers in technology innovation in rural areas and contributes to the debate on the Agricultural Innovation System.

Les Réseaux Sociaux, Moteurs Des Pratiques Agroécologiques : Le Cas De La Plateforme Multi-Acteurs De L'avocat Au Kenya

Résumé

Les petits exploitants agricoles pratiquent l'agroécologie pour améliorer la productivité, l'efficacité et l'accès au marché tout en faisant face à l'incertitude du marché, aux menaces environnementales et à l'instabilité financière. La gestion des risques s'attaque aux vulnérabilités climatiques agricoles, mais le rôle des moteurs de réseaux sociaux sur les pratiques de résilience agricole n'a pas été exploré. Cette étude examine les facteurs de réseau social qui soutiennent les pratiques agroécologiques de l'avocatier parmi les producteurs sur une plateforme multipartite. Elle utilise l'analyse des réseaux sociaux pour identifier les connexions et les mesures de centralité dans les réseaux de production, de marché et d'échange d'informations. La méthodologie consiste en des entretiens avec les agriculteurs et se concentre sur la promotion des pratiques agroécologiques. Un modèle de régression linéaire multiple a ensuite été utilisé pour déterminer si les mesures de centralité du réseau, les facteurs

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Mots clés:

Agroécologie ;
avocat ;
plateforme multipartite ;
analyse des réseaux sociaux ;
chaîne de valeur

sociodémographiques des agriculteurs et les attributs de l'exploitation influencent l'adoption de techniques agroécologiques pour l'avocatier. L'étude révèle que la centralité du marché et les réseaux d'échange d'informations influencent les pratiques agroécologiques de manière plus significative que les réseaux de production. L'adoption est fortement influencée par l'âge et l'éducation des agriculteurs, mais pas par la taille de l'exploitation, le sexe ou le niveau d'éducation. Les résultats montrent l'importance des stratégies multipartites dans la résolution des problèmes sociétaux, en particulier dans le secteur de l'avocatier. L'étude soutient les initiatives locales impliquant les agriculteurs dans l'innovation technologique dans les zones rurales et contribue au débat sur le système d'innovation agricole.

Introduction

Social networks in agroecological systems significantly influence farm innovation by providing support and knowledge sharing and fostering long-term territorial development (Cofré-Bravo et al., 2019). Innovation is a social and interactive process, requiring actor interaction and information flow (Skaalsveen et al., 2020). Network structure influences innovation growth and performance, and understanding uptake and processing is essential. Network approaches are useful in agro-food systems research, as they consider power balances between supply chain actors.

Social network analysis (SNA) is a method used to analyze relational data, based on graph theory (Chiffolleau & Touzard, 2014). It reveals that farmers are connected to various networks, including family, friends, and stakeholders, which influence their practices and performance. Farmers interact with various public and private authorities, including organizations, associations, and institutions. Stakeholder networks have a greater impact on farmers' decision-making than technical support, family member networks, or organization communities. This study emphasizes the importance of understanding key actors in social networks that facilitate information dissemination, aligning with previous research by Oreszczyn et al., 2010, and Issahaku, 2019.

Aguilar-Gallegos et al. (2015) found that stronger stakeholder ties among farmers lead to better technology adoption and increased profits. Collaboration networks significantly enhance farmers' chances of adopting farming innovation improvements. Filippini et al. (2020) found that knowledge flows influence technology adoption, but no study has explored the influence of networks on farmers' adoption of avocado agroecological practices. Agriculturists' perceptions of agroecological techniques are influenced by technological innovations and societal factors.

Agroecological practices aim to increase productivity while considering adaptation, resilience, and emissions reduction. Climate change impacts non-traditional weather patterns, crop choices, disease and insect infestation patterns, and nutritional value (Agbenyo et al., 2022). Smallholder agriculture faces challenges in enhancing crop production and food security due to vulnerability to climate threats. Extreme weather events like floods, droughts, and pest outbreaks can impact crop failure, yields, markets, agribusiness, food security, and individual farmer income (Ojo et al., 2022). Poor harvests can also affect lenders, governments, and intermediaries aiding (Troncarelli, 2023).

Sustainable Development Goals (SDG) 18 focuses on combating climate change, but smallholders must navigate market volatility, environmental hazards, and financial instability. Private sector players are managing vulnerabilities, but the broader interplay of components for scale resilience is not yet adequately addressed (Diaz-Sarachaga et al., 2018). The study explores the use of a multi-stakeholder platform (MSP) to tackle climate change-related issues in farming, emphasizing the importance of considering the perspectives of various stakeholders (Rasch, 2019). It suggests MSP as a potentially effective approach to tackle complex socio-economic, environmental, and problems affecting avocado producers.

The social network drivers of agroecological practices refer to the factors within social networks that influence the adoption, dissemination, and implementation of these practices in farming communities (Lin et al., 2021). These drivers include network structure, information flow, trust and social capital, learning and innovation, shared values and norms, leadership and influence, resource sharing, and policy and institutional support (Rop et al., 2023). Networks with dense connections and influential central nodes facilitate the adoption of agroecological practices more effectively.

Information flow is influenced by strong ties between farmers, researchers, extension agents, and community leaders, leading to the efficient exchange of knowledge as previously advocated by Oreszczyn et al., 2010). Trust and social capital among individuals in a network play a crucial role in encouraging the sharing of ideas, experiences, and resources related to agroecology, fostering collective learning and adoption.

Learning and innovation are accelerated by learning from each other's successes and failures, while shared values and norms within a community or network influence behavior (Yu & Gamba, 2024). Influential individuals or opinion leaders within networks can significantly impact the adoption of agroecological practices.

Resource sharing is facilitated by networks, leading to greater cooperation and support among farmers. Policy-making and institutional support for agroecological practices can also be influenced by networks as advocated earlier by Mazé et al., 2021). Understanding these drivers helps practitioners, policymakers, and researchers design more effective interventions, outreach programs, and policies that leverage existing social structures to promote and support the adoption of agroecological practices within farming communities.

This study explores the significant role of multi-stakeholder strategies (MSPs) in addressing societal challenges, particularly in the avocado sector. It examines factors such as momentum, ownership, and awareness, as well as the influence of age, education, and personal capability on climate-smart practices. Understanding these factors is crucial for developing needs-specific farming practices and disseminating agricultural knowledge (Diaz-Sarachaga et al., 2018).

The objectives of the study were: (i) To explore the role of social network drivers in on-farm resilience practices among avocado producers in Kenya. (ii) To use social network analysis to identify connections and centrality measures in production, market, and information exchange networks among avocado producers. (iii) To determine the factors that influence the adoption of avocado agroecological techniques among avocado producers.

Methodology

Study location

The research focused on the Upper Mara Watershed, specifically the East Bomet and Narok West Sub-County region, located in the Mau Forest Complex, at 1900-2970M elevation (Figure 1). The Upper Mara watershed, with a climate of 12° -16° C and Andosols and Nitisols soils, is primarily used for forest and agriculture. Its lowland region, encompassing grassland, livestock, and wildlife, preserves the ecosystem. However, human expansion and resource depletion have led to lower productivity. To counter this, avocado farming has been integrated into cattle rearing, preserving watersheds, and promoting cultural and economic values (Oware, 2020).

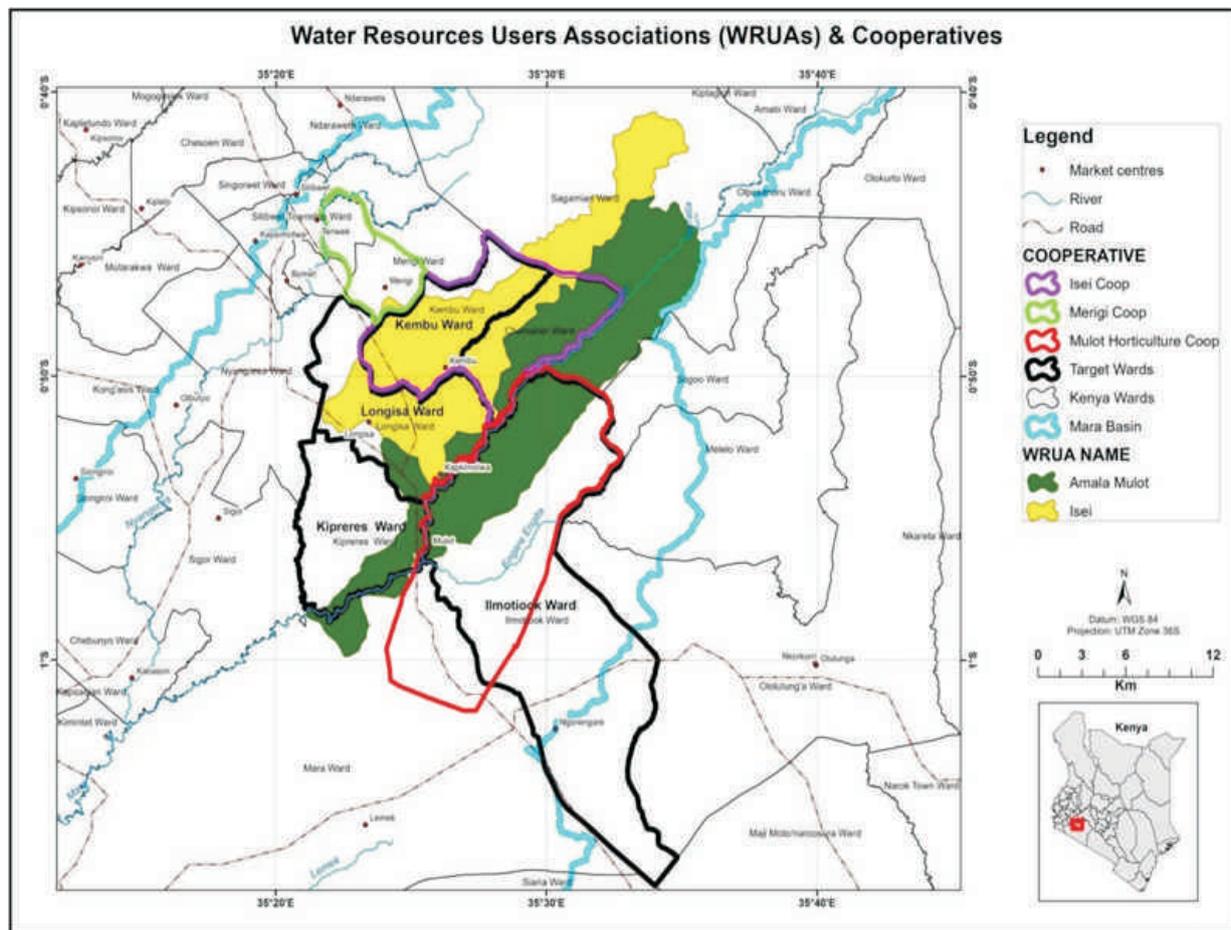


Figure 1: Map of Upper Mara Watershed Showing the water users associations and farmer cooperative groups.

Sample Technique and Sample Size

The study investigated the avocado value chain in Kenya by conducting interviews with a total of 80 stakeholders and 60 farmers affiliated with four cooperatives. To select the stakeholders, a combination of simple random sampling and stratified sampling techniques was employed. Specifically, 80 avocado stakeholders were chosen from three cooperatives located in Bomet East and Narok West Sub-Counties, ensuring a representative sample from various strata within these cooperatives. Similarly, a stratified sampling method was utilized to select 60 avocado farmers from the list of four cooperatives, facilitating diverse perspectives across different segments of the value chain. This approach aimed to provide a comprehensive understanding of the avocado value chain by capturing insights from a range of stakeholders and farmers. It delved into sociodemographic traits, challenges in implementing climate-smart practices, and information sharing within the industry. The research identified three types of networks: production, market, and information exchange networks.

Data analysis

The analysis involves defining and quantifying social networks among avocado farmers and applying multiple linear regression analysis to determine if sociodemographic information and smallholder farm characteristics influence agroecological techniques adoption.

Social Network Analysis

The study used social network analysis (SNA) to examine the relationships between different stakeholders in the avocado value chain. The study used a dichotomous matrix to represent the presence or absence of a relationship

between two nodes, and Gephi software to analyze the data. The study applied two levels of analysis: degree centrality and betweenness centrality, which measure the importance and influence of each node, respectively. The study also uses density, transitivity index, and cluster coefficient to assess the characteristics of the whole network, such as its cohesion, openness, and sub-group formation.

The analysis was based on the concept of agroecology in the sense that it applies ecological and social concepts and principles to the design and management of the avocado production system. Agroecology is a holistic and integrated approach that seeks to optimize the interactions between plants, animals, humans, and the environment while also addressing the need for socially equitable food systems. By using SNA, the study identifies the key actors and linkages in the avocado value chain, as well as the potential opportunities and challenges for improving its sustainability and resilience. Agroecology also recognizes that food systems are context-specific and depend on local conditions, constraints, and opportunities. Therefore, SNA can help to understand the diversity and complexity of avocado value chain systems and their interactions with ecological and social factors.

In graph theory, a subgraph having a route linking every pair of vertices is referred to as a connected component. Network analysis is a method of studying the connections and interactions between different elements in a system (Muller et al., 2019). The connected components as a part of a network where every element can reach every other element through some path (Muller & Peres, 2019). The largest part of a network is called the giant component, and it shows how well the network is connected overall. The degree of assortative is the tendency of elements in a network to link with other elements that are similar or different from them in some way (Yuan et al., 2021). The degree centrality, which is the number of connections an element has, illustrates how degree assortativity can be calculated and interpreted. The degree of assortativity is expressed as a correlation coefficient between the degrees of two connected elements. A positive coefficient means that elements tend to link with elements that have similar degrees, while a negative coefficient means that elements tend to link with elements that have different degrees. The degree of assortativity indicates how well a network can connect its core and periphery, and thus its level of connectivity (Rop et al., 2023).

Results and Discussion

The role of social network drivers in on-farm resilience practices among avocado producers

Gender and marital status

The survey reveals that men outnumber women in avocado growing, a labor-intensive industry with specific duties for males and teenagers. Women prefer other food crops for family food security, while males prefer avocado cultivation. Gender plays a crucial role in knowledge learning, sharing, and decision-making, particularly in climate-smart practices and agricultural production. Gender is essential for addressing societal and economic needs, fostering climate-smart practices, and agricultural resilience. In developing countries, where women manage farm labor, gender is especially important (Ma et al., 2022 & Jaroenwanit et al., 2023).

The research revealed that 90% of respondents were married, with 3.89% being widows/widowers. Gender roles in land use choice-making are influenced by marital status, labor allocation, and agricultural activities. Marriage creates familial duties, emphasizing the need for socioeconomic networks for access to information and funds. The availability of family labor may inspire married farmers to plant more crops and apply agricultural knowledge. The study supports previous research showing that information connection among avocado smallholder farmers varies by gender, with women having more intimate networks and media use. Balancing open interaction with sources and strong family networks is crucial for climate change awareness.

Age and education level

The majority of avocado growers in rural areas are aged between 34.41 and 60.53, with older farmers making up 19.0% and younger farmers making up 34.4%. Age significantly influences climate-smart avocado farming adoption, knowledge acquisition, and adaptation approaches. Elderly farmers are less likely to adopt labor-intensive and knowledge-intensive farming technologies compared to younger farmers. Most avocado farmers have moderate literacy levels, with most obtaining primary school certificates. Education for smallholder farmers is a viable technique for addressing farming constraints like diseases. Age may be a barrier to farmers adopting technology, but education is a key influencing factor.

Education level is crucial for farmers to adopt climate-smart practices effectively. Farmers with higher education can perceive, analyze, and respond to new information more effectively (Setshedi&Modirwa, 2020). However, avocado farmers with modest literacy levels can still participate in development. Action learning can increase their capacity for creativity in innovation systems, even if they have a minimum level of literacy and awareness (Andrew et al., 2019).

Farm size and avocado planting techniques on farms

The study revealed that farm sizes vary across three agroecological zones, with 0.1-0.1 ha accounting for 9.8%, 1-2 ha for 25.5%, 2.1-3 ha for 19.6%, and 3.1 ha for more than 45.6%. Farm size is crucial for implementing climate-smart practices, as smallholder farmers often struggle to adapt to new technologies (Salmorin&Gepty, 2023). However, uncertainty about benefits and land pressure can hinder adoption. Farm size is often included in modeling acceptance processes, as it is highly connected to the adoption of new technologies (Marescotti et al., 2021).

The study reveals that smallholder farmers with varying experience in avocado planting, with most having matured trees, are more likely to adopt climate-smart practices. These practices include intercropping, pure stands, boundary planting, and alternate rows. Climate variables define agroecological zones, and climate-smart techniques like integrated nutrient management and conservation tillage are more successful in preserving soil moisture (Zerssa et al., 2021).

The study reveals a positive correlation between avocado yield and farm size, particularly among small farms that participate in a multi-stakeholder platform. Climate-smart practices and technology adoption can boost productivity and land resilience, impacting farm income (Rop et al., 2022). Even smaller farms with lower yields can benefit from increased production and communication through a multi-stakeholder platform, communication, and data management. This supports previous research showing that climate-smart methods can increase avocado output.

Rainfall and temperature trends are posing risks to agriculture, necessitating regionally appropriate knowledge and technologies (Wise, 2020). Indigenous knowledge is crucial for sustainable practices, and climate-smart avocado planting techniques are influenced by planting technique and duration, making the chosen farming strategy crucial for avocado farming sustainability.

The Avocado Farmers' Social Network Analysis

The networks of avocado stakeholders in the value chain are depicted in Figure 2, showing the paths through which growers, cooperative societies, input suppliers, and purchasing companies share information. Farmers with higher degrees interact with farmers in cooperative societies and other stakeholders in the production network, whereas higher-degree nodes connect stakeholders (Agneessens et al., 2017).

This may be explained by the fact that, as was already mentioned, the cooperatives had different agroecological coverage, and that during the interviews, farmers recognized other farmers in the production network who were typically opinion farmers. Farmers typically request assistance with field tasks such as pruning, watering, weeding, mulching, sharing sprayers, and harvesting at the same time. As a result of the geographical configuration, they are more likely to seek assistance from neighbors. In comparison to the information exchange network, the production network is likewise less dense (Agneessens et al., 2017).

Agroecological zones are important to the information exchange network because they allow for the identification of farmers from mid-agroecological zones by both far-off and nearby farmers as well as by numerous farmer groups and cooperatives. Connecting to the network depends on the reputation of the farmers. The market network, however, is fragmented, with farmers selling their fruit infrequently and mostly selling small quantities of avocado to nearby retailers in urban centers. Due to damage or malformation, these avocados are of low quality.

At the same time, unless there was a preexisting contract arrangement with avocado export corporations, farmers are typically independent in their marketing. In discussions about the sale of avocado fruits, growers voiced doubt about the methods used by other farmers and export companies. As a result, they frequently opt to market their avocado in other locations through brokers or new buyer organizations that provide higher rates. A tailored policy from the cooperatives, involving contract agreements and even regulatory action from government authorities, was in reality used to encourage the sale of avocados among export firms in order to better manage the quality of the avocado for export.

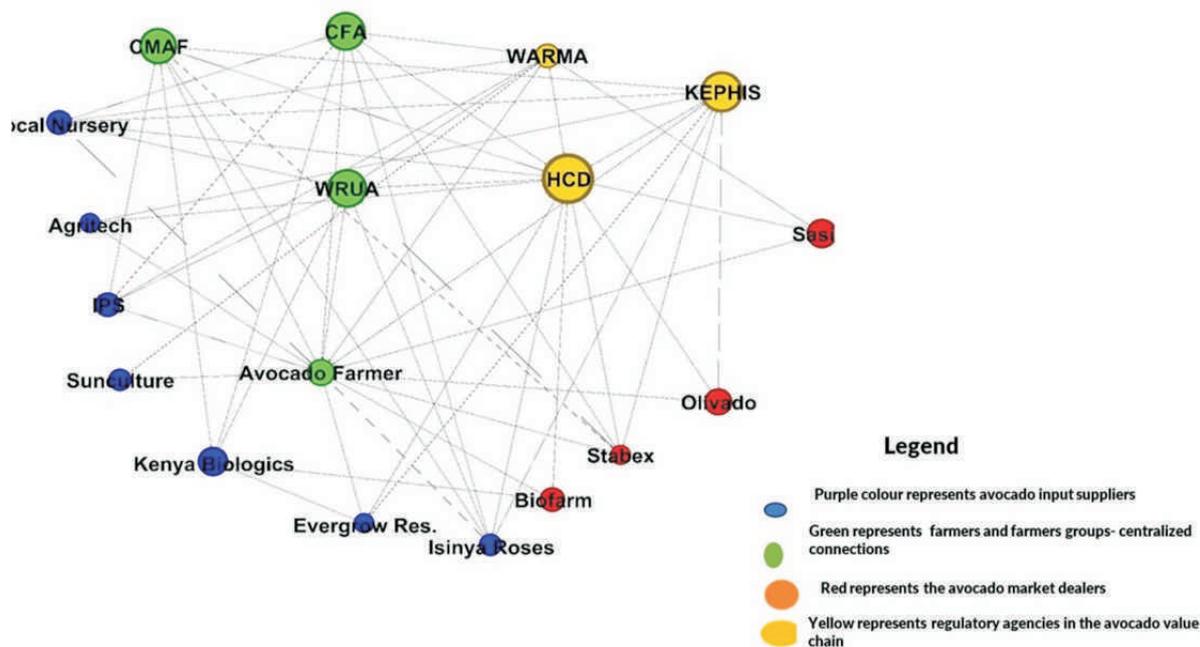


Figure 2: Avocado value chain stakeholder network with nodes indicating centrality, color-coded, representing node size and centrality.

Table 1 lists the key characteristics of developed networks. The production network links 44% of nodes, but the market network connects just 16% of the entire sample. All nodes (100%) are connected by the information exchange network. As a result, the production and market networks' information exchange networks have lower density values than the regulatory service providers' networks, indicating less cohesion. The production network's transitivity index reveals node clustering, with a low-density score of 0.012 (1.2%), as compared to the regulatory services' 0.25 (25%). The study confirms discussions by finding that farmers often collaborate on production support tasks in small groups of related farms. Both the production and the information exchange networks have a negative assortativity coefficient, with the former being significantly more disassortative ($r = -0.73$) than the other network ($r = 0.99$).

Table 1: Structural characteristics and network statistics

	Network of Producers	Network of Marketers	Network for Information Dissimulators
Number of linked nodes	33 (44%)	16 (21%)	38 (100%)
Number of edges	82	27	147
Degree—av. (st.dev.)	1.32 (1.75)	0.99 (0.21)	0.99 (0.34)
Top 3 nodes (degree score)	AF (25), IR (11), WRUA (8)	CMAF (13), OV (6), BF (4)	HCD (10), WRA (10), KEPHIS (10)
Betweenness—av. (st.dev.)	23.04 (44.460)	7.96 (3.89)	23.49 (14.25)
Top 5 nodes (betweenness score)	AF (152), IR (78), WRUA 16)	CMAF (27), OV (2), BF (1.8)	HCD (37), WRA (33), KEPHIS (22)
Density	0.012	0.2	0.25
Massive component (% of nodes)	33 nodes (44%)	16 nodes (11%)	38 nodes (100%)
Assortativity coefficient (r)	-0.73	0	0.991

Note: AF represents avocado farmer; WRUA is the water resource user's association, CMAF is the cis-mara avocado farmer cooperative; HCD is the horticultural crop directorate; IR is Isinya Roses seedling supplier; BF is Biofarm avocado exporter; OV is Olivado avocado exporter; KEPHIS is Kenya plant health inspectorate service.

The production network connects core nodes to peripheries well while being less dense than the information exchange network. Given a low density of 1.2%, the big component clusters 44% of nodes, which is a moderate score. This is supported by centrality measurements, which show that nodes with low betweenness centrality and low centrality degree have a limited ability to link with peripheral sub-groups. Both the production network and the information exchange network exhibit a stronger propensity in this direction.

Although the production network has a lower density score than the information exchange network, it has a greater average betweenness centrality, indicating a lesser connection capacity. The production network also has a greater average degree of centrality, which suggests that the information exchange network has fewer connections. The analysis of the standard deviation, however, points to a more uniform distribution.

In this study, which examines several networks, links between farmers are found (Crespo et al., 2014). The findings demonstrate how centrality factors in production networks, such as support and advisory services, significantly impact the use of climate-smart practices in avocado farming. Networks for information sharing do not, however, significantly influence adoption rates. Compared to individual farmers, multi-stakeholder platforms provide information to farmers more quickly. Higher adoption of climate-smart techniques to increase resilience on the farmers' farms is more likely to be influenced by the stakeholders with more clout who are more vital to the production network. In other words, by expanding the network of information exchange, having extra advisory service relationships with other stakeholders improves the likelihood that they would adopt climate-smart activities (Mwawuda et al., 2023).

The results support networks' beneficial role in driving the adoption of climate-smart practices. In particular, the research reveals that when examining the role that networks play in the dissemination of technological knowledge, it's necessary to consider not just the network's presence but also the nature of the relationships between the players (Borgatti et al., 2009; Muller & Peres, 2019).

A further significant finding is related to the network structure learning. The examination of the network structure offered a crucial insight, even if this study did not regress the network structure's indicators, such as density, transitivity, and assortativity, to the adoption indicator for climate-smart activities. Due to stronger connections and less information redundancy, the production network appears to be more effective than the information exchange network at disseminating knowledge about agricultural practices (Muller & Peres, 2019).

Empirical test evaluating factors for adoption of avocado agroecological techniques among avocado producers

The SNA research investigates stakeholders' involvement in networks and their influence on the structure of networks. As the dependent variable in a multiple linear regression analysis, climate-smart practices are used to assess network adoption.

Following the theoretical argumentation previously explained, the adoption of climate-smart techniques is explained by the model using centrality metrics from stakeholder networks along the avocado value chain. Information exchange degree centrality measures the nodes of regulatory service providers in the information exchange network, while production degree centrality considers the centrality of farmers in the production network, and market degree centrality considers the centrality of the market network. In the model, these measurements serve as independent variables (Filippini et al., 2020). In addition, the market betweenness centrality considers the betweenness centrality in the market network, the information exchange betweenness centrality measures the betweenness centrality in the network of regulatory service providers, and the production betweenness centrality refers to the betweenness centrality of farmers in the production network.

The model contains control variables such as farm characteristics and unique farmer traits. The farm's output capability is determined by the quantity of avocado trees planted. Farmers' views toward avocado climate-smart techniques are influenced by their sociodemographic features. The models investigate the potential impact of age, education, and gender on the use of climate-smart practices. While gender is a gender-specific variable, primary, middle, high school, and university levels are categorical variables. These elements aid in understanding why avocado climate-smart techniques have been adopted (Mwawuda et al., 2023).

The variables' descriptive statistics are presented. For the avocado value chain networks, notably for the network for producers, the correlation matrix reveals strong relationships between the degree and the betweenness centrality variables (Table 3). In this situation, age and education with the degree and betweenness centrality, polychoric correlation is especially intended to quantify dependency between observable variables that match the criteria for

Likert items while the postulated underlying phenomena they measure are continuous. It displays their linear connection given only discrete observable variables under the condition of bivariate normality for two latent variables (Lyhagen& Ornstein, 2023).

Table 2: Correlation matrix of stakeholders

Attributes	1	2	3	4	5	6	7	8	9	10
Age		-0.16**	1	0.21**	-0.03	-0.29**	0.14**	0.11**	-0.24	0.32
Education			-0.09	-0.27	0.11	1	-0.02	0.14	0.73	0.06
Gender				-0.16	-0.27	-0.19**	-0.86	-0.05	0.11	-0.07
Avocado amount					0.55	0.70	0.25	0.615	0.36	0.62
Producer Degree of Centrality						0.69**	0.51	0.59**	0.45	0.47
Marketing Degree of Centrality							0.73	0.51	0.51	0.61
Information Dissemination Degree Centrality								0.50	0.54	0.69**
Producer Betweenness Centrality									0.63**	0.43
Marketing Betweenness Centrality										0.59**
Information Dissemination Betweenness Centrality										

Note: For variables 1, 4, 5, 6, and 7, Pearson correlation is used, whereas for variables 1 and 2, polychoric correlation is relied on. ** represents 5% significance.

The study reveals a strong correlation between degree and betweenness centrality in the producers' network, which positively influences the adoption of avocado as a climate-smart practice in all three networks (Table 2). This suggests that central nodes can spread technology, unlike in the other two networks, and aligned with the earlier work by Marescotti et al. (2021). The capacity of the farmer's network has an impact on the introduction of avocado as a climate-smart practice, with producer degree centrality being the most important factor. This implies that while core nodes do not substantially expand the adoption of avocado as a climate-smart practice technology in the marketing and information dissemination networks, their connectedness has a beneficial impact on the adoption of avocado in the producers' network.

A multivariate linear regression model with y_i as the dependent variable and β_i as the intercept is described by formula (1). Three-degree centrality measures are the independent variables, while the control variables are age (z_1i), education (z_2i), gender (z_3i), and the number of avocado trees on the farm (z_4i).

$$y_i = \beta_i + x_i + z_1i + z_2i + z_3i + z_4i \tag{1}$$

Table 3 displays the findings of the created models, where the independent variables are the degree of centrality in the producers' network (Network 1), the marketing network (Network 2), and the information dissemination network (Network 3) networks.

Table 3: Multiple linear regression on sociodemographic attributes of the avocado growers

Attributes	Network 1			Network 2			Network 3		
	Coefficient	St.Dev.	p Value	Coefficient	St.Dev.	p Value	Coefficient	St.Dev.	p Value
Intercept	0.40	0.28	0.163**	0.45	0.21	0.04**	0.86	0.15	0.000**
Age	-0.09	0.019	0.354	-0.02	0.07	0.8**	0.04	0.05	0.42
Education 2	-0.02	0.003	0.534	0.001	0.003	n.s.	0.00	0.021	0.9
Education 5	-0.29	0.38	0.534	0.03	0.03	n.s.	-0.02	0.19	0.4
Avocado yields	0.11	0.00	0.777	0.00	0.00	n.s.	0.01	0.00	0.01**
Gender	0.001	0.32	0.063	0.09	0.001	n.s.	0.06	0.05	n.s.
Producer degree centrality	0.11	0.001	0.00**						
Marketing degree centrality				-0.027	0.08	n.s.			
Information dissemination degree centrality							0.04	0.03	n.s.
R ²		0.58			0.084			0.18	
p-value		**			**			**	

Note: The dependent variable is the centrality of the producers, and the number of plants on the farm determines avocado production. Education 2 refers to elementary school, and Education 5 to secondary school or diploma level. ** indicates significant at 5%.

Age has a substantial influence on the uptake of avocado as a climate-smart practice on farms; as people get older, fewer farmers use the technology (Table 3). The use of avocado as a climate-smart practice is not, however, considerably impacted by the scale of the farm. The adoption of avocado as a climate-smart technology is common across farms of all sizes. The adoption of avocado as a climate-smart practice is unaffected by the gender or educational status of farmers.

None of the three models alter the socio-demographic attributes of avocado producers, such as age, gender, education level, and farm size (Table 3). However, relationship outcomes vary. Benefits from avocado yields, market relationships, and general advice and information sharing among the stakeholders all have an impact on the introduction of climate-smart strategies. The final type of network appears to be more coherent than the producers' network, indicating that avocado yield advantages have an impact on the adoption of climate-smart techniques (Mwawuda et al., 2023).

Farmers can exchange general information and tips on farming activities via the information dissemination network, which links them with other farmers. Input providers and regulatory service providers serve as central nodes and are more commonly considered by avocado producers. These interactions take place in informal settings, on multi-stakeholder platforms, during cooperative meetings, and on farms (Kabirigi et al., 2022). The expertise and involvement in communities of central farmers determines their reputation. Due to the lower likelihood of older farmers adopting climate-smart initiatives, the network is essential for disseminating knowledge about these techniques and enhancing farm resilience (Jaroenwanit et al., 2023).

The producer network links those who want to assist avocado farmers with those who want assistance from avocado farmers, frequently in exchange for support (Troncarelli, 2023). This network is fragmented, with connections made between each farmer and a few nearby stakeholders. In the value chain, there is a clear distinction between cooperatives and other farmer groups (Horton et al., 2022). Farmers who have more connections exchange information more frequently and consult with other stakeholders, who have a greater influence over agricultural practices, values, and regulatory services. This makes it simpler to exchange knowledge regarding avocado planting methods, marketing strategies, and phytosanitary standards.

Conclusions

Networks promote the sharing of knowledge, assets, and assistance, which aids in the uptake and application of agroecological practices.

Key nodes, communication paths, and resource-sharing patterns within these networks using social network analysis. Trust, information exchange, shared values, and the participation of prominent stakeholders or leaders within the networks are factors promoting the adoption of avocado agroecological approaches.

Social networks play important role in fostering resilience among Kenyan avocado growers. Producers may create a more resilient and productive environment by improving communication channels, establishing trust, including important influencers, promoting sustainable production, and funding capacity-building initiatives.

Recommendations

Enhancing communication channels, fostering cooperation and trust, locating, and involving individuals with influence, promoting laws that support sustainable avocado farming, conducting ongoing research and oversight, and funding capacity-building, training, and educational projects are some of the recommendations of the study.

To boost production and resilience on farms, these suggestions seek to establish a conducive atmosphere for farmers to adopt and responsibly apply agroecological techniques.

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Farmers' Ethno-ecological Knowledge, Practices and Attitudes on Pesticidal Plant use against Vegetable Pests in Makoni District, Zimbabwe

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Keywords:

Pesticidal plants, vegetables, aphids, red spider mites, organic farming

Abstract

Pests are a major constraint in vegetable production in many parts of Zimbabwe, but there is considerable untapped traditional knowledge on pesticidal plant use against vegetable pests. A study was conducted in Makoni district, Zimbabwe, to evaluate the current farmers' knowledge, attitudes and practices on pesticidal plant use against vegetable pest. Seven focus group discussions were conducted and structured questionnaires were administered to 200 farmers. Results indicated that farmers in Makoni were using both chemical pesticides and pesticidal plants. The survey showed that farmers practicing organic farming systems were using more pesticidal plants than those using conventional farming systems. Over 70% of the respondents who used pesticidal plants were above 40 years while slightly more females used pesticidal plants than males. Most respondents were growing crucifers and tomatoes and there were 19 different plant species and 16 synthetic pesticides used against vegetable pests. Pesticidal plants were mainly applied in crucifers against aphids and on tomatoes against red spider mites. Farmers applied pesticidal plant extracts at varied rates. However, the majority of them (60%) were using an application of 1 kg/5 litres (w/v) for all pesticidal plant liquid formulations. Most farmers alluded to an application frequency of four and three times per month and 90% perceived pesticidal plants to be moderately to highly effective. This study revealed that farmers in Makoni were well aware of pesticidal plants and were using them as an alternative pest control measure. Although the use of pesticidal plants has been promoted, there is no clear validation of their application frequency and efficacy against specific pests. This study formed the basis for prioritizing plant species for evaluation of their efficacy, application rates and frequency of application to users and provides a platform for scientific research.

Connaissances, pratiques et attitudes ethno-écologiques des agriculteurs concernant l'utilisation de pesticides contre les ravageurs des légumes dans le district de Makoni, au Zimbabwe

Résumé

Les ravageurs constituent une contrainte majeure pour la production de légumes dans de nombreuses régions du Zimbabwe, mais il existe un savoir traditionnel considérable et inexploité sur l'utilisation de pesticides contre les ravageurs des légumes. Une étude a été menée dans le district de Makoni, au Zimbabwe, afin d'évaluer les connaissances, les attitudes et les pratiques actuelles des agriculteurs sur l'utilisation de pesticides contre les ravageurs des légumes. Sept groupes de discussion ont été organisés et des questionnaires

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structurés ont été administrés à 200 agriculteurs. Les résultats indiquent que les agriculteurs de Makoni utilisent à la fois des pesticides chimiques et des plantes pesticides. L'enquête a montré que les agriculteurs pratiquant des systèmes d'agriculture biologique utilisaient davantage de plantes pesticides que ceux utilisant des systèmes d'agriculture conventionnelle. Plus de 70 % des personnes interrogées qui utilisaient des plantes pesticides avaient plus de 40 ans, et les femmes étaient légèrement plus nombreuses que les hommes à utiliser des plantes pesticides. La plupart des personnes interrogées cultivaient des crucifères et des tomates, et 19 espèces végétales différentes et 16 pesticides synthétiques ont été utilisés pour lutter contre les ravageurs des légumes. Les plantes pesticides ont été principalement appliquées sur les crucifères contre les pucerons et sur les tomates contre les araignées rouges. Les agriculteurs ont appliqué des extraits de plantes pesticides à des taux variés. Toutefois, la majorité d'entre eux (60 %) appliquaient 1 kg/5 litres (p/v) pour toutes les formulations liquides de plantes pesticides. La plupart des agriculteurs ont fait allusion à une fréquence d'application de quatre et trois fois par mois et 90 % d'entre eux ont perçu les plantes pesticides comme étant modérément à très efficaces. Cette étude a révélé que les agriculteurs de Makoni connaissaient bien les plantes pesticides et les utilisaient comme mesure alternative de lutte contre les ravageurs. Bien que l'utilisation des plantes pesticides ait été encouragée, il n'y a pas de validation claire de leur fréquence d'application et de leur efficacité contre des ravageurs spécifiques. Cette étude a servi de base à la hiérarchisation des espèces végétales pour l'évaluation de leur efficacité, des taux d'application et de la fréquence d'application aux utilisateurs, et fournit une plate-forme pour la recherche scientifique.

Mots clés:

Plantes pesticides,
légumes,
pucerons,
araignées rouges,
agriculture biologique

Introduction

To minimize the negative effects caused by over-use of agro-chemicals, researchers, farmers and some agro-chemical companies are exploring alternatives to chemical pesticides. One such option is the use of pesticidal plant extracts. Available evidence suggests that pesticidal plants generally have a much shorter half-life in the environment compared to synthetic pesticides (Duke, 1989). Use of chemical pesticides has led to many problems that include pest resistance, pest resurgence, killing of non-target organisms, and pollution of the environment when used indiscriminately (Kumar *et al.*, 2008).

Despite environmental challenges posed by synthetic insecticides, they work relatively quickly and can kill target pest faster than possibly most of the pesticidal plants, and this may affect the adoption of pesticidal plants. Pesticidal plants potentially offer cost-effective pest control to smallholder farmers in developing countries if highly active extracts can be prepared simply from the readily available plants (Amoabenget *et al.*, 2013). However, the major problem that may affect adoption of pesticidal plants could be improper extraction methods and lack of standardisation as pesticidal plant usage is promoted by development agents without rigorous scientific study. What is clear from recent history is that synthetic insecticides effectively relegated botanicals from an important role in agriculture to an essentially trivial position in the market of crop protectants (Isman, 2006). However, history also shows that overzealous use of synthetic insecticides led to numerous problems unforeseen at the time of their introduction (Isman, 2008).

Studies have shown that the use of plants with pesticidal properties in pest management in the smallholder farming sector could be an affordable alternative to the use of conventional pesticides (Mwaleet *et al.*, 2005). In this regard, direct environmental benefits accrue because pesticidal plants are less likely to leave harmful environmental residues compared to commercial synthetic pesticides. Pesticidal plant usage can, therefore, enhance environmental management and conservation efforts.

Pesticidal plants are an effective alternative to pest control and their promotion, particularly when accompanied by optimised protocols and effective extension services, would lead to a substantial positive impact on the ability of farmers to manage insect pests (Stevenson, *et al.*, 2012). However, data on regulated pesticidal plants are not readily available for most African countries (Isman, 2008) and, hence, not enough information on their use is available.

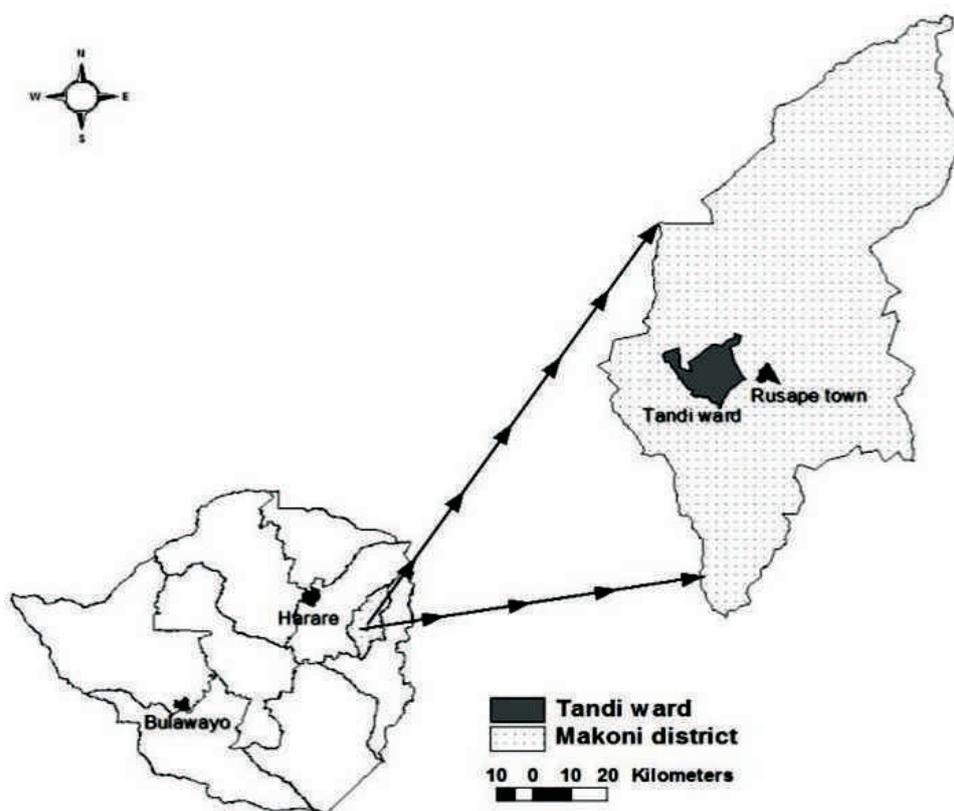
Farmers in Makoni district were known to practice both organic and conventional agriculture since 2007 through the assistance of Non-Governmental Organisations (NGOs) (personal experience). These farmers who were in the organic farming project were sponsored by NGOs such as the Global Environment Facility Small Grants Program of the United Nations Development Program (GEFSGP-UNDP). In Kenya Goldberger (2007) observed that NGOs were increasingly involved in agricultural development activities, especially efforts focused on sustainable/organic farming methods. Makoni district farmers involved in the organic farming project were using pesticidal plants. Hence, we hypothesized that there was considerable untapped traditional knowledge on pesticidal plants used against vegetable pests. The objective of the study was, therefore, to investigate the current farmer knowledge, attitudes and practices on pesticidal plants usage against vegetable pests in Makoni district through a household and community survey instrument.

Methodology

Study area

The study was conducted in the Tandi Ward (ward 12) of Makoni District located in Manicaland Province, Zimbabwe (Figure 1). The study took advantage of on-going work in Makoni district by NGOs such as the Organic Network Forum (ONF) and the Makoni Organic Farmers Association (MOFA) through support from GEFSGP-UNDP since 2007. The NGOs mainly focused on the promotion of organic farming. In this work, there was inclusion of pesticidal plant use but with little attention to scientific rigour to generate scientifically verifiable recommendations.

Figure 1. The ward used to investigate the current farmer knowledge, attitudes and practices on pesticidal plants usage against vegetable pests in Makoni district through the household and community survey instrument



Data collection and analysis

Data were collected through a community and household survey instrument conducted between September and November 2013. Structured questionnaires were administered to two hundred purposefully sampled farmers. The experimental group consisted of 140 farmers who were in the organic farming project while the control farmers consisted of 60 who were not in the organic farming project. Focus group discussions (FGDs) involving 7 groups were conducted. Five groups were experimental and 2 constituted the control. Information on different kinds of pesticidal plants, application rates, formulations, target pests, frequency of application, efficacy and attitudes towards the use of pesticidal plant extracts was explored and documented. The quantitative data were summarized and frequency tables were constructed. SPSS version 16 was used to analyse quantitative data. Semantical content analysis was used for analyzing Focus Group Discussion data.

Results

Characteristics of respondents and farming methods

The majority of the respondents in Makoni district Tandri ward 12 were older than 40 years of age, and most of them had undergone formal education (Table 1). The respondents had more females compared to males who practiced both organic and conventional agriculture (Table 1). However, there was no correlation between sex and pesticidal plant use (Table 2). Survey results showed that adoption of organic farming in Makoni is age depended as more than 77% were above the age of 40 years (Table 1). There was a correlation between age and pesticidal plant usage (Table 2). All the respondents owned a piece of land for farming activities with the majority (above 65%) owning 1-2 ha. The majority of farmers (95%) in Makoni had undergone secondary and primary school education (Table 1) and there was no correlation between education and pesticidal plant usage.

The majority of the farmers (94%) practiced conventional agriculture (dry land) compared to organic agriculture (dry land) and most of them had more than 10 years farming experience (Table 3). More farmers grew maize followed by groundnuts compared to those who grew other crops in conventional fields. Half of the farmers in the organic farming project practiced conventional horticulture while very few farmers in the conventional group were organic household gardens (Table 3). Crucifers were the most popular crops in conventional horticulture. Very few farmers practiced both organic horticulture and organic household gardening and the dominant crops were crucifers too (Table 3). Organic farming was practiced in the community gardens. The dominant crops in the organic community garden were legumes and all the farmers had less than 10 years organic farming experience.

Table 1: Percentage gender, age, education and land ownership of respondents from a survey conducted in Ward 12 of Makoni district, Zimbabwe to study the current farmer knowledge, attitudes and practices on pesticidal plants usage against vegetable pests.

Variable	Category	Experimental group, Organic n=140)	Control group, (Conventional n=60)
Sex	Male	47.9	43.3
	Female	52.1	56.7
Age	Young (< 25 years)	1.4	5.0
	Middle (25-40 years)	21.4	31.7
	Old (> 40 years)	77.2	63.3
Education	None	1.4	1.7
	Primary (up to Grade 7)	45	43.3
	Secondary (up to form 4)	50	46.7
	Advanced (up to Form 6)	1.5	3.3
	Tertiary (Diploma)	2.1	5
Land ownership	Farmers who own land	100	100
			13.3
Land size	Below 1 Ha	4.3	
	1-2 Ha	72.1	68.4
	Above 2 Ha	23.6	18.3

Table 2: The Pearson chi-square results on determinants of farmers’ pesticide use in relation to gender, age and education as depicted by data collected in a survey, conducted in Ward 12 of Makoni district (Zimbabwe), to study the current farmer knowledge, attitudes and practices on pesticidal plants usage against vegetable pests.

Variable	Category	Chi-square	Chi-square	Probability
Sex	Male	47.9	0.48	0.49
	Female	52.1		
Age	Young (< 25 years)	1.4	193.97	<0.001
	Middle (25-40 years)	21.4		
	Old (> 40 years)	77.2		
Education	None	1.4	1.48	0.21
	Primary (up to Grade 7)	45		
	Secondary (up to form 4)	50		
	Advanced (up to Form 6)	1.5		
	Tertiary (Diploma)	2.1		

Table 3: Percentages of respondents with regard to farming practices and crop type as revealed by data collected in a survey, conducted in Ward 12 of Makoni district (Zimbabwe), to study the current farmer knowledge, attitudes and practices on pesticidal plants usage against vegetable pests.

Conventional field cropping (dry land) Experimental group (n=140)							Conventional field cropping (dry land) Control group (n=60)						
Farmers implementing	Area	For how long		*Dominant crops			Farmers implementing	Area	For how long		Dominant crops		
Yes 94.3	<1Ha	9.1	<10 years	17.8	Maize	93	Yes 98.3	<1Ha	17	<10 years	23.7	Maize	96.7
No 5.7	1-2Ha	52.3	>10 years	82.2	Groundnuts	58.6	No 1.7	1-2Ha	54.2	>10 years	72.3	Beans	18.3
	>2 Ha	38.6			Beans	10		>2 Ha	28.8			Groundnuts	51
					Millet	9.3						Bambara nuts	1.7
					Sunflower	2.8						Soya	5
					sweet potato	1.5						Sunflower	3.3
					Cowpeas	0.7						Wheat	1.7
												Millet	11.7
												Cow peas	5
Organic field cropping Experimental group (n=140)							Organic field cropping Control group (n=60)						
Farmers implementing	Area	For how long		Dominant crops			Farmers implementing	Area	For how long		Dominant crops		
Yes 47.1	<1Ha	84.4	<10 years	47.1	Beans	0.71	Yes 6.7	<1Ha	33.3	<10 years	33.3	Crucifers	1.8
No 52.9	1-2Ha	17.6	>10 years	52.9	Crucifers	24.3	No 93.3	1-2Ha	66.7	>10 years	66.7	Maize	3.3
	>2 Ha	0			Carrots	2.9		>2 Ha	0			Cowpeas	3.3
					Onions	9.3						Yams	1.7
					Peas	6.4							
					Tomatoes	5.4							
					Yams	3.8							
					Maize	2.9							
					Pumpkin	0.7							
Conventional horticulture Experimental group (n=140)							Conventional horticulture Control group (n=60)						
Farmers implementing	Area	For how long		Dominant crops			Farmers implementing	Area	For how long		Dominant crops		
Yes 50.0	<1Ha	75.9	<10 years	9.3	Beans	2.1	Yes 22.9	<1Ha	82.4	<10 years	24.4	Beans	
No 50.0	1-2Ha	24.1	>10 years	90.7	Crucifers	26.4	No 87.1	1-2Ha	17.6	>10 years	75.6	Crucifers	
	>2 Ha	0			Maize	17.1		>2 Ha	0			Groundnuts	
					Potatoes	0.7						Yams	
					Tomatoes	4.3						Maize	
					Wheat	1.4						Onions	
					Garlic	2.1						Peas	
					Groundnuts	0.7						Pumpkin	
					Yams	5						Tomatoes	
					Onions	4.2							
					Soybeans	0.7							
**Organic Horticulture Experimental group (n=140)							Organic horticulture Experimental group (n=60)						
Farmers implementing	Area	For how long		Dominant crops			Farmers implementing	Area	For how long		Dominant crops		
Yes 32.8	<1Ha	82.3	<10 years	50.9	Crucifers	24.3	Yes 18.3	<1Ha	100	<10 years	30	Crucifers	
No 67.2	1-2Ha	17.7	>10 years	49.1	Yams	3.6	No 81.7	1-2Ha	0	>10 years	70	Beans	
	>2 Ha	0			Maize	2.9		>2 Ha	0			Carrots	
					Peas	0.7						garlic	
					Pumpkins	0.7						Onions	
					Tomatoes	11.4						Peas	
					Beans	0.7						Tomatoes	
					carrots	2.9							
					Yams	5							
					Onions	4.2							
***Organic Household Garden Experimental group (n=140)							Organic Household Garden Experimental group (n=60)						
Farmers implementing	Area	For how long		Dominant crops			Farmers implementing	Area	For how long		Dominant crops		
Yes 25	<1Ha	100	<10 years	65.7	Crucifers	22.9	Yes 15	<1Ha	100	<10 years	44.5	Crucifers	15.0
No 75	1-2Ha	0	>10 years	34.3	Carrots	1.4	No 85	1-2Ha	0	>10 years	55.5	Carrots	6.7
	>2 Ha	0			Herbs	0.7		>2 Ha	0			Onions	6.7
					Onions	13.4						Peas	1.7
					Potatoes	4.3							
					Tomatoes	0.7							
					Tomatoes	2.9							
					Maize	0.7							
****Organic Community Garden Experimental group (n=140)							Organic Community Garden Experimental group (n=60)						
Farmers implementing	Area	For how long		Dominant crops			Farmers implementing	Area	For how long		Dominant crops		
Yes 59.3	>1Ha	100	>10 years	0	Beans	32.4	Yes 0	>1Ha	0	>10 years	0		
No 40.7	1-2Ha	0	<10 years	100	Crucifers	31.1	No 100	1-2Ha	0	<10 years	0		
	<2 Ha	0			Garlic	0.7		<2 Ha	0				
					Crucifers								
					Onions	25.7							
					Peas	50.0							
					Tomatoes	0.7							
					Carrots	0.7							

*Multiple responses are possible

**Organic horticulture; farming practice in gardens and does not involve the use of chemical pesticides and inorganic fertilisers

***Organic household garden; farmers grow their vegetables in small gardens closer to homestead without the use of chemical pesticides and inorganic fertilisers

****Organic community garden is a single piece of land cultivated collectively by a group of people without the use of chemical pesticides and inorganic fertilisers

Focus Group Discussion Data

According to the focus group discussions, the majority of farmers in Tandri ward 12 of Makoni district practiced three farming methods; conventional agriculture, organic farming and conservation farming. Many of the farmers perceived organic conservation farming as very effective under dryland and community gardens. Many farmers used both synthetic pesticides and pesticidal plants. During the focus group discussions about 57% of the farmers mentioned cases of synthetic pesticide poisoning. There was also a contradiction on pesticidal plant use by some churches and traditional leaders. Some churches were against the use of pesticidal plants because their doctrines were against such use. Traditional leaders were concerned about the protection of some tree species which may be destroyed through use as a pesticidal plant. Concerns were on trees which provided bark and roots as source of plant pesticides. All the farmers preferred to consume organic vegetables. All the farmers were marketing their produce locally but some organic farmers marketed their peas to international markets.

Farmer practices of vegetable pests' management

Farmers in Makoni used both chemical pesticides and pesticidal plants. Survey results showed that the majority of farmers (Table 5) in the organic farming project were used various pesticidal plants freshly prepared and soaked overnight. The most commonly used synthetic chemical was dimethoate in both experimental and control groups followed by Actellic Super dust (Table 4) which was used by higher numbers in the control group. Conventional farmers used more synthetic chemical pesticides relative to organic farmers (Table 4). The pesticidal plants that were mostly used by farmers include *Melia azedarach*, *Bobgunniam adagascariensis*, and *Solanum delagoense* (Table 5). A number of farmers in both experimental and control groups used wood ash.

Table 4: Percentage of respondents showing synthetic chemical pesticide use and pesticide type in Ward 12 of Makoni District

Organic Farmers (Experimental Group) n=140	Conventional Farmers (Experimental Group) n=60	Name of pesticide	Pesticide registered for	Organic Farmers (Experimental Group) n=140	Conventional farmers control group n=60
Yes 37.1	Yes 61.6	Dimethoate (rogor)	Insecticide	12.5	38.4
No 62.9	No 38.4	Temaronmethamidophos	Insecticide, Acaricide	5.7	11.7
		Dithane M45	Insecticide	4.6	10.1
		Actellic Super dust	Insecticide	13.4	6.8
		Dipterex(trichlorfon)	Insecticide		6.7
		Diaznon 30EC	Insecticide	2.9	3.3
		Agridust (Malathion)	Insecticide	1.4	1.7
		Amitraz 20EC	Acaricide		1.7
		Termic (Aldicarb)	Insecticide		1.7
		Kontakill 60EC (Fetrothion)	Insecticide		1.7
		Carbaryl	Insecticide	0.7	1.0
		Mancozeb	Fungicide		1.0
		Agricura powder	Insecticide		0.5
		Garden care (Carbaryl)	Insecticide	0.7	
		Diazinon	Insecticide	0.7	0.7

Table 5: Percentage respondents using specific pesticidal plants in Makoni

Local name	Common name	Scientific name	Plant part used	Organic Farmers (Experimental Group) n=140	Conventional farmers control group n=60
Mukina	Chinaberry, Syringa	<i>Melia azedarach</i>	Leaf	37.9	6.0
Mucherekese	Snake bean	<i>Bobgunniamadagascariensis</i> ,	Seed	38.8	5.0
Chowa	Bitter Apple	<i>Solanumdelagoense</i>	Seed	27.1	3.4
Gariki	Garlic	<i>Allium sativum</i>	Root	25.7	3.7
Dota	Wood Ash	Wood Ash		14.3	3.4
Mhiripiri	Chillies	<i>Capsicum spp</i>	Seed	10.3	3.3
Chowa	Thorn apple, Devil's Apple,	<i>Daturastramonium</i> ,	Leaf	12.5	
Heji	Rubber-hedge	<i>Euphorbia tirucalli</i>	Stem	4.3	
Manyowaemvura	Liquid manure	Compost tea		5.4	
Tsine	Blackjack	<i>Bidenspilosa</i>	Leaf	5.7	
Gavakava	Aloe vera	<i>Aloe vera L.</i>	Leaf	5	1.7
Mbanda	Mexican Marigold	<i>Tagetesminuta</i>	Leaf	2.9	
Zumbani	Fever tea	<i>Lippiajavanica</i>	Leaf	5.6	
Muzeze	African wattle	<i>Peltophorum africanum</i>	Leaf	0.5	
Mulandana	Lantana camara	<i>Lantana camara</i>	Leaf	3.6	1.7
Muunga	Red thorn.	<i>Acacia nilotica</i>	Root	2.1	1.7
Munwahuku	Popcorn Cassia	<i>Senna didymobotrya</i>	Leaf	1.5	1.7
Mupopo	Paw-paw	<i>Carica papaya</i>	Leaf	2.1	
Mupfuta	Castor bean	<i>Ricinuscommunis</i>	Leaf	0.5	
Hanyanisi	Onions	<i>Allium cepa</i>	Root	0.5	

Farmers practices vis-à-vis application frequency rates and effectiveness

The majority of farmers in Makoni were applying pesticidal plants in crucifers (Figure 1) against aphids (Figure 2). A smaller percentage of farmers used pesticidal plants on tomatoes (20%) and peas (2%) against red spider mites and caterpillars respectively. Many application rates were used by the farmers (Figure 3). However, many farmers (at least 60%) applied at 1kg/5lw/v. The highest application rate of 1kg/2l w/v and the lowest rate of 1kg/20l w/v were used by less than 15% of the farmers. Most farmers used an application frequency of four times a month followed by three times per month (Figure 3). Fewer farmers used the highest and lowest application rates (Figure 4). Most farmers perceived pesticidal plants to be effective (Figure 5). A few thoughts they were not effective. Most farmers used hand sprayers for pesticidal plant application while a few used the traditional sweeping broom and bucket technique (Figure 6).

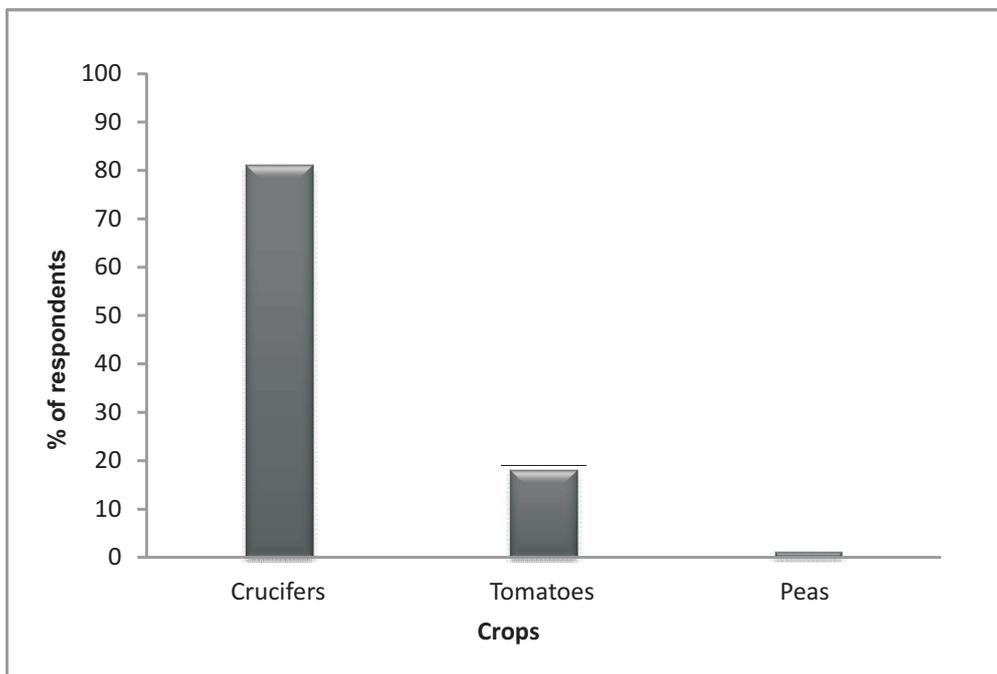


Figure 1: The major crops grown by respondents in Makoni district. Values were calculated as the percentages of all crops mentioned by the respondents

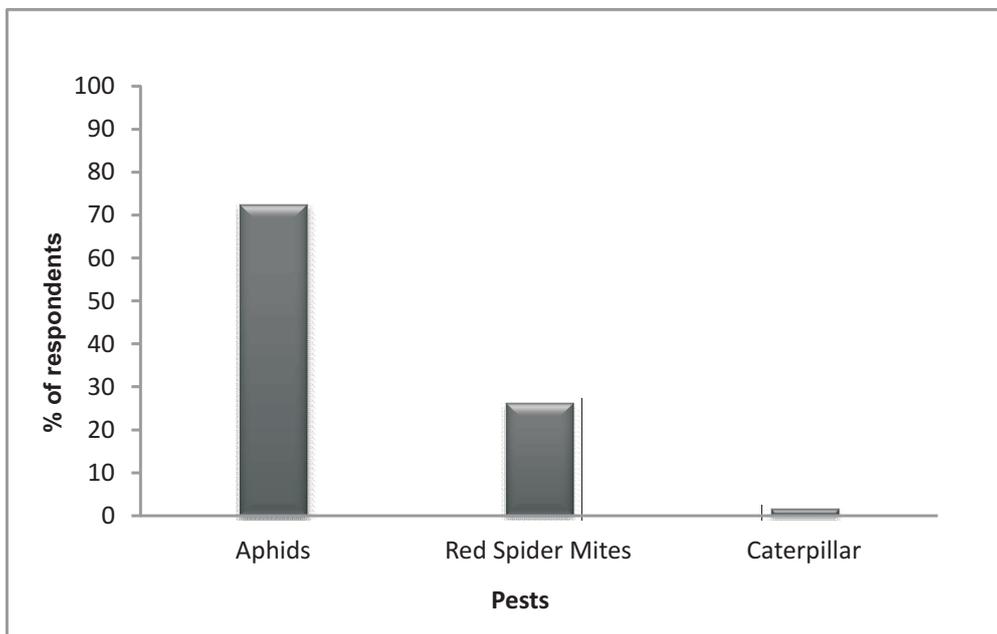


Figure 2: The major vegetable pests prevalent in Makoni district as perceived by the respondents. Values were calculated as the percentages of all insect pest species mentioned by the respondents

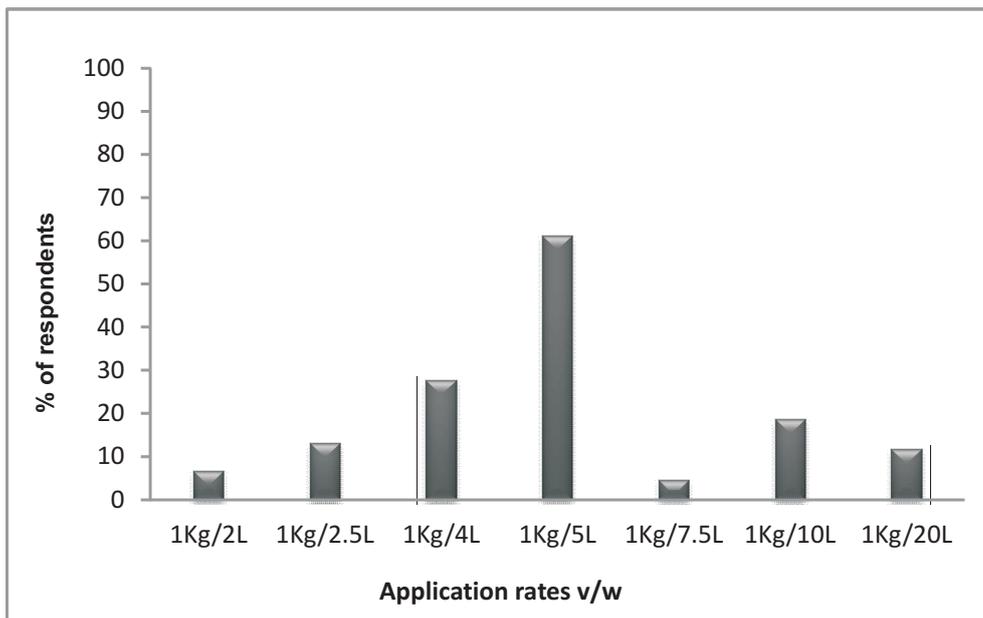


Figure 3: Application rates used by respondents in Makoni district. Values were calculated as the percentages of all the application rates mentioned by the respondents

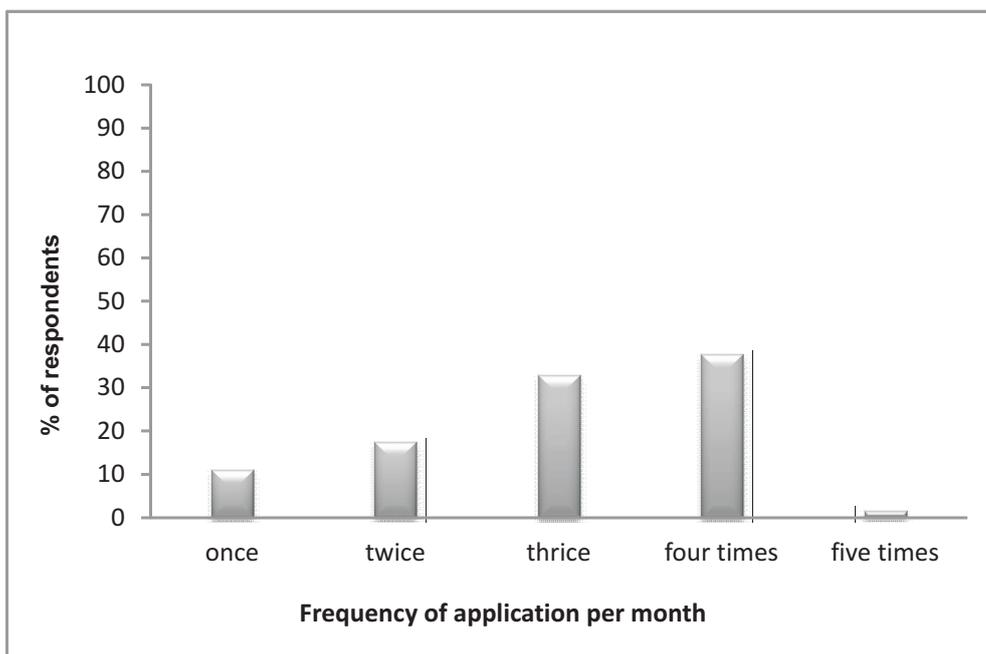


Figure 4: Frequency of application of pesticidal plants by respondents in Makoni District. Values were calculated as the percentages of all the frequencies mentioned by the respondents

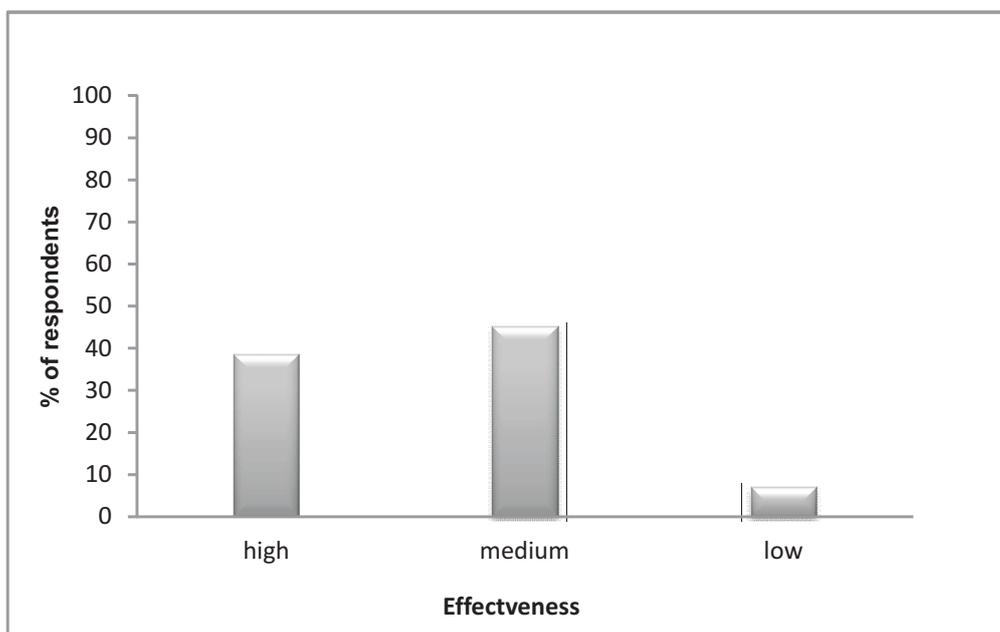


Figure 5: Pesticidal plant effectiveness as perceived by respondents in Makoni District. Values were calculated as the percentages of all the level of effectiveness mentioned by the respondents

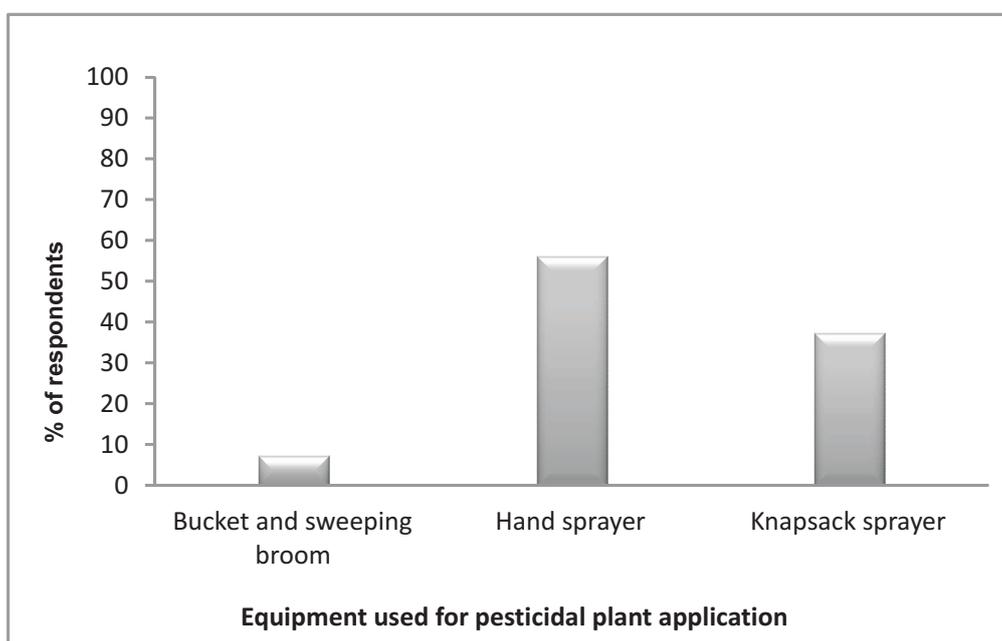


Figure 6: Equipment for pesticidal plant application used by respondents in Makoni District. Values were calculated as the percentages.

Attitude of farmers on pesticidal plant use

A larger percentage of respondents who used pesticidal plants perceived them as effective and thought they improved their yield and income (Table 6). Fifty eight percent of the respondents admitted that pesticidal plants could improve their yields when the weather was good. The majority of respondents agreed that pesticidal plants do not require too much labour to use while fewer respondents thought they required a lot of labour. Many of the respondents would use

pesticidal plants even if they must pay for them (Table 6). Most of the respondents agreed that pesticidal plants were getting more and more available while 11% did not have opinion on the issue of availability. More than 70% of the respondents thought that pesticidal plants did not affect crop quality, while fewer farmers thought that they did (Table 6). The majority of the respondents strongly agreed that pesticidal plants were affordable and have improved their income.

Table 6: Percentage of respondents according to attitude on pesticidal use in Makoni District

Variable	Category				
	Strongly agree	Agree	Disagree	Strongly Disagree	No opinion
Pesticidal plants are not effective in this area	0	19	65	9	7
Pesticidal plants can improve yields when the weather is good	0	73	9	0	19
Pesticidal plants require too much labor for me to use it	0.7	22.9	42.1	27.1	7.1
Pesticidal plants are worth using if it is free, but not if you must pay for it	2	14	59	13	12
Pesticidal plants are getting more and more available	5	60	22	2	11
Pesticidal plants are not affordable	6	9	8	71	5
Pesticidal plants use has improved my crop yield	1	78	9	0	13
Pesticidal plants use has increased my income	1	65	9	1	24

Discussion

The study showed that farmers in Makoni district practice both conventional farming and organic agriculture. This is mainly because of the campaigns by NGOs encouraging farmers to do organic agriculture. This concurs with the findings done by Goldberger (2007), that NGOs have become increasingly involved in agricultural development activities, especially efforts focused on sustainable/organic farming methods. This is probably the main reason why farmers were now shifting from chemical pesticide use to pesticidal plants. According to the study, farmers in the organic farming project mainly used pesticidal plants compared to farmers who were not in the organic farming project. Many farmers in Makoni were growing crucifers and tomatoes. This is in agreement with other surveys that were conducted in Malawi and Zambia by Nyirenda *et al.*, (2010) which revealed that tomatoes and crucifers were grown by smallholder farmers two to three times a year. This indicates how important these vegetables are to subsistence farmers in the study areas. The study found that the major pests encountered were aphids and red spider mites, consolidating observations by previous researchers ((Dubeet *et al.*, 1996), (Dobson *et al.*, 2002)). The most damaging pest of tomatoes, red spider mites, *Tetranychusevansi* and of rape, aphids, *Brevicorynebrassicae* cause both direct and indirect qualitative and quantitative losses. Most farmers in the study responded by applying pesticidal plants compared to synthetic pesticides.

According to the farmers' perceptions the major chemical used was dimethoate and surprisingly actellic super dust which is a grain protectant. Farmers thought it was less toxic to consumers since it was already used on grain. Generally, farmers in Makoni were considerate of negative health implications caused by chemical pesticides hence many of them were now using pesticidal plants. This may be because of campaigns that were conducted in the area by NGOs. Gahukar, (2008) observed that pesticide residues could be detected in raw and processed vegetables and their misuse and persistence could present risks to human health. Pesticidal plants that were used by farmers according to the study were *Melia azedarach*, *Bobgunniamadagascariensis*, and *Solanumdelagoense*, and *Alliumsativum*. Most of the pesticidal plants could control both aphids and red spider mites and hence can be applied in both crucifers and tomatoes. This concurs with a study by Muzemuet *al.* (2011) which demonstrated that plant-based extracts of *Lippia javanica* and *Solanumdelagoense* at 25 % (w/v) could significantly reduce aphids, *B. brassicae* and red spider mites, *T. evansi* numbers in Zimbabwe. On safety issues, farmers were also particular about the pesticidal plants they used and most pesticidal plants used were considered to be generally safe as some of them were consumed e.g. garlic. Gandhi and Pillai (2011) argued that use of plant parts with insecticidal properties have been reported from all over the world as they are convenient and less expensive.

Farmers in Makoni used a wide range of application rates perhaps due to lack of scientific information regarding optimum application rates. Katsvanga and Chigwaza (2004) agreed that very little information has been acquired which describes how farmers apply the pesticidal plant remedies and at what concentration despite that Zimbabwean farmers use pesticidal plants regularly. There is lack of harmonization as some traditionalists and NGOs promotes pesticidal plants at different applications rates. This may lead to losses due to the poor efficacy of pesticidal plants resulting in household food insecurity. Confusing messages are not helpful to farmers and hence any promotional activities must be supported by empirical evidence. There were variations in application frequency by farmers, ranging from once a month to five times a month. However, many farmers alluded to application frequencies of three and four times a month. The higher frequency compared to synthetic pesticides may be due to the fact that many pesticidal plants have repellent and deterrent properties rather than acute toxicity as reported by Isman (2008). Many farmers reported medium effectiveness and a sizeable number also reported high effectiveness rates. The medium effectiveness maybe due to improper uses of botanical pesticides especially the application rates.

This study revealed that smallholder farmers were using pesticidal plants as an alternative and thought that they benefited from their use although relatively few farmers admitted to not using them due to religious reasons. The use of plant and plant-derived products to control pests in the developing world is very common (Adeyemi, *et al.*, 2010). Prior to the discovery of synthetic pesticides, plant or plant-based products were the only pest-management agents available to farmers around the world and even today several plant-based products are still in use to control a wide variety of pests (Adeyemi, *et al.*, 2010). Many farmers admitted that pesticidal plant usage was effective and improved their yields and income. This is true since the efficacy of some of the pesticidal plants used has been validated, e.g. *M. azedarach*. According to reports by Isman (2006) seeds from the, *M. azedarach*, contain a number of triterpenoids, the meliacarpins, that are similar but not identical to the azadirachtins, and these too have insecticidal properties. The majority of farmers agreed that pesticidal plants were affordable and they were becoming more available as many plants with pesticidal properties are unveiled through research by scientists. This agrees with reports from many workers. For instance, Isman (2008) reported that pesticidal plants provide environmentally benign and low-cost alternatives with high potential efficacy that is particularly relevant to the farming systems of sub-Saharan Africa. Some studies have also shown that the use of plants with pesticidal properties as tactics in pests management in the smallholder-farming sector could be a cheap, affordable and easier options than the use of synthetic pesticides control methods (Katsvanga and Chigwaza, 2004; Munyima *et al.*, 2004; Mwale *et al.*, 2005).

Conclusion

This study showed that farmers in Makoni were well aware of pesticidal plants and were using them as an alternative to synthetics for pest control. Although the use of pesticidal plants has been promoted, there is no clear validation of their application frequency and efficacy against specific pests. This study formed the basis for prioritizing plant species for evaluation of their efficacy, application rates and frequency of application to users and provides a platform for scientific research.

Acknowledgments

We acknowledge the funding support from Organic Network Forum and Global Environment Facility Small Grants Program. Acknowledgements also go to Agritex officers, Ward 12 of Makoni District for assisting in enumeration and University of Zimbabwe, Statistics Department for Data Analysis.

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Published by:





Effect of Organic Fertilizers Types on Soil Properties, Growth and Yield of Amaranths (*Amaranthus cruentus* L)

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Keywords:

Amaranthus,
organic fertilizer,
soil, yield

Abstract

The use of organic fertilizer cannot be over emphasized because of its usefulness in the improvement of physical and biological conditions of soil which in turn improves the crop growing environment and culminates in the better crop production. Two phased pot experiments were conducted in a screenhouse at Kwara State University, Malete, Ilorin, Nigeria to examine the effect of organic fertilizer types on soil chemical properties, growth and yield of Amaranthus. The treatments comprised of control, composts (Tithonia, Gateway, Sunshine grade B, vetiver) and NPK 15-15-15. All the treatments were applied at the rate of 100kg N/ha. The treatments were laid out in a completely randomized design (CRD) with three replicates. Data collected were subjected to analysis of variance (ANOVA) and significant differences among the treatment means were evaluated using Duncan's Multiple Range Test (DMRT) at 5 % probability level.

Agronomic parameters taken were; plant height, number of leaves, stem girth, fresh and dry shoot weight. Amaranthus plants grew better ($P<0.05$) with the application of NPK fertilizer at first planting. The use of tithonia compost had greater positive effects on growth and yield of Amaranthus at second planting. Tithonia compost significantly ($P<0.05$) improved the dry shoot weight of *Amaranthus cruentus* by 77.6% during first planting and by 88.8% during second planting compared with the control. Tithonia compost had a significant and additive effect on soil nutrients after harvesting when compared with NPK and other treatments after cropping. This suggests that Tithonia has a high potential than NPK for building up nutrients in the soil with time. Hence, Tithonia compost could serve as alternative to mineral fertilizer for the production of *A. cruentus*

Effet des types d'engrais organiques sur les propriétés du sol, la croissance et le rendement des amaranthes (*Amaranthus cruentus* L)

Résumé

On ne saurait trop insister sur l'utilisation d'engrais organiques en raison de leur utilité pour l'amélioration des conditions physiques et biologiques du sol qui, à leur tour, améliorent l'environnement de croissance des cultures et aboutissent à une meilleure production agricole. Deux expériences en pot ont été menées dans une serre de l'Université de l'État de Kwara, Malete, Ilorin, Nigeria, afin d'examiner l'effet des types d'engrais organiques sur les propriétés chimiques du sol, la croissance et le rendement de l'Amaranthus. Les traitements comprenaient le contrôle, les composts (Tithonia, Gateway, Sunshine grade B, vétiver) et NPK 15-15-15. Tous les traitements ont été appliqués au taux de 100kg N/ha. Tous les traitements ont été appliqués à raison de 100 kg N/ha. Les

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traitements ont été répartis selon un plan complètement aléatoire (CRD) avec trois répétitions. Les données collectées ont été soumises à une analyse de variance (ANOVA) et les différences significatives entre les moyennes des traitements ont été évaluées à l'aide du test de gamme multiple de Duncan (DMRT) à un niveau de probabilité de 5 %.

Les paramètres agronomiques pris en compte étaient la hauteur des plantes, le nombre de feuilles, la circonférence de la tige, le poids frais et sec des pousses. Les plants d'amarante ont mieux poussé ($P < 0,05$) avec l'application d'engrais NPK lors de la première plantation. L'utilisation de compost de tithonia a eu des effets positifs plus importants sur la croissance et le rendement de l'amarante lors de la deuxième plantation. Le compost de tithonia a amélioré de manière significative ($P < 0,05$) le poids sec des pousses d'*Amaranthus cruentus* de 77,6 % lors de la première plantation et de 88,8 % lors de la deuxième plantation par rapport au témoin. Le compost de Tithonia a eu un effet significatif et additif sur les nutriments du sol après la récolte, comparé au NPK et aux autres traitements après la culture. Cela suggère que le Tithonia a un potentiel plus élevé que le NPK pour accumuler des nutriments dans le sol avec le temps. Par conséquent, le compost de Tithonia pourrait servir d'alternative aux engrais minéraux pour la production d'*A. cruentus*.

Mots clés :

Amaranthus,
engrais organique,
sol, rendement.

Introduction

Amaranthus cruentus species is most commonly grown in Africa (Iren *et al.*, 2016). *A. cruentus* (*Amaranthus*) is best recognized by its leaves that are twice or three times as long as wide and often have pointed leaf tip. *Amaranthus* has a high nutritional value because of the high levels of essential micro-nutrients like iron (an important element against anaemia), manganese and zinc (Mnkeni *et al.*, 2007). It contains calcium, Mg, carotene and niacin. Vitamin A and C are also present in significant levels. The protein found in young plants of amaranths can be important for people without access to meat or other sources of protein (Mnkeni *et al.*, 2007). In years to come, utilization of organic fertilizers to meet crop nutrient requirement will be an unavoidable practice to enhance sustainable agriculture, this is because, the physical, chemical and biological properties of soil is generally improved by the addition of organic fertilizer which in turn enhances crop productivity and maintains the quality of crop produce (Olowoake, 2014). Although, in comparison to inorganic fertilizers, organic fertilizer contain smaller quantities of plant nutrients. The use of inorganic fertilizer to increase yield has been found to be effective as a short-term solution but demands consistent use on a long-term basis. The high cost of inorganic fertilizers makes it uneconomical and out of reach to poor farmers and it is also undesirable due to its hazardous environmental effects (Adekiya *et al.*, 2020). Furthermore, the use of chemical fertilizers has certain disadvantages; some of which are ground water pollution, imbalances in soil pH, loss of soil fertility and may be detrimental to health as it may contain toxic substances (Luka *et al.*, 2023). The production and consumption of Amaranth is on the increase due to its nutritional and health benefits. Therefore, it is essential to investigate the use of locally sourced organic materials which are environment friendly, cheap and probably an effective way of improving and sustaining the productivity of soils and vegetables such as *Amaranthus*. Hence, the objective of this study is to investigate the effect of organic fertilizers types on soil properties, growth and yield of *Amaranthus* (*A. cruentus* L).

Materials and Methods

Two-phased pot experiments were conducted in the screenhouse of the College of Agriculture, Kwara State University, (Latitude 8° 71'N and Longitude 4° 44'E) Malete, during the 2023 planting season. The treatments comprised of control, composts (Tithonia, Gateway (Accelerated compost), Sunshine grade B (Un-amended), vetiver) and NPK 15-15-15 were applied at the rate of 100kg N/ha (Olowoake and Ojo, 2014). The constituents of the composts were shown in Table 1.

Table 1: Chemical composition of all the fertilizers used

Treatments	Nitrogen (N) (%)	Phosphorus (P) (%)	Potassium (K) (%)
Sunshine B	3.5	1.0	2.5
Tithonia	0.2	0.2	0.3
N.P.K	15	15	15
Gateway compost	1.2	1.6	0.2
Vetiver compost	6.8	1.0	2.5

The physicochemical analysis of the experimental soil used in the screenhouse was carried out before the experiment. Eighteen plastic pots were filled with 4.5 kg of soil. The soil used for this experiment was a composite of surface soil (0-15 cm depth) collected from the Kwara State University Teaching and Research Farm, Malete, Kwara State, Nigeria and analyzed for physical and chemical properties as described by Okalebo *et al.* (2002). The treatments were arranged in a completely randomized design (CRD) with three replicates. The soils and compost were left to mineralize for two weeks before planting while the mineral fertilizer was applied two weeks after planting. *Amaranthus caudatus* seeds were broadcasted and thinned to two (2) seedlings. The experiment was repeated without any additional fertilizer application at the second planting. The data taken included, plant height, stem girth, number of leaves, fresh shoot weight and yield. The data collected were subjected to analysis of variance (ANOVA) and treatment means were separated by Duncan Multiple Range Test.

Results and Discussion

The results of the soil analysis are presented in Table 2. The textural class of the soil is sandy loam, the soil had pH (H₂O) 6.4 which could be described as slightly acidic. The values of N, P and K were below the critical values of the nutrients in the soil of Guinea Savanna (Olowoake, 2019).

Table 2: Physico-chemical properties of experimental soil

Parameters	Soil test value
pH (H ₂ O)	6.4
Org.C (g/kg)	15.6
Total N (%)	0.02
P (mg/kg)	9.6
Exchangeable bases (cmol kg ⁻¹)	
Mg	0.86
Ca	2.35
Na	0.23
K	0.19
Extractable micronutrients (cmol kg ⁻¹)	
Cu	1.37
Fe	106
Zn	1.81
Physical composition (%)	
Sand (%)	79.0
Silt (%)	12.0
Clay (%)	9.0
Textural class	Sandy loam

Table 3 showed the effect of application of composts (vetiver, Tithonia, Sunshine Grade B, and Gateway) and NPK fertilizer on growth and yield parameters of Amaranthus. There was no significant difference on plant height produced by Tithonia compost and NPK. However, amaranthus plants grown with NPK produced the highest plant height (60.3 cm), and this was significantly ($p < 0.05$) higher than other fertilizer treatments excluding Tithonia compost.

The highest stem girth (12.20 mm) recorded in Amaranthus plant was from treatment that received NPK (Table 3). This was significantly ($p < 0.05$) higher than other treatments by 28.7% - 62.3%. *Amaranthus cruentus* number of leaves influenced by the application of Tithonia compost and NPK was found to be significantly ($p < 0.05$) higher from that of control and other fertilizer treatments. Amaranthus fresh and dry weight produced from NPK resulted in highest values which were significantly ($P < 0.05$) different from value obtained from other fertilizer treatments and control respectively. At second planting, Tithonia compost produced the maximum value of height (17.8 cm) closely followed by Vetiver compost (12.8 cm) and minimum height value of 5.3 cm was obtained from control (Table 3). Also, application of Tithonia compost produced amaranthus plant with significantly higher stem girth, fresh and dry weight than NPK, control and other composts respectively. The increased in the height, number of leaves and stem girth of the amaranthus plants during first planting showed that NPK improved the growth and yield parameters significantly. This could be attributed to the immediate availability of nutrients in the chemical fertilizer as previously observed by (Adeoluwa and Adeogun 2010; Olowoake and Akinrinola, 2023). The low performance of the composts (Tithonia, Gateway and Vetiver) on *Amaranthus cruentus* at the end of first planting could be due to slow rate of decomposition of compost compared with NPK. The residual fertilizer treatments from Tithonia compost treatment having better plant height, number of leaves, stem girth and yield parameters compared to NPK and other treatments in this investigation could be as a result of better nutrient mineralization with time of application. This is in line with the report of several authors Olowoake, (2014), Ayanfeoluwa, (2015) and AdeOluwa *et al.* (2021) that organic fertilizers are characterized with slow release of nutrients, which is closely associated with improvement of soil organic matter, soil water availability, structural stability, cation exchange, buffer capacity, and ultimately crop productivity. The lower yield obtained from the mineral fertilizer (NPK) treated pot probably could be due to leaching and volatilization of nitrogen from the mineral fertilizer (AdeOluwa *et al.*, 2016).

Table 3: Effect of fertilizer types on the growth and yield parameters of Amaranthus plants during first and second planting

Treatment	Plant height cm	Stem girth mm	Number of leaves	Fresh weight (g)	Dry weight (g)
<u>First planting</u>					
Control	11.4d	4.6c	19.0c	2.9e	0.5e
Vetiver	13.0d	4.8c	21.3c	3.9d	0.8d
Tithonia	55.6ab	8.5b	60.7a	13.0b	2.6b
Sunshine B	23.7c	8.4b	44.3b	9.7c	1.5c
Gateway compost	50.8b	8.7b	38.0b	15.3b	3.1b
NPK	60.3a	12.2a	63.7a	27.4a	6.4a
<u>Residual planting</u>					
Control	5.3c	1.53c	11.8bc	2.0c	0.2c
Vetiver	13.8ab	2.94b	31.7b	5.2b	0.7b
Tithonia	7.7bc	4.15a	41.3a	8.1a	1.6a
Sunshine B	7.8bc	2.83b	18.7c	4.9b	0.8b
Gateway compost	9.0bc	2.85b	15.3c	4.3b	0.7b
NPK	17.08a	2.81b	29.3b	3.3b	0.3c

Means having the same letter along the columns indicate no significant difference using Duncan's Multiple Range Test at 5% probability level.

At first planting pots treated with tithonia compost had higher pH compared to other pots (Table 4). In terms of OC, K and N contents, pots treated with tithonia compost had higher contents than other fertilizer treatments. At Second planting pots treated with tithonia compost had higher pH, P, OC higher K and N contents when compared with other

fertilizer treatments and control, respectively (Table 4). The increase in the soil pH level of the pots after the first and second crop's harvest is an indication of the buffering capacity of the tithonia composts applied as reported by Shokalu *et al.* (2011). The low fertility status of the soil treated with NPK observed after second harvest might be partly due to early nutrient mineralization, thereby making the nutrients readily available for plant use and partly due to nutrient leaching. Olowoake, (2014) reported that the application of inorganic fertilizers does not always improve soil organic matter which is a store house for nutrients.

Table 4: Effects of fertilizer types on some soil chemical and physical properties at harvest during the first and second field cropping.

Treatment	pH (H ₂ O)	Available P mgkg ⁻¹	K cmolk g ⁻¹	OC	N	Clay gkg ⁻¹	Silt	Sand
<u>First harvest</u>								
Control	6.5c	22.36e	0.22d	4.01c	0.24e	13.0b	174.0a	813.0c
Vetiver	6.9b	44.30b	1.00b	11.67	1.86c	13.0b	154.0b	833.0b
Tithonia	7.4a	60.17a	1.52a	15.72a	2.75a	33.0a	134.0c	833.0b
Sunshine B	7.0b	30.84d	1.06b	13.45b	2.15b	33.0a	114.0d	853.0a
Gateway compost	7.0b	53.18b	1.04b	12.31b	2.16b	33.0a	114.0d	853.0a
NPK	6.7c	39.40c	0.36 c	10.78c	0.98d	33.0a	164.0b	803.0c
<u>Second harvest</u>								
Control	6.3c	25.90e	0.14d	1.13d	0.12d	41.0b	33.0c	926.0a
Vetiver	7.0b	40.70c	0.25b	9.71b	0.77b	54.0a	31.0c	915.0b
Tithonia	7.6a	66.80a	0.36a	10.45a	1.11 a	55.0a	35.0b	910.0b
Sunshine B	7.1b	31.30d	0.24b	6.50c	1.01a	43.0d	33.0c	924.0a
Gateway compost	7.1b	58.00b	0.24b	7.90c	0.88b	54.0a	43.0a	903.0b
NPK	6.5c	27.40e	0.18c	1.74d	0.20c	51.0a	38.0b	911.0b

Means having the same letter along the columns indicate no significant difference using Duncan's Multiple Range Test at 5% probability level.

Conclusion

All the fertilizers used were found to increase the growth and yield parameters of *Amaranthus cruentus* significantly; however, the effect of tithonia compost were most prominent. Tithonia compost were also found to have better residual effects on soil nutrients than NPK fertilizer. Therefore, use organic compost showed promising potential for improving soil fertility and growth and yield performance of *A. cruentus*.

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Published by:





Determinants of Utilisation of Sustainable Plantain Production Practices among Farmers in Osun State

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Keywords:
Constraints, plantain, production, sustainable, technology

Abstract

Utilisation of sustainable Plantain Production Practices (PPP) by farmers will not only control diseases but also increase crop yields in the long run. This study examined the determinants of utilisation of sustainable PPP among farmers in Osun State, Nigeria. Multistage sampling procedure was used to select 125 plantain farmers for the study. Data were collected with structured interview schedule and analysed using frequencies, percentages, mean, chi-square and linear regression. The results reveals that 64.8% of the respondents were male, mean aged 55.4 ± 8.28 years and 94.4% were literate. Respondents averagely (51.2%) engaged in farming as major occupation and 74.5% were members of cooperative society with over 96.8% sourcing for information from fellow farmers and radio. In terms of utilisation of sustainable PPP, pruning ($\bar{x}=2.63$), desuckering ($\bar{x}= 2.93$), right planting time ($\bar{x}= 2.92$) and debudding ($\bar{x}= 2.90$) were utilised by respondents. Constraints such as top down approach to information delivery ($\bar{x} = 1.99$), lack of follow up by extension agents after training ($\bar{x} = 1.98$), low access to planting materials ($\bar{x} = 1.86$), insufficient information ($\bar{x} = 1.86$) and complexity of technology were identified in the study. Membership of association ($\beta = 1.661$, $p = 0.000$) and constraints ($\beta = 1.861$, $p = 0.000$) to utilisation were the major determinants of utilisation of sustainable PPP among respondents. The need for extension agents and other relevant stakeholders to follow up on plantain farmers on the use of these practices becomes imperative so as to achieve a sustainable production over time.

Déterminants de l'utilisation de pratiques durables de production de plantain chez les agriculteurs de l'État d'Osun

Résumé

L'utilisation de pratiques de production durables pour le plantain par les agriculteurs permettra non seulement de lutter contre les maladies, mais aussi d'augmenter les rendements des cultures à long terme. Cette étude a examiné les déterminants de l'utilisation de pratiques de production durables chez les agriculteurs de l'État d'Osun, au Nigeria. Une procédure d'échantillonnage à plusieurs degrés a été utilisée pour sélectionner 125 agriculteurs de plantain pour l'étude. Les données ont été collectées à l'aide d'un programme d'entretien structuré et analysées à l'aide de fréquences, de pourcentages, de moyennes, d'un chi carré et d'une régression linéaire. Les résultats révèlent que 64,8% des personnes interrogées étaient des hommes, âgés en moyenne de $55,4 \pm 8,28$ ans et 94,4% étaient alphabétisés. En moyenne, les personnes interrogées (51,2 %) font de l'agriculture leur activité principale et 74,5 % sont membres d'une

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Mots clés :

Contraintes,
plantain,
production,
durable,
technologie

société coopérative ; plus de 96,8 % d'entre elles s'informent auprès de leurs collègues agriculteurs et à la radio. En termes d'utilisation de PPP durables, les répondants ont utilisé la taille ($\bar{x}=2,63$), l'épamprage ($\bar{x}= 2,93$), le bon moment pour planter ($\bar{x}= 2,92$) et l'ébourgeonnage ($\bar{x}= 2,90$). L'étude a mis en évidence des contraintes telles que l'approche descendante de la diffusion de l'information ($\bar{x} = 1,99$), le manque de suivi par les agents de vulgarisation après la formation ($\bar{x}= 1,98$), le faible accès au matériel de plantation ($\bar{x} = 1,86$), l'insuffisance de l'information ($\bar{x} = 1,86$) et la complexité de la technologie. L'appartenance à une association ($\beta = 1,661$, $p = 0,000$) et les contraintes ($\beta = 1,861$, $p = 0,000$) à l'utilisation ont été les principaux déterminants de l'utilisation de PPP durables parmi les personnes interrogées. La nécessité pour les agents de vulgarisation et les autres parties prenantes concernées de suivre les planteurs de plantain sur l'utilisation de ces pratiques devient impérative afin d'atteindre une production durable dans le temps.

Introduction

Plantain (*Musa paradisiaca*), a giant perennial herb of the genus *Musa* also known as cooking banana in some part of the world, is undoubtedly one of the oldest cultivated fruits in agriculture in West and Central Africa (Siddhesh and Thumbali, 2019). Plantain origin is believed to be from South East Asia. However, a remarkable diversity of plantain exists in sub-Sahara Africa. In 2012, total world production was estimated to be 102 million metric tons. Thirty three million metric tons are produced in Africa annually (Fakayode, Rahji, Ayinde and Nnom, 2014). Food and Agriculture Organisation Corporate Statistical Database (FAOSTAT, 2018) reported that in West Africa, Nigeria is one of the highest plantain producers with an annual production of about 3.1 million metric tons mostly obtained from the Southern States. Report shows that the crop serve as a staple food for at least 400 million people in the world and as a result, has been ranked as the 4th most valuable food after rice, wheat and maize (Sahayaraj and Kombiah, 2009; IITA, 2014). Plantain is more advantageous over other starchy foods because it contains protein, mineral and vitamins. It can be used in the treatment of sore throat, tongilolitis, diarrhea vomiting which is said to be a major diet in the production of soymusa which can be used in the treatment of Kwashiorkor (Awojodu, 2020).

Unstable rainfall, poor proliferation of suckers, decline land fertility, outdated age-old cultural practices, inappropriate use of pest control methods and pests and diseases, especially the plantain wilt disease are some of the factors attributed to decline in plantain production. Fusarium wilt of plantain is an important disease of plantain (Dale, James, Paul *et al*, 2017). The disease has a high persistence in the soil for more than 35 years and has no effective control method, making it inadvisable to replant with the same susceptible unimproved sucker. The application of chemical control methods for these pests may be inadvisable so as to save crops, the environment and prevent human health hazards which is also central to the sustainability of the environment.

Sustainable crop production refers to production that does not impose any harm to environment, biodiversity and quality of agricultural crops. It entails keeping the soil alive with organic matter, integrated pest management and reduction in usage of pesticides, ensuring food safety and lowering greenhouse gas emission (Imadi, Shazadi, Gul and Kakeem, 2016). According to Szczepanek, Piotrowska-Dlugosz and Konopka (2021), the aim of sustainable production is not only to satisfy the need of human for food and the industry for raw materials but also to protect the environment and natural resources. Production practices that will boost better performance and sustainability of crops is key to achieving food security which is one of the reasons why IITA produce plantain hybrids that will offer farmers the opportunity of bumper harvest with pest and disease resistance varieties.

Eleven varieties were deployed to the farming systems in the Southern States of Nigeria plantain growing belt. The varieties were; PITA14, PITA17, PITA28, BITA3, FHIA17, FHIA18, FHIA20, FHIA23, FHIA25, CRBP39 and Agbagba (Landrace). Agronomic practices and maintenance were the same for all the varieties and they had similar but slightly different physiological characteristics. These hybrids and improvement varieties produce suckers profusely

which allow for rapid multiplication. The utilisation of these plantain varieties by farmers will not only control plantain diseases but will also increase crop yields in the long run.

Research has shown that more than 80% of plantain production comes from smallholder farmers of less than one hectare farmland (Ekunwe and Ajayi, 2010), growing the crop either for home consumption or for local markets. According to Ojediran, Adewumi, Falola *et al*(2018), a major constraint to the expansion of plantain cultivation is the scarcity of healthy planting materials. Farmers usually depend on natural regeneration of plants for the supply of planting materials that are usually contaminated by various soil borne pathogens such as nematodes and fungi (Tumuhimbise *et al.* 2016). Propagating plantain by suckers from a diseased and pest infested mother plant is the main channel through which pests and diseases are spread. Diseases and pests are among the main constraints that severely reduce plantain yields and longevity to only one or two cycles of cultivation, beyond which lodging occurs, often leading to total disappearance of plantations (Blomme *et al.* 2011; Dubois and Coyne 2011; Tumuhimbise *et al.* 2016).

One of the ways of improving agricultural productivity is through the introduction of improved and sustainable agricultural technologies to farmers. The utilisation of these technologies is an important means of increasing the productivity and ensuring sustainability of smallholder agriculture thereby fostering economic growth and improving wellbeing. Thus, Ejechi (2015) found a positive correlation between utilisation of extension recommendations by farmers and crop yields which translate into increased income and improved quality of life of farmers. However, for a successful utilisation of a technology, farmers must not only know about it, but must be able to follow the recommendations given (Olojede, *et al.*, 2018).

Unfortunately, despite all the innovations, interventions, campaigns and strategies introduced over the years, the output from the system has continued to decline across the globe. According to Bal and Trainor (2016), the trend of plantain production in Nigeria between 1990 and 2009 showed that yield per hectare consistently made a downward move from 7.54 tons per hectare in 1992 to 4.94 tons per hectare in 1999; 5.10 tons in 2000 to 4.90 tons in 2001 and 6.31 tons in 2007 to 5.90 tons in 2008. Conversely, an unsustainable increase in the area cultivated or harvested steadily rose from 162,000 hectares in 1990 to 481,000 hectares in 2009 (Bal and Trainor, 2016). If the expansion recorded in farm size over the years corresponds progressively with increase in output, then there would be a huge turnover on productivity and this production turnover can only be achieved through the implementation and utilisation of technologies disseminated to farmers (Olumba and Rahji, 2014).

From the findings of Akintade, Okunlola, and Akinbani, (2016), attempts and break-through have been made by agricultural development partners, research institutions such as the International Institute of Tropical Agriculture (IITA) and National Horticultural Research Institute (NIHORT) towards technology in plantain production, some of such development include macro propagation technique; a farmer friendly rapid sucker multiplication technology, hybrid varieties, sucker cleaning, hot water treatment, propping, pruning, mulching, planting space, de-suckering, planting time, debudding etc which are believed to produce sustainable practices. This study therefore investigated determinants of utilisation of sustainable plantain practices among Osun State farmers.

Objectives of the study

The general objective of the study is to determine the utilisation of sustainable Plantain Planting Practices (PPP) among farmers in Osun State, Nigeria. The specific objectives of the study are to:

1. describe the socio-economic characteristics of respondents,
2. determine the enterprise characteristics of the respondents,
3. ascertain the sources of information on sustainable PPP,
4. examine the awareness of respondents to sustainable PPP,
5. identify the level of utilisation of sustainable PPP and
6. determine the constraints to the utilisation of sustainable PPP.

Hypotheses of the Study

Ho₁: There is no significant relationship between socioeconomic characteristics of respondents and utilisation of sustainable PPP.

Ho₂: There is no significant contribution of variables to the utilisation of sustainable PPP

Methodology

Study area

The study was conducted in Osun state. Osun state is bounded by the states of Kwara on the Northeast, Ekiti and Ondo on the East, Ogun on the south, and Osun on the West and Northwest. The major occupation of the people is farming, though some of them engage in some other occupations such as trading and commercial activities of all sorts like: bakery, transportation, sawmilling, plank selling, bricklaying and so on. The area is popularly noted for the production of plantain/banana, which is usually processed into what is known as Dodo Ikire. This is because the tropical climate in the area favours the growth of some varieties of annual crops, which include yam, cassava, maize, rice, cowpea, and perennial crops such as cocoa, kolanuts, plantain, and palm produce. The climate of Osun is tropical savanna usually warm, with a wet and dry season. It has a yearly average temperature of 64 °F and receives approximately 596 inches of rainfall. It is dry for 59 days throughout the year, with an average moisture in the air of 77% and a UV index of 7. The target population of the study consists of all trained banana/plantain producers. The population of the study comprises all plantain farmers involved in improved production, in Osun State.

A multi stage sampling technique was used to select respondents for the study. The study covered the three zones in Osun state; Iwo, Osogbo and Ife Ijesa zones. At the first stage, a purposive selection of three Local Government Areas (LGAs) from Ife-Ijesa (Oriade, Atakumosa and Ife North), one LGA from Osogbo (Odo-otin) and Iwo (Iwo) zones were selected due to dominance in plantain production. At the second stage, communities and respondents were selected from the LGAs proportionate to size and they are Erin-Oke (18), Erin-Ijesa (12) and Akola (10) communities in Oriade LGA. Iperindo (15) in Atakumosa and Ipetumodu (10) in Ife North Local Government. In Odo-Otin, 23 respondents were selected and 17 in Iwo LGA. Twenty respondents were selected in Ile ogbo of Iwo zone making 125 respondents that form the sample size for the study.

Farmers' awareness of sustainable PPP: Respondents' awareness of sustainable PPP was measured on a 14-item list of awareness questions. A dichotomous scale of 'aware' or 'not aware' with scores 1 and 0 respectively was used to measure the response options. Respondents were categorised into two using a bench marked mean score. Respondents whose scores fall below the mean, were regarded as having low awareness, while those with equal or above the mean, were categorised as having high awareness of sustainable Plantain Planting Practices.

Constraints to the utilisation of sustainable PPP: A list of nine possible constraints to the use of sustainable PPP was presented to the respondents for them to choose as applicable. This was measured on a 3-point Likert type scale of "severe constraint", "mild constraint", and "not a constraint" assigned scores of 2, 1 and 0, respectively. The mean score of each of the constraint item was determined and used to rank the constraints in order of severity.

The dependent variable for the study is utilisation of sustainable PPP. Respondents' utilisation of sustainable PPP was measured on a 14-item question of utilisation. A scale of 'always utilised', 'sometimes utilised', and 'not utilised' with scores of 2, 1 and 0 was assigned, respectively to measure the response options. Respondents were categorised into two using a bench marked mean score. Respondents whose scores fall below the mean, were regarded as having low level of utilisation, while those that are with equal or above the mean were categorised as having high level of utilisation of sustainable PPP. Data collected were analysed using frequencies, percentages, mean, standard deviation, chi-square and linear regression.

Results and Discussion

The mean age of respondents was 55.40 ± 8.28 years. Majority (64.8%) of the farmers were male. This implies that there is a dominance of male gender and this could be because most of the production activities were carried out by men while women are mostly involved in processing and marketing of products as supported by Solomon (2020). For marital status, 92.0% of the farmers were married. The marital status of household is one of the considered explanatory variables of adoption decisions. The reason for this as revealed by Ojo and Baiyegunhi (2020); Ojo, *et al.* (2021) is that unmarried farmers have fewer responsibilities and channel their financial resources to agricultural technology adoption, contrary to their married counterparts. This suggests that married respondents may not be able put in their

resources into the use of new technologies due to greater responsibilities from family. About 24.0% of the respondents had tertiary education, 33.6% had secondary education, 36.8% had primary education, while only 5.6% of them had no formal education. It implies that the farmers have the tendency of utilising improved technology if properly disseminated. According to Orisakwe and Agomuo (2011), farmers' level of education has a positive relation with adoption of technologies. The result also reveals that 64.0% of the farmers depended solely on farming as their major occupation. The implication of this is that they have a better chance to improve practices, due to the fact that such households are better off in taking risks associated with new technologies and practices. This is consistent with the findings of Mulukenet *al.*, (2021). The study also shows that the mean household size is 4.8 ± 1.48 . The greater the number of helping hands a farmer has on his farm, the greater the motivation for more hectares cultivation as corroborated by Udemezue (2014). It was observed that majority (98.4%) of the respondents had their income from personal savings. This finding agrees with the work of Mohamed and Temu (2008) who reported that access to credit loan stimulate the adoption of technology adoption. It was again observed that majority (74.5%) of the respondents were members of cooperative society. This would also have positive effect on awareness and utilisation of technologies since it is easier to disseminate information through a group. This corroborates the findings of Adeleke and Alani (2020) that asserted that farmers who are members of cooperative societies have access to information on technology and funds which could give them opportunity to better utilise suitable technologies for their production.

Table 1: Distribution of respondents according to socioeconomic characteristics (n=125)

Variable	frequency	percentage (%)	Mean ± SD
Age (in years)		55.40	± 8.28
Less than 41	6.0	4.80	
41-55	56.0	44.8	
56-70	61.0	48.8	
Sex			
Male	81.0	64.8	
Female	44.0	35.2	
Marital status			
Married	115.0	92.0	
Single	10.0	8.00	
Level of education			
No formal education	7.0	5.60	
Primary education	46.0	36.8	
Secondary education	42.0	33.6	
Tertiary education	30.0	24.0	
Occupation			
Artisans	17.0	13.6	
Farming	64.0	51.2	
Others	6.0	4.8	
Source of income			
Personal savings	123.0	98.4	
Loan	2.0	1.60	
Membership of association			
Member	83.0	74.5	
Non-member	42.0	25.5	

Source: Field survey, 2023

Enterprise characteristics of respondents

The study reveals that 89.4% of the respondents engaged in mixed cropping. From the result, 50.4% of the respondents engage in intercrop practice. This is consistent with Erasmus (2021) findings that intercropping of plantain was advantageous over sole cropping as it increase yield in all instances. Result shows that majority (80.8%) of farmers had farming experience of over 10 years in plantain production, an indication that many of the farmers are quite knowledgeable about plantain production which could boost their tendency to want to explore the use of sustainable practices. The result also shows that 51.2% had plantain farm between 1.1 to 3.0ha while only 5.6% of the respondents had above 5ha. This implies that the respondents are mainly smallholder farmers with limited funds, this might limit their quest for the use of sustainable technologies as many may not consider expanding their farmland due to cost.

Table 2: Distribution of enterprise characteristics of respondents (n=125)

Variable	frequency	percentage (%)	Mean	± SD
Cropping system				
Monocropping	13.0	10.4		
Intercropping	63.0	50.4		
Mixed cropping	112.0	89.4		
Farming experience				
1-10 years	24.0	19.2		
11-20years	38.0	30.4		
21-30years	42.0	33.6		
Above 30 years	21.0	16.8		
Farm size (ha)				
0.1-1.0ha	37.0	29.6		
1.1-3ha	64	51.2		
3.1-5.0ha	17.0	13.6		
Above 5.0ha	7.0	5.6		

Source: Field survey, 2023

Sources of information on sustainable Plantain Planting Practices

The result from figure 1 shows that the majority (96.8%) of the respondents sourced information on sustainable planting practices from fellow trained farmers/friends, 54.4% from radio, 40.0% from research institutes, 36.5% from extension agents and 35.2% from internet. This is an indication that information flow faster and easier among farmers due to close contact and sharing of views. This result agrees with the work of Nwachukwu (2014) that fellow farmers' aid in the dissemination of innovation among local farmers. It also shows poor delivery of extension services. ADPs should stand out and take-up their responsibilities in information dissemination in order to encourage better and sustained productivity among farmers.

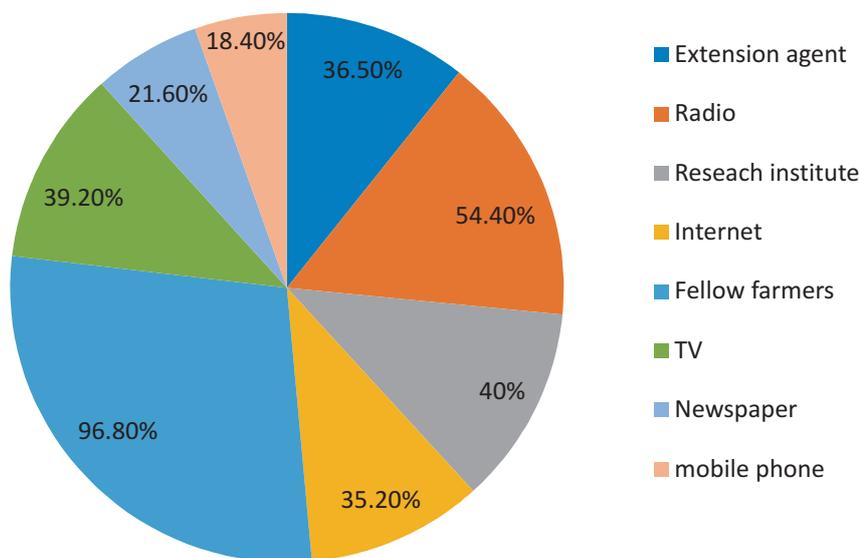


Figure1: Distribution of respondents sources of information on sustainable PPP (n=125)

Farmers' awareness of sustainable PPP

The result in Figure 2 shows that majority of the respondents are aware of PPP such as rapid sucker multiplication (split technique, 80.8%), hybrid varieties of plantain (90.4%) which may have positive impact on the farmers' profitability because the gestation period of hybrid cultivar is shorter and it attracts higher prices compared to other varieties, sucker cleaning (88%), hot water treatment (54.4%) and agro chemical application (99.2%). By implication, there was high level of awareness of the practices. This confirm Olojede, *et al* (2018) that there is high level of awareness on plantain practices among farmers.

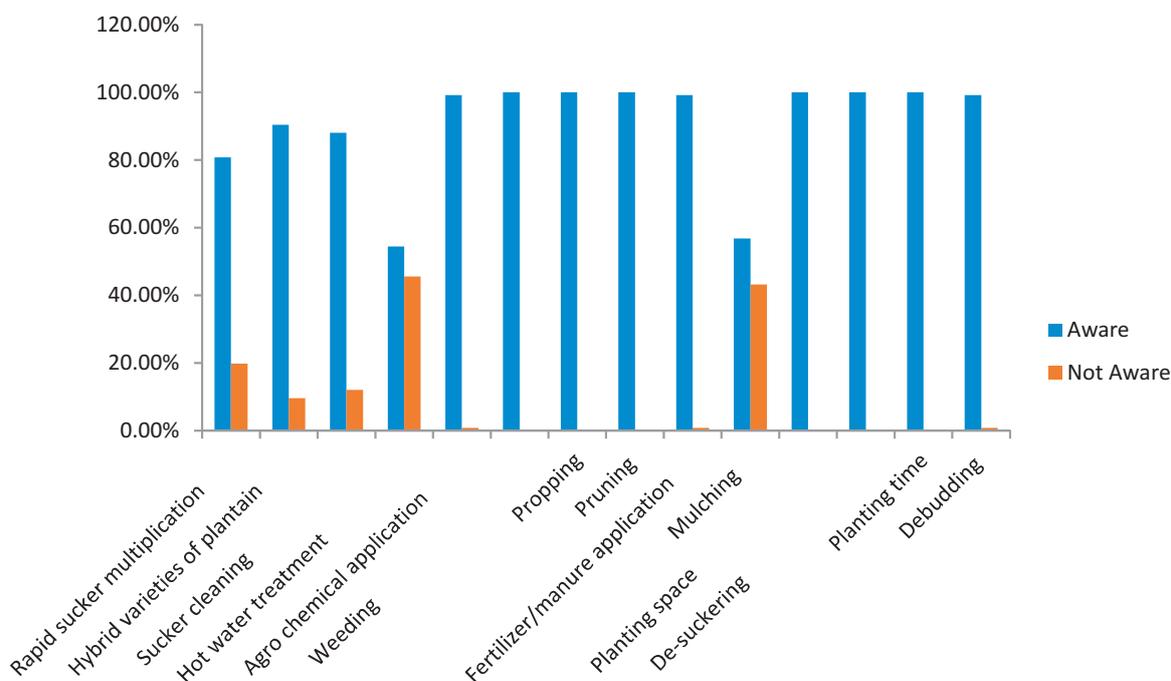


Figure 2: Distribution of respondents on awareness of sustainable PPP (n=125)

Constraints militating against the utilisation of sustainable PPP

Results in Table 3 reveals that constraints such as top down approach to information delivery ($\bar{x}=1.99$), lack of follow up by extension agents after training ($\bar{x}=1.98$), low access to planting materials ($\bar{x}=1.86$), insufficient information ($\bar{x}=1.86$), complexity of technology ($\bar{x}=1.56$) and poor access to technology ($x=1.55$) were constraints militating against utilisation of sustainable PPP. This implies that extension agents must be conscious to offer practices that will meet the demands of farmers and also follow up after dissemination of information. If constraints associated with plantain production are tackled, it could lead to increased production and income for stakeholders. In addition, Mgbenka and Mbah (2016) opined that limited access to credit facilities and poor marketing system also discourage farmers production. The result also conforms to the findings of Akinyemi *et al.* (2010) who found that top down approach and low access to good planting varieties are constraints to plantain production in Nigeria.

Table 3: Distribution of respondents on constraints to utilisation of sustainable PPP

Constraints	Severe const. (%)	Mild const. (%)	Not a constraint (%)	Mean	SD	Rank
Low access to planting materials	92.0	1.6	6.4	1.86	0.50	3
Inadequate labour	91.2	0.8	8.0	1.83	0.55	5
Lack of follow up by extension agent after training	98.4	-	1.6	1.98	0.13	2
Complexity of PPP tech	73.6	12.0	14.4	1.56	0.78	6
Land availability	59.2	17.6	23.2	1.36	0.83	8
Insecurity	40.0	24.0	36.0	1.04	0.87	9
Poor access to PPP tech	68.0	19.2	12.8	1.55	0.71	7
Insufficient information	85.6	6.0	14.4	1.86	0.35	3
Top down approach to information delivery	99.2	0.8	-	1.99	0.89	1

Source: Field survey, 2023

Utilisation of sustainable Plantain Planting practices

The result in Table 4 shows utilisation of sustainable PPP among respondents. The results show that pruning ($\bar{x}=2.63$), desuckering ($\bar{x}=2.93$), right planting time ($\bar{x}=2.92$), weeding ($\bar{x}=2.64$), sucker cleaning ($\bar{x}=2.34$) and debudding ($x=2.90$) were practices utilised by farmers in the study area. The reason for this utilisation may be due to the fact that these practices may not be new to farmers since the techniques were traditionally practiced. This result is in line with the findings of Akintade *et al.* (2016) that farmers will utilise farm practices that are friendly and not complex.

Table 4: Distribution of respondents' utilisation of sustainable Plantain PPP

Sustainable PPP	Always utilised	Sometimes utilised	Never utilised	Mean	SD	Rank
Rapid sucker multiplication	11.2	85.6	3.2	1.92	0.37	11
Hybrid varieties	12.0	79.2	8.8	1.97	0.46	10
Sucker cleaning	8.8	48.0	43.2	2.34	0.64	7
Hot water treatment	11.21	8.0	80.8	1.30	0.66	13
Weeding	8.8	17.6	73.6	2.64	0.64	5
Propping	25.6	40.8	33.6	2.08	0.77	9
Pruning	64.8	33.6	1.6	2.63	0.52	6
Manure application	47.2	38.4	14.4	2.33	0.72	8
Mulching	8.0	17.6	74.4	1.34	0.62	12
Planting space	75.2	14.4	10.4	2.65	0.66	4
Desuckering	92.8	7.2	-	2.93	0.26	1
Right planting time	92.0	8.0	-	2.92	0.27	2
Debudding	88.0	2.0	10.0	2.90	0.33	3

Source: Field survey, 2023

Categorisation of utilisation of sustainable PPP

Table 5 shows that 52.0% of the respondent had high level of utilisation of sustainable PPP. This indicates that there is a close margin between farmers that utilise and those that did not utilise. This contradicts Olojede (2018) revealing low utilisation of sustainable PPP in a similar study. This suggests that farmers are already demonstrating positive response towards utilisation of these practices. At this point, extension agents should intensify adequate follow up and on farm visits after training in other to further increase utilisation.

Table 5: Categorisation of utilisation of sustainable PPP (n=125)

Level of utilisation	Freq.	Percent	Max.	Min.	Mean	SD
Low (28.0-32.1)	60	48.0	42.0	28.0	32.1	2.43
High (32.2- 42.0)	65	52.0				

Source: Field survey, 2023.

Test of relationship between socioeconomic characteristics of respondents and utilisation of sustainable PPP

Result shows from Table 6 that there was a significant relationship between membership of association and utilisation of sustainable PPP. According to Adeleke and Alani (2020), it was observed that farmer's association play an important role to help members increase their access to supports of information, capital, and technology; bring benefits to members and partly promote production, enhance productivity and increase income.

Table 6: Relationship between selected socioeconomic characteristics of respondents and utilisation of sustainable PPP

Variable	χ^2	p-value
Occupation	3.686	0.297
Source of income	2.202	0.138
Membership of association	0.023	0.006*

Source: Field survey, 2023.

Contribution of independent variables to utilisation of sustainable PPP

The R-Square (0.409) on the regression Table 7 shows that 41.0% of the utilisation of sustainable PPP is determined or can be explained by these variables; membership of association (7.009) and constraint (8.209). Constraint group had 82.0% contribution to the utilisation of sustainable PPP while membership of association had 70.0%. If these constraints encountered by plantain farmers are eliminated, respondents are better placed to utilise sustainable PPP. This is in line with the result of Olojede (2018) that constraints like poor access to technologies and labour intensity, have significant effect on utilisation of sustainable plantain practices. The need to encourage formation of groups among farmers becomes pertinent by extension agents.

Table 7: Contribution of variables to the utilisation of sustainable PPP

	Standard coefficients (Beta)	t-value	p-value
(Constant)	1.620	2.588	0.11
Constraint group	1.661	8.209	0.000*
Aware group	0.089	0.941	0.349
Farm size group	0.041	0.413	0.681
Marital status	0.023	0.279	0.781
Form of education	0.052	0.560	0.576
Occupation	0.113	1.330	0.186
Source of income	0.056	0.754	0.452
Association membership	1.861	7.009	0.000*

R= 0.639 R Square=0.409 Adjusted R square = 0.339

Source: Field Survey, 2023

Conclusion and Recommendations

The study concluded that most of the respondents were male and source for information on sustainable PPP from fellow farmers and radio. Constraints to utilisation of sustainable PPP were low access to planting materials, complexity of technology and lack of follow up by extension agents after training. Constraints to utilisation and membership of association were the major determinants of utilisation of sustainable PPP. Research institutes and ADP should work closely to make sustainable planting materials more accessible to plantain farmers. ADP should leverage on the farmers' association to intensify the need for utilisation of required techniques. This could be achieved through adequate demonstration and exhibitions of adopted farmers output, thus combating food insecurity.

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Published by:







Evaluation of Different Grades of Ibadan Brewery Waste Compost on the Yield of Cucumber (*Cucumis sativus* L.)

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Keywords:

Composts,
Brewery waste,
Cucumber,
soil fertility

Abstract

Production and recycling processes adaptable within farming systems promote ecological agriculture. One of such processes is the conversion of brewery waste to fertiliser, a sustainable waste management ethos. Characterising the nutritional potentials of brewery waste composts and their effect on crops is imperative to optimise its use. Thus, the objective of this study is to evaluate the effect of different grades of Ibadan Brewery Waste (IBBW) Compost on the yield of cucumber and soil properties.

The study was carried out at the experimental field, Department of Agronomy, University of Ibadan. Treatments used were three grades of IBBW composts; IBBW-1A, IBBW-1B, IBBW-2 and Control (no nutrient applied), arranged in a Complete Randomised Block Design with four replications. The marketer cucumber variety was grown by applying treatments in splits at 2 weeks prior to and 5 Weeks After Sowing (WAS). The experiment was carried out between August and October, 2016 and 2017. Data collected were: number of leaves, Vine girth and Vine length were obtained from 3-6 WAS while Fresh Fruit Weight (FFW) was obtained using a sensitive scale at harvest from 6-10 WAS. Two-way ANOVA was used to determine the effects of composts and year on growth and, yield parameters of cucumber and soil chemical characteristics at $\alpha_{0.05}$. All grades of IBBW significantly improved the yield of cucumber and some soil chemical properties better than Control across years; However, IBBW-1B had the highest significant effect on FFW of cucumber.

Évaluation des Différents Taux de Compost de la Brasserie Ibadan sur le Rendement du Concombre (*Cucumis sativus* L.)

Résumé

Les processus de production et de recyclage adaptables aux systèmes agricoles favorisent l'agriculture écologique. L'un de ces processus est la conversion des déchets de brasserie en engrais, une philosophie de gestion durable des déchets. Il est impératif de caractériser le potentiel nutritionnel des composts de déchets de brasserie et leur effet sur les cultures afin d'optimiser leur utilisation. L'objectif de cette étude est donc d'évaluer l'effet de différentes qualités de compost de déchets de brasserie d'Ibadan (IBBW) sur le rendement des concombres et les propriétés du sol. L'étude a été réalisée sur le terrain expérimental du département d'agronomie de l'université d'Ibadan. Les traitements utilisés étaient trois catégories de composts IBBW: IBBW-1A, IBBW-1B, IBBW-2 et le contrôle (pas d'application d'éléments nutritifs), disposés dans un bloc aléatoire complet avec quatre répétitions. La variété de

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concombre maraîcher a été cultivée en appliquant les traitements en deux fois, 2 semaines avant et 5 semaines après le semis (WAS). L'expérience a été menée entre août et octobre 2016 et 2017. Les données collectées étaient : le nombre de feuilles, la circonférence de la vigne et la longueur du vin ont été obtenus de 3 à 6 WAS, tandis que le poids des fruits frais (FFW) a été obtenu en utilisant une échelle sensible à la récolte de 6 à 10 WAS. L'ANOVA à deux voies a été utilisée pour déterminer les effets des composts et de l'année sur la croissance et, les paramètres de rendement du concombre et les caractéristiques chimiques du sol à $\alpha 0,05$.

Mots clés :

Composts,
déchets de brasserie,
concombre,
fertilité du sol.

Toutes les catégories d'IBBW ont amélioré de manière significative le rendement du concombre et certaines propriétés chimiques du sol, mieux que le témoin, d'une année à l'autre; cependant, l'IBBW-1B a eu l'effet significatif le plus important sur l'indice de consommation du concombre.

Introduction

Soil productivity is vital for achieving food security. The capacity to supply nutrients in the correct proportions to maximize crop yields is a characteristic of productive soil. However, the dynamic nature of nutrients, subpar management practices, and its rapid depletion in tropical soils necessitate the use of fertilisers to augment nutrients. The maintenance of productive soil requires the use of fertilisers that are ecologically suitable to achieve food security, providing a wide range of nutrients and functioning as soil conditioners (Oliver and Gregory, 2015; Adugna, 2018). Inorganic fertilisers are not ecologically sustainable as they are expensive and scarce in West Africa (Mensah and Frimpong, 2018; Toungos 2019). The use of organic fertilisers serves as a competent option to inorganic sources as they are efficient for maintaining productive soil.

Compost, a form of organic fertiliser, is obtained from the decomposition of organic waste under aerobic conditions. The utilisation of compost is a means of recycling municipal and farm waste. Compost has an advantage of being more space-efficient with ease of storage and conveyance compared to other forms of organic fertiliser (Bernal *et al.*, 2009). The potential of any compost is determined by several factors such as the composting materials used; their ratios used, nutrient status, age, and production methods (Pietro *et al.*, 2013). These potentials encompass aspects like nutrient content, nutrient release and loss patterns, effects on crops, and soil characteristics, among others. The selection of composting materials depends on material availability and the intended purpose of composting. Waste materials sludge, trub, spent yeast, spent hops, and spent grains are generated from the brewery industries (Kerby and Vriesekoop, 2017). Brewery Spent Grain (BSG) constitutes approximately 85% of the total waste weight produced by breweries per brew which is capable of constituting a menace in the society (Nocente *et al.*, 2019).

The use of BSG in agriculture is a sustainable waste management strategy. The application of BSG on soils as a fertiliser has been reported to improve soil pH, water holding capacity, organic matter, and both micro and macro nutrients (Mathias *et al.*, 2014; Aboukila *et al.*, 2018). However, the use of BSG as a fertiliser is impeded by its high moisture content and substantial bulk weight. The efficiency of BSG as a fertiliser can be enhanced by composting with other organic waste materials (Assandriet *et al.*, 2021). BSG has been composted with various organic materials, including sawdust, animal dung, plant leaves, etc. Notably, composting BSG with animal dung has proven effective in improving soil characteristics, as well as the growth and yield of crops (Ebido and Ndubuaku 2019; Assandriet *et al.*, 2021). However, there is dearth of information on composts made with BSG from Ibadan Brewery Waste (IBBW) and their effect on soil characteristics and crops like cucumber.

Cucumber (*Cucumis sativus* L.) is a widely consumed fruit vegetable (FAO, 2017). The increase in demand and consumption of cucumbers result from its nutritional and economic importance. Cucumber fruits are composed of approximately 90% water, vitamins, minerals, antioxidants, and pantothenic acid, making them a valuable source of food and medicine (Abbey *et al.*, 2017). Cucumbers are also cultivated for use as raw materials in the cosmetic industry, and cucumber cultivation is considered a profitable business venture (Jimoh *et al.*, 2016; Uthpala and Navaratne, 2019).

However, the cultivation of cucumbers in Nigeria is limited by various challenges, such as poor soil fertility. Efforts have been made to enhance soil productivity for cucumber cultivation in Nigeria by use of different fertilisers. Evaluating the potential of various available organic materials as a source of fertiliser is crucial for sustainable soil productivity. Therefore, it is imperative to characterise the nutritional qualities of different grades of IBBW compost for crops like cucumbers to ensure their effective use. The objective of this study is to assess the impact of different grades of IBBW compost on the growth, yield of cucumbers and soil properties.

Materials and Methods

Experimental site

The experiment spanned two years from August to October in both 2016 and 2017 on the experimental field of the Department of Soil Resources Management, Agronomy building, Faculty of Agriculture, University of Ibadan. The coordinates for this site is 7° 24'N, 3° 54'E, 234m above sea level. Ibadan is located within the tropical rainforest zone of Nigeria. The prevailing soil order in Ibadan are Alfisols and Inceptisols originating from basement complex rocks. The soils at this location are characterised by their depth, permeability, and friability, featuring a finer surface layer of sandy loam, which transitions into heavier sandy clay loam or sandy clay deeper down (Chude *et al.*, 2012).

Agronomic practices

Land clearing, tillage and beds were carried out manually. A total of sixteen beds (2m²) were made and seeds were sown on each bed at a distance of 50×30cm. Twelve seeds were sown on each bed (one seed per stand). Weeding was done manually at two and five weeks after planting and supplementary Irrigation was practiced. Plants were trellised at four weeks after sowing.

Treatments and experimental design

Three composts made up of brewery spent grain and poultry manure in varying ratios were compared with Control (no nutrient) and used as treatments as follows:

Treatment 1(T1)-IBBW1A-Ibadan Brewery Waste Compost Grade 1A

Treatment 2(T2)-IBBW1B-Ibadan Brewery Waste Compost Grade 1B

Treatment 3(T3)-IBBW2- Ibadan Brewery Waste Compost Grade 2

Treatment 4(T4) - Control (no application)

Treatments were analysed for some nutritional characteristics (Table 1) as described: 0.5g of treatments were placed in a beaker; 5ml of Nitric acid was added. The beaker was placed on a hot plate at a temperature of about 100° C for 20- 30 minutes to digest. The digest of a light clear yellowish solution was obtained. Nitrogen content of the digest was determined using the kjeldahl method as described by Purificación *et al.* (2013), phosphorus using the Murphy and Riley method as described by Raun *et al.* (1987) and potassium content was read on a flame photometer. Total organic carbon (OC) was determined as described by Shaw (1959).

Table 1: Chemical Composition of Composts

Total Nutrient element (%)	IBBW1A	IBBW1B	IBBW2
Total Nitrogen	1.80	0.78	0.75
Phosphorus	1.93	1.59	1.60
Potassium	2.10	0.21	0.21
Organic Carbon	0.58	6.73	13.28

Treatments were incorporated into the soil at the rate of 200kg K/hectare in splits; at two weeks before planting and four weeks after planting. They were arranged in a Randomized Complete Block Design (RCBD) with four replications.

Data Collection

Data was collected from the two centre tagged plants on growth (Number of leaves, Vine girth and Vine length) and yield (Fresh fruit weight) parameters. Number of leaves was obtained by visual counting while the vine girth and vine length were measured using a flexible tape from the third to the sixth week after sowing. Matured fruits were handpicked and weighed from the sixth to the tenth week after sowing using a sensitive scale.

The effect of treatments was also evaluated on soil chemical properties and was carried out in the consultancy laboratory of the department. Soil samples (0-30cm depth) were collected before planting and per treatment and post-harvest. The samples were air dried and sieved using 0.5 and 2mm sieve. The following standard procedure were used to determine the nutrient contents soil samples: Particle size distribution was analyzed as described by Dane and Topp (2002). Total nitrogen was determined using Kjeldahl method as described by Bremner (1960). Available Phosphorus was determined by the Bray and Kurtz method as described by Sims *et al.* (2000). Organic carbon was determined using the Walkley and Black as described by Pramod *et al.* (2014). The soil pH was read using a pH meter at ratio 1:1 (soil: water). Micro nutrient contents of the soil were extracted using Mehlich III and reading was done using the atomic absorption spectrophotometer. Exchangeable bases were extracted using 1N ammonium acetate (NH₄OAc). K and Na were read using a flame photometer while Ca and Mg were read using spectrophotometer.

Statistical analysis

All data obtained were subjected to two-way analysis of variance (ANOVA) using GenStat Discovery version (2015) and means were separated using least significance difference (LSD) at $p < 0.05$.

Results and Discussion

The textural class of the soil used for this study is the recommended sandy-loam textured soil while the pH ranges of 6.9-7.0 slightly above 5.6-6.5 as described by Jimenz-Ballesta *et al.* (2018) for cucumber cultivation (Table 2). The organic carbon ranged from 12 to 13.2g/kg, phosphorus from 2 to 11mg/kg and Nitrogen from 0.05 to 0.1g/kg (Table 2). Organic carbon and Phosphorus contents were moderate while Nitrogen content was low in all the soil samples making the soil suitable for a fertiliser trail experiment (Chude *et al.*, 2012).

Table 2: Pre-planting chemical characteristics and particle size distribution of soil used for the study

Parameter	First year	Second year
pH(1:1 H ₂ O)	6.9	7.0
Organic Carbon (g/kg)	13.2	12
Total Nitrogen (g/kg)	0.1	0.1
Available Phosphorus (mg/kg)	9	11
Exchangeable Cations (cmol/kg)		
Ca	0.90	1.2
Mg	0.2	1.3
K	0.1	0.1
Na	0.1	0.2
Micronutrients (mg/kg)		
Mn	12	15
Fe	10	7.0
Cu	1	3.0
Zn	4	2.0
Particle size analysis (g/kg)		
Sand	750	790
Silt	140	110
Clay	110	100
Textural class	Sandy Loam	Sandy loam

There was no significant effect of fertiliser sources on the number of leaves and Vine girth while there was significant increase in vine length and yield of cucumber plant (Table 3). However, the effect of fertiliser on growth and yield parameters were not significant except with vine girth. The highest number of leaves was obtained from IBBW-1B and was higher than IBBW-2, IBBW-1A and Control at 18%, 22% and 58% respectively. The vine girth of 2.3 cm was obtained from IBBW-2 which increasingly varied from IBBW-1B, IBBW-1A and Control at 9%, 14% and 35.9%. The vine length 77cm was obtained from IBBW-1B which was higher than IBBW-2, IBBW-1A and Control at 3.4%, 23% and 67.6% respectively.

Table 3: Two-way ANOVA examining the effects of fertiliser and year on the growth and yield of cucumber

Variables		Number of leaves	Vine girth (cm)	Vine length(cm)	FFW (t/ha)
Fertiliser	IBBW-1A	16	2.0	61.0	20.5
	IBBW-1B	20	2.1	77.0	45.3
	IBBW-2	19	2.3	74.4	34.1
	Control	11	1.6	38.1	7.5
	LSD (= 0.05)	ns	ns	2.64	11.6
Year	1	18	3.0	71.31	30.3
	2	15	1.0	53.96	23.3
	LSD (= 0.05)	ns	0.7	ns	ns
Interaction	Year*fertiliser	ns	ns	<0.05	<0.05

FFW- Fresh fruit weight, ns – not significant

The Fresh fruit weight of 45.3t/ha was obtained from IBBW-1B which was higher than IBBW-2, IBBW-1A and Control at 28%, 75% and 143% respectively. The number of leaves and vine girth obtained in this study is higher while the vine length and yield is lower than the reports of AdeOluwa *et al.* (2021). The effect of IBBW composts on post-harvest soil chemical properties is shown in Table 4. There was slight increase in the pH across treatment except Control which ranges from 6.1-7.3. However, the pH is still within the recommended range for Nigerian soils (Chude *et al.*, 2012). Organic carbon ranges from 5.8-15.6g/kg, increased across treatments except control with IBBW-2 having the highest significant effect on soil organic carbon. This may be because the organic carbon content of IBBW-2 was the highest across treatments. Organic fertiliser sources such as compost have the ability to improve the organic carbon content of soils (Abiokila *et al.*, 2018). IBBW composts had significant effect on Nitrogen while it was not significant with potassium content in the soil which varied across treatments from 0.05-0.3g/kg and 0.1-0.2cmol/kg respectively.

Table 4: Two-way ANOVA examining the effects of fertiliser and year on some post-harvest soil chemical characteristics

Variables		pH	OC (g/kg)	TN (mg/kg)	Avail. P (g/kg)	Exchangeable cations (cmol/kg)				Micro nutrients (mg/kg)			
						K	Na	Ca	Mg	Mn	Fe	Cu	Zn
Fertiliser	IBBW-1A	7.3	14.6	0.3	10	0.2	0.1	0.4	0.2	18.5	5	3	4.5
	IBBW-1B	7.1	15.2	0.2	14	0.2	0.2	0.6	0.3	25.5	6.5	2.5	4.5
	IBBW-2	7.0	15.6	0.17	17	0.2	0.1	0.8	0.4	23.0	5	3.5	4.5
	Control	6.1	5.8	0.05	5	0.1	0.1	*	0.1	11.5	4	0.6	1.2
	LSD (= 0.05)	ns	0.3	0.02	2.5	ns	ns	ns	Ns	2.3	ns	ns	0.01
Year	1	6.9	12.0	0.18	12	0.1	0.1	0.5	0.3	19.8	6.3	2.0	3.8
	2	6.8	13.6	0.18	12	0.2	0.1	0.48	0.3	19.5	4	2.8	3.7
	LSD (= 0.05)	ns	Ns	ns	ns	ns	ns	ns	Ns	ns	ns	ns	ns
Interaction	Year*fertiliser	ns	<0.01	<0.001	<0.005	ns	ns	ns	ns	<0.001	<0.01	<0.01	<0.05

OC-organic carbon, TN- total Nitrogen, Avail. P.- Available P, K- potassium, Na- Sodium, Ca-Calcium, Mg-magnesium, Mn- manganese, Fe- Iron, Co-Copper, Zinc –Zn, ns- not significant, LSD-least significant difference, *- below detectable unit

The nitrogen and potassium content in the soil were below the critical range of 1.6-2.0g/kg and 0.3-0.6cmol/kg for Nigerian soils (Chude *et al.*, 2012). This may be due to the nitrogen content of composts as reflected on the effect of IBBW-1A post-harvest soil nitrogen. Additionally, the ease of detachability of nitrogen and potassium from soils colloids to solution. These nutrients in solution could be taken up by plant or lost through leaching, thus, their low content in the soil.

The available phosphorus increased for all treatments except Control with values ranging from 5-17mg/kg. The application of composts increases the availability of phosphorus in soils by reducing the sorption of phosphorus to soil colloids through its reaction with clay minerals (Atoloye *et al.*, 2021). The highest significant soil phosphorus was from IBBW-2 although IBBW-1A had the highest phosphorus content. The exchangeable cations varied across treatments with no significant effect as values range from 0.04-0.44cmol/kg. The values of micro-nutrients across treatments range from 0.6-25.5mg/kg. Fertiliser sources had significant effect on the manganese and zinc while the values varied for copper and iron. The effect of IBBW composts on soil chemical properties were same across years while there was no significant interactions between composts and years for pH and exchangeable cations.

Conclusion

The evaluation of the potentials of Ibadan Brewery Waste Composts as a fertiliser for the cultivation of cucumber revealed that all grades significantly improved the yield of cucumber and some soil chemical properties better than Control across years. However, IBBW-1B had the highest significant effect on FFW of cucumber.

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Published by:







Determinants of Consumers' Preference for Purchase of Organic Agricultural Produce in Ibadan Metropolis

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Keywords:

Consumer,
organic agricultural produce,
organic sales outlets,
preference

Abstract

The preference for purchasing organic agricultural produce has gained significant attention in recent years as consumers increasingly prioritize healthy and sustainable food options. This study therefore was carried out to investigate the factors that determine consumers' preference for purchasing organic Agricultural produce in the Ibadan metropolitan area, Ibadan, Oyo State, Nigeria. The specific objectives were: socio-economic characteristics of the respondents, the types of organic agricultural produce that are available, and factors responsible for the respondents' preference for organic produce in the study area. A multistage sampling procedure was used to select 91 respondents for the study and data collected through questionnaires were analyzed using both descriptive and inferential statistics. Result shows that majority of the respondents had mean age of 38 ± 13 years, 54.9% of the respondents were female, married (54.9%), had formal education (98.9%), had mean family size of 5 ± 2 members, mean average monthly income of ₦90,000 \pm 50,000 and majority (52.7%) indicated low availability of organic produce. Most of the respondents had low preference for organic produce based on the quality of the organic produce with highest mean of 0.93 and ranked 1st. Respondents' sex ($\beta = -0.218$) and availability ($\beta = -0.350$) had a direct influence on the market choice for purchasing organic agricultural produce in the study area. The study concluded that availability of organic produce and respondents' preference determines their choice for purchasing organic agricultural produce in the study area. It is therefore recommended that more organic sales outlets /markets are needed in various locations to make the organic produce closer to the consumers so as to increase the consumer's access and preference to purchase organic agricultural produce in the study area.

Déterminants de la Préférence des Consommateurs Pour L'achat de Produits Agricoles Biologiques dans la Métropole D'ibadan

Résumé

La préférence pour l'achat de produits agricoles biologiques a fait l'objet d'une attention particulière ces dernières années, car les consommateurs privilégient de plus en plus les options alimentaires saines et durables. Cette étude a donc été réalisée pour examiner les facteurs qui déterminent la préférence des consommateurs pour l'achat de produits agricoles biologiques dans la zone métropolitaine d'Ibadan, Ibadan, Oyo State, Nigeria. Les objectifs spécifiques étaient les suivants : les caractéristiques socio-économiques des personnes interrogées, les types de produits agricoles biologiques disponibles et les facteurs responsables de la préférence des personnes interrogées pour les

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produits biologiques dans la zone d'étude. Une procédure d'échantillonnage à plusieurs degrés a été utilisée pour sélectionner 91 répondants pour l'étude et les données recueillies par le biais des questionnaires ont été analysées à l'aide de statistiques descriptives et inférentielles. Les résultats montrent que la majorité des personnes interrogées avaient un âge moyen de 38 ± 13 ans, 54,9% des personnes interrogées étaient des femmes, mariées (54,9%), avaient une éducation formelle (98,9%), avaient une taille de famille moyenne de 5 ± 2 membres, un revenu mensuel moyen de $N90,000 \pm 50,000$ et la majorité (52,7%) a indiqué une faible disponibilité des produits biologiques. La plupart des personnes interrogées avaient une faible préférence pour les produits biologiques en raison de leur qualité, la moyenne la plus élevée étant de 0,93, ce qui les plaçait en première position. Le sexe des répondants ($\beta = -0,218$) et la disponibilité ($\beta = -0,350$) ont eu une influence directe sur le choix du marché pour l'achat de produits agricoles biologiques dans la zone d'étude. L'étude conclut que la disponibilité des produits biologiques et les préférences des personnes interrogées déterminent leur choix d'acheter des produits agricoles biologiques dans la zone d'étude. Il est donc recommandé de multiplier les points de vente et les marchés de produits biologiques dans différents endroits afin de rapprocher les produits biologiques des consommateurs et d'améliorer l'accès et la préférence de ces derniers pour l'achat de produits agricoles biologiques dans la zone d'étude.

Mots clés :

Consommateur,
produits agricoles biologiques,
points de vente de produits biologiques,
préférence

Introduction

Organic agricultural produce offers immense benefits to consumers as it contains a higher content of nutrients and antioxidants (Rahman, *et al.*, 2019). The benefits of organic agricultural produce over conventional produce have been demonstrated by in-vitro experiments, whereby statistical analysis has shown that both types of produce can have equivalent benefits. With increasing awareness in consumers about safe and healthy foods, the demand for organic agricultural produce is growing as well, which has led to an increase in sales of organic agricultural produce in markets. The major reason for the popularity of organic agricultural produce is the notion that they are the healthier alternative to regular foods (Baydas, 2021). As per common understanding, such food products have higher nutritional value and are free of pesticides and heavy metals (Gomiero, 2018). In other cases, people may be interested in organic agricultural produce because of the promise of environmental sustainability that organic agriculture offers (Al Mutiri and Al Sowayan, 2021).

A number of studies have reported a difference in the nutrient content of organic and conventional food produce. A richer nutrient content is generally present in organic food as compared to conventional food (Al Mutiri and Al Sowayan, 2021). For instance, in their natural states, the level of antioxidants is higher in organic food produce than in conventionally grown agricultural produce. Research has also shown organic crops to have the highest concentration of vitamin C, iron, magnesium, and phosphorus (Premamali, Kannagara and Yapa, 2019).

The risk of obesity is reported to decrease by 31% in individuals who consume organic foods as compared to individuals who consume conventional foods (Vigar, *et al.*, 2019). A strong correlation was observed to exist between reduced risk of obesity and introduction of organic foods in diet. Increased consumption of organic foods has been associated with a decreased risk of developing non-Hodgkin's lymphoma (Lemaitre, *et al.*, 2021). Similarly, it has also been established that there is a reduced risk of breast cancer and soft tissue sarcoma in people with preferential consumption for organic food (Al Mutiri and Al Sowayan, 2021).

The term market covers many types of trading, as market squares, market halls and food halls, and their different varieties. Thus, markets can be both outdoors and indoors, and in the modern world, online markets (Quach, *et al.*, 2020). Markets have the major sales points for locally manufactured produce and food crops, which provide a vital link between rural producing areas and urban areas as well as sustaining farmers and supporting local economies. However,

there still lie potentially important interconnections that can inform and enlighten theories on retailing and consumption in new exciting ways.

It is generally perceived that Nigerian markets especially the open markets still rely solely on the supplies from the produce of rural farmers; and in many cases, farmers are forced to sell their produce at a very low rates since they may lose out due to lack of storage facilities or access to further processing and packaging facilities that could add value to their produce or improve the shelf life. Yet, these middle - men or market traders increase the cost of the produce making more profit than the farmer.

It is rather unfortunate that farmers produce bulk of our food yet remain poor or financially handicapped. It is a challenge that needs to be tackled to ensure that they are reasonably financially independent and less reliant on Government or private institutions for almost all their activities. There are possibly several factors that have contributed to this situation; amongst which is a poor comprehension of the importance and dynamics of marketing in production. Value chain thinking is revolutionizing Agriculture and the food industry as focus has shifted from Agricultural production to consumer demand, marketing and coordination of product flows from producer to consumer. The role of consumers has oftentimes been undermined irrespective of the consumer's importance in the food supply chain. Consumer opinion also matters when it comes to value addition to organic agricultural produce because this will help the farmers know what to produce and how to market it to the right consumers. It is believed that consumer interest has a major role in the expansion of modern food retail outlets such as supermarkets.

Objective of the Study

The objective of the study is to investigate the factors that determine the consumers' preference for purchasing organic agricultural produce. Specific objectives of the study are to:

1. describe the socio-economic characteristics of the respondents.
2. identify the types of organic agricultural produce that are available in the study area.
3. examine the factors responsible for the respondents preference for organic produce/products in the study area.

Research Hypotheses

H₀1: There is no significant contribution of selected factors influencing the consumers' preference for purchasing organic agricultural produce in the study area.

Methodology

The study was carried out in the Ibadan metropolitan area, Ibadan, Nigeria. Ibadan which is the capital of Oyo state came into existence in 1829. It is located in the South-western Nigeria and in the south eastern part of Oyo state about 120km east of the border with the republic of Benin in the forest zone close to the boundary between the forest and the savannah and covers a total of 3,080 square kilometer of land mass with a population of over 3 million. It is the largest metropolitan geographical area and the third most populous city in the country after Lagos and Kano. Ibadan metropolis is made up of five (5) local government areas with a population figure of approximately 2,550,593 according to 2006 population census, 37 percent of the population is engaged in agriculture. Trading is, however, the primary activity of the city (almost 40 percent) mostly among women. The population for the study consists of all consumers of organic agricultural produce in the study area.

A multi stage sampling procedure was employed in selecting respondents for this study. The first stage involved a purposive selection of one local government area in Ibadan metropolis based on high concentration of organic markets which is Ibadan north. For the second stage, simple random sampling technique was used to select 10% of 40 organic markets in Ibadan north which are Teaching and Research Farm (Abadina), Ibadan Go Organic sales outlet (Barth Road University of Ibadan), Ibadan Go organic sales outlet (Jaja clinic University of Ibadan) and Ibadan Go organic sales outlet (Secretariat Ibadan). Simple random sampling technique was used to select 20% of 151, 120, 90 and 98 registered consumers of organic produce at Teaching and Research farm (Abadina), Ibadan Go organic sales outlet (Secretariat), Ibadan Go Organic sales outlet (Jaja clinic) and Ibadan Go Organic sales outlet (Barth road) respectively, which is 30, 24, 18 and 19 respondents respectively. The total respondents for this study are 91. Data were collected using well - structured questionnaires. A one-on -one interview was conducted for the respondents who cannot fill the questionnaires.

The dependent variable is consumers' market preference in purchasing organic agricultural produce. The respondents were asked to indicate their preference for the purchase of organic agricultural produce in the study area. It was measured on a two-point scale of Yes = 1 and No=0 or specify others. Data collected were subjected to both descriptive and inferential statistics using the statistical package for social science (SPSS). Descriptive statistics involve the use of frequency counts and percentage distribution to describe the data collected, while inferential statistics such as Pearson Product Moment Correlation (PPMC) was used to test relationships.

Results and Discussion

Socio-economic Characteristics of the Respondents

Age

Result of age in Table 1 shows that the majority (73.7%) of the respondents were aged 20-45 years, 17.6% aged 46-58 years while few (8.8%) of them were aged 59-75 years. The mean age of 32 ± 13 years implies that most of the respondents were growing adults who were still in their active, energetic and productive years in the study area. This is in line with the findings of Mottalib, Ragut, Kruseman and Erenstein, (2018) that also reported adults patronizing organic markets.

Sex

Result of sex in Figure 1 shows that more than half (54.9%) of the respondents were female while 45.1% of them were male. This implies that females are more involved in purchasing organic products in the study area. This corroborates the findings of Rahman and Neena (2018) that reported females to be more involved in purchasing organic products.

Marital Status

Result of marital status in Figure 2 shows that the majority (54.9%) of the respondents were married, 4.9% of them were single while 1.1% of the respondents were widowed and divorced, respectively. This implies that married people were more involved in the purchase of organic products in the study area. This may be because food must be provided for the households having more than two persons to cater for. This is in line with the findings of Sharon and Jonathan (2017) that reported marriage to influence the consumption of organic products.

Educational Level

Result of educational level in Table 1 shows that the majority (91.2%) of the respondents had tertiary education, 6.6% of them had secondary education while 1.1% had primary education and no formal education respectively. This implies that most of the respondents were educated and this could influence the rate at which they purchase organic products in the study area. This is supported by Thogersen, Zhou and Huang (2016) that reported education to increase the tendency of consuming organic products.

Family Size

Result of family size in Table 1 shows that the majority (53.8%) of the respondents had 5-6 members in their households, 30.8% had 3-4 members in their household, 7.7% had 1-2 members, and 5.5% had 7-8 members while 2.2% of them had 9-10 members in their households. The mean family size of 5 ± 2 members implies that most of the households had a fairly large household size in the study area. This means that larger households are likely to consume organic products if available to them. This is supported by the findings of Yilmaz and Ilter (2017) that also reported the number of people living in an household tending to influence organic product consumption.

Average Monthly Income

Result of average monthly income in Table 1 shows that the majority (82.5%) of the respondents earned ₦10,000-₦100,000 on a monthly basis while 17.5% of them earned above ₦100,000 on monthly basis in the study area. The mean average monthly income of $₦90,000 \pm 50,000$ implies that most of the respondents were high income earners in the study

area. This is supported with the findings of Horská, (2016) that also reported higher income earners among the respondents in a similar study carried out on organic consumers.

Table 1: Socio-economic characteristics of the respondents

Variables	Frequency	Percentage	Mean	SD
Age				
20-32	40	44.0	32	13
33-45	27	29.7		
46-58	16	17.6		
59-75	8	8.8		
Educational level				
No formal education	1	1.1		
Primary education	1	1.1		
Secondary education	6	6.6		
Tertiary education	83	91.2		
Family size				
1-2	7	7.7		
3-4	28	30.8		
5-6	49	53.8	5	2
7-8	5	5.5		
9-10	2	2.2		
Average monthly income (₦)				
10,000-50,000	38	41.8	90,000	50,000
50,001-100,000	37	40.7		
100,001-150,000	4	4.4		
150,001-200,000	4	4.4		
Above 200,000	8	8.7		

Source: Field survey, 2023

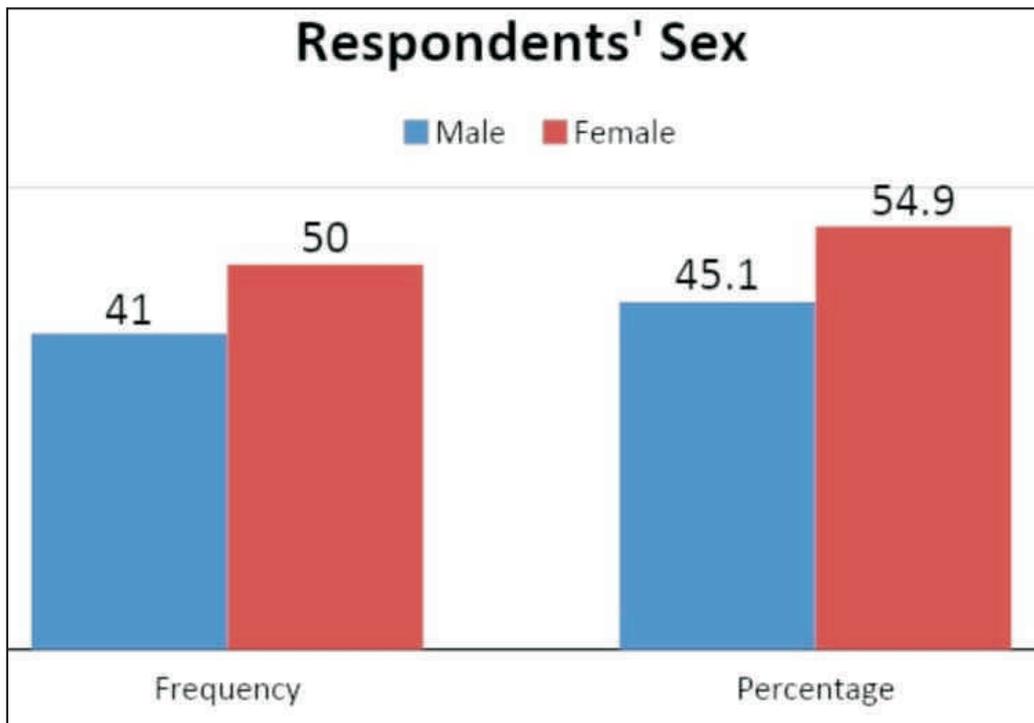


Figure 1: Respondents' sex

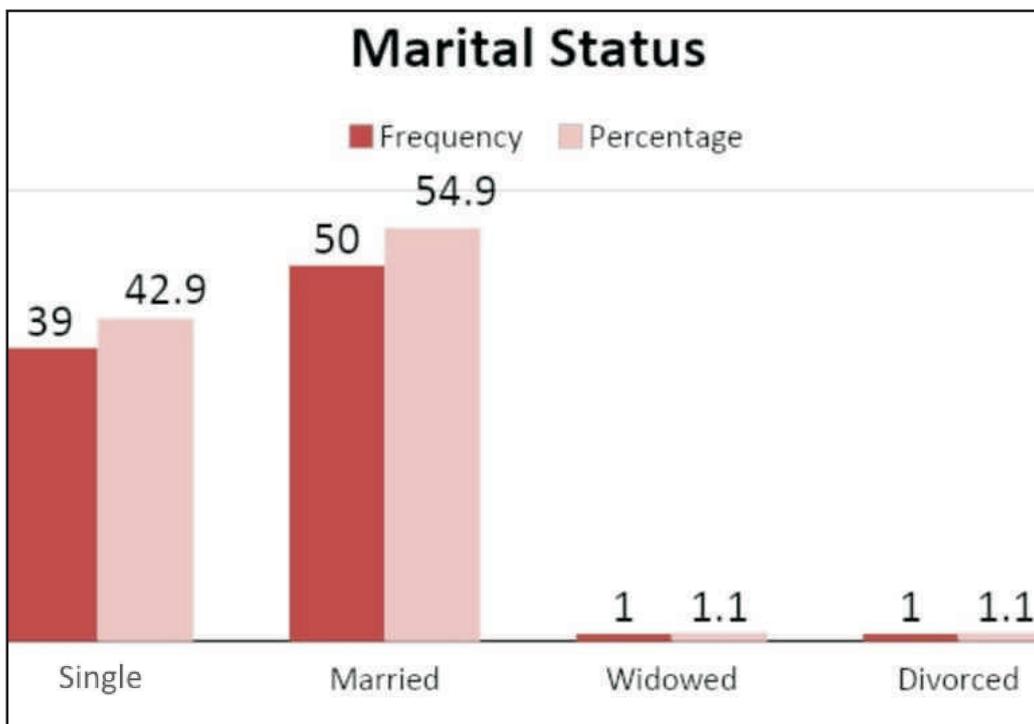


Figure 2: Respondents' marital status

Types of Organic Produce Available in the Study Area

Result of types of organic produce that are available in Table 2 shows that the crop that is mostly available was maize with highest percentage of 90.1%. This is followed by sweet corn (63.7%), groundnut (50.5%) and soybean (46.2%) while the least available organic crops were wheat (29.7%), guinea corn (18.7%) and Barbara nut (4.4%). In addition, on fruit/vegetables, amaranth was the most available organic produce with highest percentage of 100.0%. This is followed by celosia (soko) (97.8%), chocorus (ewedu) (94.5%) and cucumber (90.1%). However, the least available fruit/vegetables were broccoli (24.2%) and wild lettuce (yanrin) (23.1%) respectively. On root/tubers, yam was the most available organic root/tuber crop with highest percentage of 78.0%. This is followed by sweet potato (73.6%) and cocoyam (61.5%). However, the least available root/tuber organic produce was Irish potato (38.5%). On spices, ginger was the most available organic produce with highest percentage of 96.7%. This is followed by turmeric (86.8%) and scent leaves (81.3%). However, the least available spices organic produced were basil (30.8%), clove (24.2%) and cinnamon (17.6%).

Table 2: Types of Organic produce that is available in the study area

Types of organic fertilizer	Available	Not available
Crop Maize	82 (90.1)	9 (9.9)
Millet	27 (29.7)	64 (70.3)
Sorghum	15 (16.5)	76 (83.5)
Wheat	27 (29.7)	64 (70.3)
Sweet corn	58 (63.7)	33 (36.3)
Soybean	42 (46.2)	49 (53.8)
Guinea corn	17 (18.7)	74 (81.3)
Groundnut	46 (50.5)	45 (49.5)
Bambara nut	4 (4.4)	87 (95.6)
FRUIT/VEGETABLES. Amaranths	91 (100.0)	-
Carrot	58 (63.7)	33 (36.3)
Cucumber	82 (90.1)	9 (9.9)
Broccoli	22 (24.2)	69 (75.8)
Lettuce	51 (56.0)	40 (44.0)
Spinach	38 (41.8)	53 (58.2)
Okra	76 (83.5)	15 (16.5)
Celosia (soko)	89 (97.8)	2 (2.2)
Chocorus (ewedu)	86 (94.5)	5 (5.5)
Telfaria (ugwu)	80 (87.9)	11 (12.1)
Garden eggplant (gbagba)	72 (79.1)	19 (20.9)
Cabbage	53 (58.2)	38 (41.8)
Water leaf	76 (83.5)	15 (16.5)
Bitter leaf	70 (76.9)	21 (23.1)
Wild lettuce (yanrin)	21 (23.1)	70 (76.9)
ROOT/TUBERS. Yam	71 (78.0)	20 (22.0)
Cocoyam	56 (61.5)	35 (38.5)
Irish potato	35 (38.5)	56 (61.5)
Sweet potato	67 (73.6)	24 (26.4)
Cassava	36 (39.6)	55 (60.4)
Radish	45 (49.5)	46 (50.5)
SPICES... Ginger	88 (96.7)	3 (3.3)
Tumeric	79 (86.8)	12 (13.2)
Cinnamon	16 (17.6)	75 (82.4)
Clove	22 (24.2)	69 (75.8)
Rosemary	18 (19.8)	73 (80.2)
Basil	28 (30.8)	63 (69.2)
Scent leaves	74 (81.3)	17 (18.7)
Onion	52 (57.1)	39 (42.9)
Garlic	43 (47.3)	48 (52.7)

Source: Field survey, 2023

Factors Responsible for Respondents' Preference for Organic Produce/Product

Result of factors responsible for respondents' preference for organic produce/product in Table 3 shows that the most of the respondents had higher preference for organic produce based on the quality of the organic produce with the highest percentage of 93.4%. This is followed by farmer/seller's attitude (87.9%), the location of the organic market (78.0%) and time of sales of organic produce/products (75.8%). This corroborates the findings of Rahman and Noor (2016) that also isolated access to market to purchase organic products and quality of the products as the most influencing factors responsible for purchase of organic produce in a similar study. However, the least factors responsible for respondents' market preference were promptness of transactions (63.7%), health issues (57.1%) and spacious and conducive environment (53.8%) in the study area.

Table 3: Factors responsible for respondents' market preference

Factors	Yes	No
The quality of the organic produce	85 (93.4)	6 (6.6)
The farmer/seller's attitude	80 (87.9)	11 (12.1)
The promptness of transactions	58 (63.7)	33 (36.3)
The location of the organic market	71 (78.0)	20 (22.0)
Other family members'/friends' patronage and positive comments about the organic produce/products	67 (73.6)	24 (26.4)
Time of sales of organic produce/products	69 (75.8)	22 (24.2)
Health issues	52 (57.1)	39 (42.9)
Spacious and conducive environment	49 (53.8)	42 (46.2)

Source: Field survey, 2023

Results of Hypotheses Testing

Hypothesis One

There is no significant contribution of some selected factors that determine the consumers' choice for purchasing organic agricultural produce in the study area.

Contribution of some Selected Factors Influencing the Consumers' Choice for Purchasing Organic Agricultural Produce

Regression analysis was conducted on the contributions of selected factors that determine the consumers' choice for purchasing organic agricultural produce in the study area. Table 4 shows a R^2 value of 0.318 revealing that the variables in the regression model put together could explain 31.8% of the variance that contributed to their choice for purchasing organic agricultural produce in the study area. The table further shows that two (2) of the variables significantly predicted the market choice for purchasing organic agricultural produce in the study area. These are: sex ($\beta=-0.218$) and availability ($\beta=-0.350$) respectively. All had a direct influence on the consumers' choice for purchasing organic agricultural produce in the study area.

Table 4: Contribution of some selected factors that determine the market choice for purchasing organic Agricultural produce

Variables	Beta	T	Sig
Constant		0.864	0.390
Age	-0.189	-1.295	0.199
Sex	-0.218	-2.060	0.043*
Marital status	0.025	0.167	0.868
Educational level	0.123	1.241	0.218
Religion	0.152	1.440	0.154
Family size	-0.039	-0.366	0.716
Occupation	-0.209	-1.573	0.120
Average monthly income	-0.103	-0.800	0.426
Constraints	-0.049	-0.458	0.648
Factors	-0.028	-0.267	0.790
Availability	0.350	2.859	0.005*

R=0.564, R²=0.318, Adjusted R square=0.222, Std Error=3.223

Source: Field survey, 2023

Conclusion

The study concluded that most of the respondents were adults, female, married, educated, and had large family size; high monthly income and had low preference for purchasing organic agricultural produce in the study area. There was also low availability of organic produce/products in the study area.

Recommendations

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

1. Production of exotic organic produce that attracts higher prices should be introduced to the organic farmers in the study area.
2. Organic produce should be sold at a cheaper rate so as to increase the consumer's preference to purchase them in the study area.
3. Digital organic marketing should be introduced to the organic consumers for easy flow of transactions relating to buying and selling of organic products.
4. Organic markets should be increased and made available closer to the households for ease of accessibility.

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Published by:





Effect of Moringa Leaf Soil Amendment on Maize (*Zea mays* L.) Growth and Soil Nutrient Contents

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Keywords:

Moringa oleifera,
Maize,
Amendment,
Organic fertilizer

Abstract

An experiment was conducted at the Landmark University Omu-Aran, Kwara State, Nigeria to determine the potential *Moringaoleifera* leaves (dry - powdered, fresh whole leaves) as organicfertilizer. There were seven treatment combinations, consisting of 0, 2, 4, and 6 tonnes per hectare which translated to 0, 10 20, and 30 grams per 10 kg of soil for both dry leaf powder and fresh whole leaves. The plastic pots were arranged in Randomized Complete Block Design (RCBD) with three (3) replicates. The treatments were incorporated into the soil, after which three (3) maize seeds were planted into each pot three (3) days after treatments incorporation. After seedling emergence, the most vigorous seedling was left in each pot. The experiment lasted for 12 weeks. Data collected included number of leaves and plant height at 3-week intervals and were subjected to Analysis of Variance (ANOVA). Significant means were separated using Duncan's Multiple Range Test (DMRT). The results obtained showed that there was significant difference in maize growth when 2 t/ha of Moringa Dry Leaf Powder was used, compared with all other levels and amendment types. The number of leaves did not differ significantly at all levels of Moringa leaf and amendment types. The 2 t/ha Moringa Dry Leaf powder treatment gave an equivalent result as the 6 t/ha of Moringa Whole Fresh Leaf treatment. It was concluded that *M.oleifera* applied at 2 t/ha of the dry leaf powder has potential to be used as organic fertilizer.

Effet de L'amendement du sol Par la Feuille de Moringa sur la Croissance du Maïs (*Zea mays* L.) et les Teneurs en Nutrients du Sol

Résumé

Une expérience a été menée à l'université Landmark d'Omu-Aran, dans l'État de Kwara, au Nigeria, afin de déterminer le potentiel des feuilles de Moringa oleifera (feuilles sèches - en poudre, feuilles fraîches entières) en tant qu'engrais organique. Il y a eu sept combinaisons de traitement, consistant en 0, 2, 4 et 6 tonnes par hectare, ce qui correspond à 0, 10, 20 et 30 grammes par 10 kg de sol pour la poudre de feuilles sèches et les feuilles entières fraîches. Les pots en plastique ont été disposés selon un plan en blocs complets aléatoires (RCBD) avec trois (3) répétitions. Les traitements ont été incorporés dans le sol, après quoi trois (3) graines de maïs ont été plantées dans chaque pot trois (3) jours après l'incorporation des traitements. Après l'émergence des semis, le semis le plus vigoureux a été laissé dans chaque pot. L'expérience a duré 12 semaines. Les données collectées comprenaient le nombre de feuilles et la hauteur des plantes à des intervalles de 3 semaines et ont été soumises à

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Mots clés :

Moringa oleifera,
maïs,
amendement,
engrais organique

l'analyse de la variance (ANOVA). Les moyennes significatives ont été séparées à l'aide du test de gamme multiple de Duncan (DMRT). Les résultats obtenus ont montré qu'il y avait une différence significative dans la croissance du maïs lorsque 2 t/ha de poudre de feuilles sèches de Moringa étaient utilisées, par rapport à tous les autres niveaux et types d'amendement. Le nombre de feuilles ne diffère pas significativement à tous les niveaux de feuilles de Moringa et à tous les types d'amendement. Le traitement de 2 t/ha de poudre de feuilles sèches de Moringa a donné un résultat équivalent au traitement de 6 t/ha de feuilles fraîches entières de Moringa. Il a été conclu que *M.oleifera* appliqué à 2 t/ha de poudre de feuilles sèches a le potentiel d'être utilisé comme engrais organique.

Introduction

Maize is a cereal crop that is widely grown throughout the world in a range of agroecological environments (IITA, 2015). It is also regarded as corn, which is an important grain crop of the world. It has its origin from Central and South America (Oladejo and Adetunji, 2012). It is a cereal crop that is important for both man and animal. Low capitalization, low soil fertility, price fluctuation, disease and pest, poor storage facilities and inefficiency of resources utilization are the identified problems in maize production in Nigeria (Ojo, 2000).

The use of inorganic fertilizers is becoming unpopular because of its negative impact on soil, plant, and animal (Alori et al 2019). Organic agriculture is the trend now. In addition, the politicization of the distribution of inorganic chemical fertilizers in Nigeria and increase in fertilizer prices coupled with its unreliable availability to farmers necessitate the need for an alternative type of fertilizer that is not hazardous to life and the environment. Consequently, inorganic fertilizers are available, but expensive and can result in soil degradation, erosion, toxicity and nutrient imbalance, etc. organo-mineral fertilizers are now being sold, and there is the need to look for materials for such a large enterprise (Aduloju et. al., 2013).

Organic fertilizers have been known to provide a ready source of carbon and nitrogen for microorganisms in the soil, improve soil structure, reduce erosion, and lower the temperature at the soil surface and aid in seed germination and increase the soil's water holding capacity (Adeyolanu, 2010). Organic fertilizers do not release chemicals or salts that could cause the buildup of toxic substances in the soil that can have very adverse effects on both the soil and plants grown on them and since they release nutrient slowly into the soil, it unlikely for a farmer to over fertilize. Organic fertilizer contains and releases organic matter into the soil which serves as an important source of energy for organisms such as bacteria, fungi earthworms that take residence in the soil (David and Whitting, 2014). Additionally, Robert, 2009 mentioned in his work that organic soil amendments have several importance such as the increase of nutrient – holding capacity of the soil, additional nutrients and mineral value for plant growth and aeration and soil pH stabilization.

Moringa is a fast growing, drought-resistant, deciduous tree that is native to Agra and Oudh in the Northwest region of India and is naturalized in other tropical and subtropical regions (Mulghal *et al.* 1999). It is a very important tree crop that is often used for medicinal, agricultural, and industrial purposes (Foidl and Paul, 2008; Fuglie, 2005).

Mona (2013) opined that *Moringa oleifera* is a plant that is valued highly and it is distributed in many countries of tropics and subtropics. Ebido (2014) reported that *moringa oleifera* is a popular plant in the seed bank of the underutilized crops of the tropics. It was reported by Agbogidi and Ilondu (2012) that every part of moringa tree (leaves, bark, stem, root, pod, flower, seeds and gum, oil (from some seeds) is beneficial in some way; therefore, it is regarded as the tree with the greatest benefits on earth. The tree also provides many products from oil to soil amendments (fertilizers) and tisanes are made from the leaves (Wikipedia, 2015). Utietiang *et al.*, (2013) concluded in an article that *Moringa oleifera* leaves can serve as an alternative soil organic matter and Ca source or a replacement for inorganic fertilizers, with facilitating effect on soil pH and plant nutrients release for the optimal garden egg production.

Hence, the objective of this study is to determine the effects of applying different levels of Moringa as whole fresh leaves and dry leaf powder on soil physical and chemical properties and maize plant growth.

Materials and Methods

Experimental Site

This study was carried out at the Landmark University Teaching and Research Farms, Omu – Aran, Kwara State Nigeria. Located on 80° 9'N latitude and 50° 61'E Longitude a Guinea, or moist savanna with tall grasses and tree. The area has a bimodal rainfall pattern with rainy seasons from April to July and from September to early November.

Collection of Soil Sample used for Pot Experiment

Soil samples were randomly collected from a 0-15 cm depth at the Landmark Teaching and Research Farm Omu-Aran, Kwara State, Nigeria. Soil samples were bulked to form a representative sample which was transported to the laboratory for analysis. Samples were air dried for 3 days and passed through a 2 mm sieve in preparation for analysis.

Experimental Design

Plastic pots 30-cm diameter, filled with 10 kg of soil were arranged in a randomized complete block design (RCBD) with three (3) replicates. Treatments comprising four levels of whole fresh leaves and dry leaf powder of Moringa were incorporated into the soil in the plastic bags at the rate of 0, 2, 4, and 6, tonnes per hectare which translate to 0, 10, 20, 30 grams per 10 kg of soil. Three maize seeds were planted per plastic bag after 3 days of applying Moringa leaves to ensure mineralization at the depth of 3cm and was later thinned to one vigorous seedling. The treated soil was constantly kept moist but not waterlogged throughout the experimental period that lasted for 12 weeks.

Data Collection

Maize growth parameters such as the number of leaves per plant were determined by counting, while the plant height (cm) was taken by using a meter rule. Soil samples were taken from each treatment at three weeks intervals from 3-12 weeks after planting (WAP). These were air-dried, sieved and analyzed in the Soil Science laboratory of the Landmark University, Omu – Aran, Nigeria for physical and chemical properties.

Analysis of Soil Chemical Characteristics

Soil physical and chemical properties determined include; soil pH with an electronic soil pH meter (Model 215, Colorado, U.S.A.); soil particle size analysis with the hydrometer method (Gee and Or 2002); organic matter content was determined using the wet oxidation method (Shamshuddin et al., 1994); exchangeable bases (K, Mg, Na, and Ca), were determined by ammonium acetate method (Chapman 1965); To determine exchangeable acidity, 5g of air dried soil (sieved through 2mm sieve) were weighed into a 250ml conical flask. A 50ml of 1N potassium chloride (KCl) solution was added to the soil sample in the conical flask. The flask was shaken on a reciprocating shaker for 1 hour and the content was filtered through Whatman No. 42 filter paper. Twenty-five mls of the filtrate was pipetted into a 100ml conical flask and 50 ml distilled water was added along with 5 drops of phenolphthalein indicator. The resulting solution was titrated with 0.01N sodium hydroxide (NaOH) to a permanent pink end point. The volume of the base used was recorded and used in the calculation of total exchangeable acidity (H+Al); The Effective Cation Exchange Capacity (ECEC) was determined by the summation of the exchangeable bases (Ca, Mg, Na and K) and exchangeable acidity expressed in cmolkg^{-1} ; total soil nitrogen was determined by Macrokjedahl method (Bremner 1982), and the Bray 1 method was used to determine available phosphorus (Murphy and Riley 1962).

Data Analysis

All data from the experiment were subjected to analysis of variance (ANOVA) using IBM SPSS statistical package 21. Means were separated using Duncan's Multiple Range Test ($P \leq 0.05$).

Results and Discussion

Results of initial soil properties of the soil before applications of treatments are presented in Table 1. The soil used in the location used was Loamy sand. The organic matter content was found to be 5.52 mg/kg, which is considered low for crop production (Landon, 1991). The soil pH was 4.56, indicating a strongly acidic soil. The total Nitrogen (N) content

of 0.16 g/kg was lower than the critical level of 1.5 g/kg recommended for tropical soils by Enzenwor *et al* (1979). The available P was found to be 6.52 mg/kg soil. This is also below the critical value of 10-16 mg/kg recommended by Adeoye and Agboola (1985). The Potassium (K) status of the soil (0.12 cmol/kg) was also found to be less than the critical level of 0.2 cmol/kg soil reported by Adeoye (1986). The low soil fertility observed in the experimental soil in respect of total nitrogen, phosphorus, and potassium contents are characteristic of the savannah soils of Nigeria in general. The soil is generally poor in the primary essential nutrients (Table 1) and the need for additional nutrients is well established and a positive response to such amendment was expected.

Table1: The physical and chemical characteristics of the experimental soil before treatment application

Soil Property	Values
Sand (%)	84.74
Silt (%)	7.00
Clay (%)	8.26
Textural class	Loamy sand
pH (1:1 soil/H ₂ O)	4.82
O.M (g/kg)	5.52
Total N (g/kg)	0.16
Available P (mg kg ⁻¹)	6.52
Exchangeable K ⁺ cmol/kg soil	0.12
Ca ⁺⁺ cmol/kg	0.25 (x 10 ²)
Na ⁺ cmol/kg	2.17
CEC cmol/kg	4.64

Effect of Soil Amendment on Soil Organic Matter

Table 2 shows the effect of soil amendment on the soil organic matter (O.M) content at 3, 6, 9 and 12 weeks after planting, respectively. On average, there was a 9% - 23 % increase in the O.M content of the soil across all levels of applied amendments. Application of moringa as dry leaf powder resulted in 6% - 60 % increase in soil organic matter content while application as whole fresh leaves resulted in about 6% - 69% increase. The highest percentage increase (69%) was recorded at 9 WAP applied at the rate of 6t/ha (Fresh) while the least (6%) was recorded at 3 WAP applied at the rate of 4t/ha (dry) and 4 and 6 t/ha (fresh). This corroborates the findings of Ebido *et al.*, (2014) who reported that incorporation of moringa leaf to soil significantly increased the soil organic matter content. Utietiang *et al.*, (2013) also reported high concentration of organic carbon with application of *Moringa oleifera* leaves.

Table 2: Effect of Soil Amendment on Soil Organic Matter

Treatment	Rate t/ha	% ORGANIC MATTER				AVERAGE
		3 WAP	6 WAP	9 WAP	12 WAP	
Control	0	4.72	4.18	1.14	2.84	3.22
*Dry	2	5.2	4.88	2.91	2.87	3.97
Dry	4	5.01	5.14	1.89	3.47	3.88
Dry	6	5.62	5.29	2.68	3.23	4.21
**Fresh	2	4.98	4.63	3.03	2.32	3.74
Fresh	4	5.01	4.17	2.24	2.79	3.55
Fresh	6	5.04	4.78	3.62	2.21	3.91
SE ±		0.104	0.164	0.309	0.170	0.121

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Effect of Amendment on Soil % Nitrogen

Table 3 shows the effect of soil amendment on the soil Nitrogen (N) content at 3, 6, 9 and 12 weeks after planting, respectively. On average, there was a 0 - 41% increase in the N content of the soil across all levels of applied amendment. Application of moringa as dry leaf powder resulted in a 0% - 74 % increase in soil N content while application as whole fresh leaves resulted in about 0% - 51% increase. The highest percentage increase (74%) was recorded at 6 WAP applied at the rate of 6t/ha (dry).

According to (Agbogidi, *et al* 2012) the protein content of moringa WFL is 6.7g while the DLP has about 27.1g of protein content. According to (Adeoye and Agboola, 1985) any soil that has % N ranging from 0.6-1.0 is considered has been low therefore even though there was increase in % N of the amended soil when compared to the pre-treated soil the % N can still be classified has low probably because the soil is very acidic. Utietiang *et al.*, (2013) reported that *Moringa oleifera* leaves showed high concentration of N.

Table 3: Effect of Soil Amendment on Soil Nitrogen

Treatment	Rate t/ha	% Nitrogen				
		3 WAP	6 WAP	9 WAP	12 WAP	AVERAGE
Control	0	0.19	0.18	0.11	0.49	0.2425
*Dry	2	0.34	0.38	0.35	0.56	0.4075
Dry	4	0.19	0.18	0.21	0.15	0.1825
Dry	6	0.32	0.69	0.21	0.11	0.3325
**Fresh	2	0.21	0.33	0.19	0.26	0.2475
Fresh	4	0.32	0.17	0.24	0.59	0.33
Fresh	6	0.39	0.13	0.18	0.53	0.3075
SE ±		0.030	0.074	0.027	0.077	0.028

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Effect of Amendment on Soil available Phosphorus

Table 4 shows the available Phosphorus at 3, 6, 9 and 12 weeks after planting, respectively. On average, there was a 16 - 26% increase in the P content of the soil across all levels of applied amendment. Application of moringa as dry leaf powder resulted in a 0% - 62 % increase in soil P content while application as whole fresh leaves resulted in about 0% - 41% increase. The highest percentage increase (62%) was recorded at 3 WAP applied at the rate of 6t/ha (dry). According to (Adepetu and Corey, 1975), it was reported that phosphorus mineralized from organic sources is by far the most important factor in determining P availability for crop uptake. The determined available P does not reflect the total P present in the soil but only an infinitesimal part of the total P present in the soil which is available to the plant for uptake at any time (Ogunwale, 2003). Ebido *et al.*, (2014) showed that *moringa oleifera* significantly increased soil available P.

Table 4: Effect of Soil Amendment on Available Phosphorus

Treatment	Rate t/ha	Available P				
		3 WAP	6 WAP	9 WAP	12WAP	AVERAGE
Control	0	6.69	9.16	24.48	25.19	16.380
*Dry	2	9.51	8.63	23.96	22.37	16.118
Dry	4	12.51	11.44	26.95	33.99	21.223
Dry	6	17.79	13.92	22.89	34.52	22.280
**Fresh	2	4.57	5.81	21.49	22.72	13.648
Fresh	4	11.27	11.63	22.55	32.76	19.555
Fresh	6	6.34	4.4	24.31	28.54	15.898
SE ±		1.70	1.27	0.66	1.99	1.20

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Effect of Amendment on Soil Calcium

Table 5 shows the exchangeable calcium at 3, 6, 9 and 12 weeks after planting, respectively. On average, there was a 0 - 18% increase in the Ca content of the soil across all levels of applied amendment. Application of moringa as dry leaf powder resulted in a 0% - 50 % increase in soil P content while application as whole fresh leaves resulted in about 0% - 50% increase.

It can also be seen from Table 5 that there was no difference between the amount of Ca in the soil for both the control to which nothing was applied and to the pots to which amendment was applied at various levels of application at 3 WAP and 6 WAP respectively. At 9 WAP there was an increase in soil Ca content to about (50 %) at 2 t/ha, 4 /ha and 6 t/ha of DLP and also at 2 and 6 t/ha rate of application for WFL. Utietiang *et al.*, (2013) reported that Moringa oleifera leaves showed high concentration of Ca.

Table 5: Effect of soil amendment on soil calcium

Treatment	Rate t/ha	Ca cmol/kg				
		3 WAP (* 10 ⁻²)	6 WAP (* 10 ⁻²)	9 WAP (*10 ⁻²)	12 WAP (* 10 ⁻²)	AVERAGE (*10 ⁻²)
Control	0	0.25	0.25	0.25	0.5	0.31
*Dry	2	0.25	0.25	0.25	0.5	0.31
Dry	4	0.25	0.25	0.25	0.5	0.31
Dry	6	0.25	0.25	0.5	0.5	0.38
**Fresh	2	0.25	0.25	0.5	0.5	0.38
Fresh	4	0.25	0.25	0.5	0.25	0.31
Fresh	6	0.25	0.25	0.5	0.5	0.38
SE ±		0.00	0.00	0.051	0.035	0.014

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Effect of Amendment on Exchangeable Potassium

Table 6 reveals the effect of soil amendment on the soil exchangeable potassium (K) content at 3, 6, 9 and 12 weeks after planting, respectively. On average, there was a 0 - 45% increase in the exchangeable K content of the soil across all levels of applied amendment. Application of moringa as dry leaf powder resulted in 20% - 57 % increase in soil K content while application as whole fresh leaves resulted in about 0% - 68% increase. The highest percentage increase (68%) was recorded at 6 WAP applied at the rate of 6t/ha (WFL). This may be because *Moringa oleifera* leaves have high concentration of K as reported by Utietiang *et al.*, (2013).

Table 6: Effect of soil amendment on soil potassium

Treatment	Rate t/ha	K cmol/kg				
		3WAP	6WAP	9WAP	12WAP	AVERAGE
Control	0	0.059	0.056	0.066	0.056	0.059
*Dry	2	0.077	0.077	0.082	0.072	0.077
Dry	4	0.100	0.082	0.089	0.087	0.089
Dry	6	0.138	0.1	0.105	0.087	0.107
**Fresh	2	0.064	0.054	0.061	0.056	0.059
Fresh	4	0.069	0.056	0.066	0.064	0.064
Fresh	6	0.072	0.174	0.079	0.064	0.097
SE ±		0.010	0.016	0.001	0.004	0.007

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Effect of Amendment on Soil Exchangeable Sodium

As shown on Table 7, the application of moringa as dry leaf powder resulted in 0% - 23 % increase in soil Na content and application as whole fresh leaves also resulted in about 0% - 23% increase. The highest percentage increase (23%) was recorded in at 6 and 9 WAP applied at the rate of 2, 4 and 6 t/ha (Dry and WFL).

Table 7: Effect of soil amendment on soil sodium

Treatment	Rate t/ha	Na cmol/kg				AVERAGE
		3WAP	6WAP	9WAP	12WAP	
Control	0	0.026	0.026	0.017	0.017	0.022
Dry	2	0.017	0.022	0.021	0.017	0.019
Dry	4	0.017	0.017	0.021	0.022	0.019
Dry	6	0.022	0.017	0.013	0.022	0.018
Fresh	2	0.013	0.022	0.022	0.022	0.018
Fresh	4	0.013	0.022	0.022	0.017	0.019
Fresh	6	0.013	0.017	0.022	0.017	0.017
SE ±		0.002	0.001	0.001	0.011	0.000

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Effect of Amendment on Cation Exchange Capacity

Table 8 shows the result obtained for soil CEC at 3, 6, 9 and 12 weeks after planting, respectively. On average, there was 0.8 - 21% increase in the CEC content of the soil across all levels of applied amendment. Application of moringa as dry leaf powder resulted in 12% - 47 % increase in soil K content while application as whole fresh leaves resulted in about 3% - 37% increase. The highest percentage increase (47%) was recorded at 9 WAP applied at the rate of 6t/ha (Dry). Ebido *et al.*, (2014) showed that *moringa oleifera* significantly increased cation exchange capacity (CEC).

Table 8: Effect of soil amendment on Cation Exchangeable Capacity

Treatment	Rate t/ha	CEC cmol/kg				AVERAGE
		3 WAP	6 WAP	9 WAP	12 WAP	
Control	0	4.04	9.36	3.85	4.82	5.518
*Dry	2	6.45	7.78	4.96	3.27	5.615
Dry	4	3.65	7.85	4.38	5.45	5.333
Dry	6	6.76	8.47	7.25	5.56	7.01
**Fresh	2	5.13	6.68	4.8	4.19	5.2
Fresh	4	4.43	7.23	5.28	5.31	5.563
Fresh	6	6.76	3.42	6.12	5.16	5.365
SE ±		0.504	0.716	0.429	0.312	0.231

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Effect of Soil Amendment on Exchangeable Acidity

Table 9 shows the result obtained for soil total acidity at 3, 6, 9 and 12 weeks after planting, respectively at 3, 6, 9 and 12 weeks after planting, respectively. Application of moringa as dry leaf powder resulted in a 0% - 38 % increase in soil total acidity content while application as whole fresh leaves resulted in about 0% - 25% increase. The highest percentage increase (38%) was recorded at 6 WAP applied at the rate of 6t/ha (Dry).

Table 9: Effect of soil amendment on total Acidity

Treatment	Rate t/ha	E.A cmol/kg			
		3 WAP	6 WAP	9 WAP	12 WAP
Control	0	0.26	0.042	0.09	0.13
*Dry	2	0.19	0.058	0.1	0.14
Dry	4	0.24	0.061	0.12	0.11
Dry	6	0.24	0.068	0.08	0.12
**Fresh	2	0.23	0.038	0.07	0.13
Fresh	4	0.14	0.048	0.12	0.13
Fresh	6	0.21	0.043	0.07	0.11
SE ±		0.015	0.004	0.008	0.004

Effect of Amendment on Maize Number of Leaves and Plant Height

Table 10 below shows the result obtained for maize height and number of leaves at 3 WAP and 6 WAP. Although there were differences in plant height obtained at 3WAP and 6 WAP respectively the differences were not significant except at 3 WAP when 2 t/ha. The application of *Moringa oleifera* leaves significantly increased number of fruits per plant (Utietiang *et al.*, 2013). This also agrees with the findings of some other researchers. Moringa leaf extract significantly improves maize plant height (Mvumi *et al* 2013, Biswas *et al.* 2016). The higher values of plant height and leaf number obtained could be as a result of adequate amount of nutrients released into the soil for optimum growth of the plant. Maishanu *et al.*, 2017 showed that moringa extract increased the number of leaves of plant because it is rich with growth hormones. Moringa leaves increased the growth parameters of maize significantly (Yusuf *et al.*, 2018). Moringa oleifera addition as soil amendment facilitated plant nutrients release for optimum production of crops (Ayuba *et al.*, 2014).

Table 10: Effect of soil amendment on maize number of leaves and plant height

Treatment	Rate t/ha	Number of leaves		Plant Height	
		3 WAP	6 WAP	3 WAP	6 WAP
Control	0	4.00a	5.33a	5.33 ab	8.60a
*Dry	2	4.00a	4.67a	4.86 b	10.26a
Dry	4	4.67a	5.33a	5.90 ab	11.50a
Dry	6	4.00a	5.33a	5.80 ab	11.50a
**Fresh	2	4.00a	5.00a	5.70 ab	9.90a
Fresh	4	4.33a	5.66a	5.23 ab	10.57a
Fresh	6	4.66a	4.66a	6.56 a	10.00a

(P = 0.05)

*Moringa Dry Leaf Powder

**Moringa Whole Fresh Leaves

Conclusion

In conclusion both Moringa Dried Leaf Powder (DLP) and Whole Fresh Leaves (WFL) have potential to be used as soil amendments for nutrient supplements (organic fertilizer). The Moringa Dry Leaf Powder releases more nutrient than Whole Fresh Leaf.

To improve soil organic matter and exchangeable potassium(K) moringa is better applied as Whole Fresh Leaf (WFL) at 6t/ha of soil while application of Dry Leaf Powder (DLP) at 6t/ha will be best for the improvement of N, P, CEC and increased total acidity. However, for the purpose of improving exchangeable Na either Dry Leaf Powder (DLP) or Whole Fresh Leaf (WFL) will do quite well at both 2, 4 and 6t/ha.

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Published by:





Field Evaluation of Biosynthesized Silver Nanoparticles from *Petiveria alliacea* Extracts on Yield and Nutritional Contents of Harvested Cowpea (*Vigna unguiculata* L. Walp) Grains

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Keywords:

Green Nano synthesized,
Cowpea,
Petiveria alliacea ,
Nutritional content,
chlorpyrifos.

Abstract

The use of Green Nanoparticles synthesized in the management practices of field crops has been assessed as an alternative to synthetic insecticides. This field experiment was conducted to examine the effects of silver nanoparticle synthesized from *Petiveria alliacea* root and leaf on the yield and nutritional contents of the harvested cowpea grain. In addition to *P. alliacea* root and leaf, Chlorpyrifos and control were included in the treatments for comparison. The treatments were arranged in a Randomized Complete Block design and each treatment was replicated thrice. Data were collected on root nodules, grain yield, proximate content, and mineral contents of the harvested cowpea grains. The result showed that all the applied treatments did not affect the root nodules. The cowpea plants treated with Nano *P. alliacea* leaf at 20% v/v had the highest significant cowpea grain yield (0.51 t/ha). However, the harvested cowpea grains from plants treated with Nano *P. alliacea* root had the highest protein and fibre contents while Nano *P. alliacea* leaf had highest ash content. The plants treated with Nano *P. alliacea* leaf had the same significant carbohydrate content (28%) with Chlorpyrifos while the highest calcium content (2.98 mg/kg) was observed from the cowpea plants treated with Nano *P. alliacea* leaf and root. However, Nano *P. alliacea* root significantly improved the Potassium and Magnesium contents of the harvested cowpea grains coupled with highest iron content from the cowpea plants sprayed with Nano *P. alliacea* root. Therefore, the biosynthesized Nano *P. alliacea* leaf and root can be used as nutritional enhancement of the harvested cowpea grains.

Évaluation sur le Terrain des Nanoparticules d'argent Biosynthésiques Provenant D'extraits de *Petiveria alliacea* sur le Yied et les Teneurs Nutritionnelles des Grains de Cowpea (*Vigna Unguiculata* L. Walp) Graines

Résumé

L'utilisation de nanoparticules vertes synthétisées dans les pratiques de gestion des cultures de plein champ a été évaluée comme une alternative aux insecticides synthétiques. Cette expérience de terrain a été menée pour examiner les effets des nanoparticules d'argent synthétisées à partir de la racine et de la feuille de *Petiveria alliacea* sur le rendement et les contenus nutritionnels du grain de niébé récolté. En plus de la racine et de la feuille de *P. alliacea*, le chlorpyrifos et le contrôle ont été inclus dans les traitements à des fins de comparaison. Les traitements ont été organisés en blocs complets aléatoires et chaque traitement a été répété trois fois. Les données ont été

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Mots clés :

Nano vert synthétisé, niébé, *Petiveria alliacea*, contenu nutritionnel, chlorpyrifos.

collectées sur les nouilles des racines, le rendement des grains, le contenu proximal et le contenu minéral des grains de niébé récoltés. Les résultats ont montré que tous les traitements appliqués n'ont pas affecté les nouilles racinaires. Les plants de niébé traités avec la feuille de Nano P. *alliacea* à 20% v/v ont eu le rendement en grains de niébé le plus élevé (0,51 t/ha). Cependant, les grains de niébé récoltés des plantes traitées avec la racine de Nano P. *alliacea* avaient les teneurs en protéines et en fibres les plus élevées tandis que la feuille de Nano P. *alliacea* avait la teneur en cendres la plus élevée. Les plantes traitées avec la feuille de Nano P. *alliacea* avaient la même teneur significative en hydrates de carbone (28%) que le Chlorpyrifos tandis que la teneur la plus élevée en calcium (2,98 mg/kg) a été observée dans les plantes de niébé traitées avec la feuille et la racine de Nano P. *alliacea*. Cependant, la racine de Nano P. *alliacea* a amélioré de manière significative les teneurs en potassium et en magnésium des grains de niébé récoltés, associées à la teneur en fer la plus élevée des plants de niébé pulvérisés avec la racine de Nano P. *alliacea*. Par conséquent, la feuille et la racine de Nano P. *alliacea* biosynthétisées peuvent être utilisées comme amélioration nutritionnelle des grains de niébé récoltés.

Introduction

Cowpea (*Vigna unguiculata* L. walp) as one of the legumes belongs to the family Fabaceae (Ibrahim *et al.*, 2017). This crop was reported to have originated from West and Central Africa (Ano *et al.*, 2008). In Nigeria, cowpea is grown mainly for human as well as animal food. According to Jefferso (2005), cowpea has 23% protein, 1.3% fats, 1.8% fibre, 67% Carbohydrate and 8 – 9% water, and Legume seeds have an average of twice as much protein as cereals. (Vijayakumari *et al.*, 1998). Several researchers reported the presence of proximate compositions such as: ash, moisture, carbohydrate, protein, crude fat and fibre; and minerals like sodium, potassium, calcium, phosphorus, magnesium, iron and zinc at varied concentrations in cowpea (Asante *et al.*, 2007, Uduak, 2018.)

One of the major challenges influencing against cowpea production in Africa is the regular susceptibility to insect pest's infestation which affect their growth and later the nutritional values of the harvested grains. Dzemo *et al.*, (2010) reported that insect pest control insecticide sprays led to increased number of cowpea pods per plant, pod weight, number of seeds per pod, seed weight, and grain yield. To protect this crop from insect pest attack, farmers usually rely on quick pest management options, mainly synthetic chemicals (Alao and Adebayo, 2011). However, synthetic compounds are associated with problems such as phytotoxicity, pest resurgence and resistance, widespread environmental hazards and high cost (Koltin *et al.*, 2006; Bloch, 2012; Grzywacz and Leavett, 2012). Sniper (2,3-dichlorovinyl dimethyl phosphate) significantly affected the quality of proximate and mineral compositions of cowpea (Tizhe *et al.*, 2021).

Due to the aforementioned problems caused by synthetic chemicals, there is a tremendous scope for the development of novel bio-oriented natural pesticides from a combination of Nano particles and plant-based chemicals which is highly environmentally safe, biodegradable and effective (He *et al.*, 2019). Nanotechnology is placed with high hopes to achieve sustainable green development. With the development of nanotechnology and the wide application of nanomaterials, the emergence of Nano-agricultural products such as, Nano-pesticides, has improved the problems in traditional agriculture and improved the nutritional quality of crops. For example, mesoporous silica nanoparticles (MSNPs) can improve the nutrient delivery speed and growth speed of *Z. japonica* (Adams *et al.*, 2019). Nano-pesticides enhance the efficacy by controlling release to reduce the threat of pests and diseases and ensure the nutritional quality of agricultural products, while paying attention to the phytotoxicity of nanomaterials. Therefore, this experiment was conducted to evaluate the effects of biosynthesized silver Nanoparticles from *Petiveria alliacea* extracts on the nutritional contents of harvested cowpea grains.

Materials and Methods

Study Site

The study was carried out at LAUTECH Teaching and Research Farm (longitude 40 301E and latitude 10051N). The region climate could be described as hot humid tropical falls in Southern Guinea Savana Nigeria with a mean temperature of 27°C and annual rainfall of 1400 mm. It is marked with dry and wet seasons, characterized by a bi-modal rainfall pattern with peaks in July and September.

Experimental Design and Management

The experimental land was ploughed and harrowed once, and 24 plots were demarcated and arranged in Randomized Complete Block Design. Each treatment was replicated three times. The plot size was 4 m by 4 m and planting was done at 1 m by 1 m with 1 m within the planting roles. The total number of plants stand per plot was 25 stands. Cowpea variety (Ife Brown) was planted, and three seeds were dropped per planting hole. Thinning was done two weeks after planting to one plant per stand. Weeding was done manually at two weeks intervals.

Nano Formulation

P. allieacea roots and leaves were collected fresh then *P. allieacea* root were chopped into pieces with the use of cutlass. *Petiveria allieacea* roots and leaves were air dried at room temperature for three weeks. Grinding of the leaves and roots was done separately using mortal and pestles. Powdered roots and leaves of *P. allieacea* were measured separately with electronic sensitive scale and was taken to Nano-technology laboratory at the Microbiology Department, LAUTECH where Nano formulation of *P. allieacea* was done by following the already established procedures by (Lateef *et al.*, 2018) by measuring out 1 g of the leaf and root powder of dried *P. allieacea* separately which was dissolved in 100 ml of distilled water. Incubate in the water bath at 60°C for an hour. The solution was filtered using a filter paper and then centrifuge the filtrate at 4000 RPM (Revolutions per minute) for 20 mins. The clear supernatant was used for the synthesis. The supernatant reacted with 40 ml of 1 mM Silver nitrate solution. It was placed under sunlight for photo activation, observed for colour change till the colour was stabilized.

Treatment Application

Application of the treatments commenced three weeks after planting. Nano *P. allieacea* extracts was applied at three different concentrates (5, 10, and 20%). Untreated plots were included in the treatments for comparison. Each of the extracts was diluted with 1000 ml of water to achieve the same spraying volume, while Synthetic insecticide (Chlorpyrifos) was applied at the manufacturer's recommended rate. The application was done with hand sprayer of 2 litre capacity.

Chlorpyrifos	1m/ 1litre v/v
Control	Unsprayed plots
Nano <i>Petiveria allieacea</i> leaf	(5, 10 and 20%) v/v.
Nano <i>Petiveria allieacea</i> root	(5, 10 and 20%) v/v.

Data Collection

Data were collected on insect population density, and this was done a day after the application of the treatments for four weeks. This was done early in the morning when the insects were relatively inactive and visual sampling of the population density was used. Data was collected on the Number of Root Noodles, and Yields. Weight of grain was taken with sensitive scale and converted to yield (t/ha).

Sample Preparation

The cowpea seed samples were air-dried at room temperature. The dried material obtained was ground to a fine powder and finally packed into airtight polyethylene plastic bottles and stored in the desiccators until required for analysis. The dried samples were analyzed for proximate composition, and minerals (Ca, Mg, Fe and K). Preparation was carried out in duplicates. The results were expressed as mg/k.

Proximate Analysis

Moisture, ash, crude fat, crude fat, and crude fiber were determined in accordance with the official methods of the Association of Official Analytical Chemists (AOAC, 2005), while nitrogen was determined by the Micro-Kjeldahl Method (Pearson, 1976) and the percentage of nitrogen was converted to crude protein by multiplying by 6.25.

Mineral Analysis

The minerals in the harvested grains were analyzed from a solution obtained when 2.0 g of the samples which was digested with concentrated nitric acid and concentrated perchloric acid in ratios 5:3. The mixtures were placed in a water bath for three hours at 80C. The resultant solution was cooled and filtered into 100 ml standard flask and made to mark with distilled water (Asaolu, 1995). Atomic absorption spectrophotometer (Buck scientific model 200A) was used.

Data Analysis

Data collected were subjected to analysis of variance (ANOVA) and means were separated using Duncan multiple Range Text (DMRT) at 5% probability level.

Results

Table 1 shows the effect of Insecticide on yield, and number of root nodules. Nano *P. alliacea* leaf had the highest significant effect on the yield parameters of the tested plants. With respect to number of root nodules, no significant difference was detected between the treated plants and untreated plants.

Table 1: Effect of Insecticides on Cowpea Grain Yield

Treatments	Rate	Yield Components		
		% Undamaged pod	Root nodules	Yield (t/ha)
Nano <i>P.alliaca</i> e root	5	28.67 ^d	3.33 ^a	0.31 ^e
	10	52.00 ^{bc}	3.33 ^a	0.25 ^d
	20	75.00 ^a	4.00 ^a	0.44 ^b
Nano <i>P.alliacea</i> leaf	5	38.33 ^{cd}	3.33 ^a	0.11 ^e
	10	62.33 ^b	3.00 ^a	0.37 ^e
	20	81.00 ^a	3.33 ^a	0.51 ^a
Chlorpyrifos	—	71.33 ^a	3.33 ^a	0.37 ^e
Control	—	43.33 ^c	4.33 ^a	0.09 ^e

Means with the same superscript(s) are not significantly different

Table 2 shows effect of insecticides on the proximate contents of *V. unguiculata*. Harvested cowpea grains from plants treated with nano *P. alliacea* root had the highest protein content (36.8%) and fibre content (24.2%) while cowpea grains from plants treated with Chlorpyrifos and untreated plants had the same significant fat content compared to cowpea grains from cowpea plants treated with the nano-insecticide formulations with the least fat content. The Nano *P. alliacea* root and Chlorpyrifos had the same significant effect on the moisture content of the harvested grains whereas, Nano *P. alliacea* leaf significantly improved the ash content of the harvested grains compared to other treatments. However, the cowpea grains treated with Nano *P. alliacea* leaf had the same significant carbohydrate content with Chlorpyrifos while the untreated cowpea grains from cowpea plants had the highest carbohydrate content (30.2%).

Table 2: Effect of Insecticides on the Proximate Contents of *V. unguiculata*

Treatment	Proximate content (%)					
	Protein	Fibre	Fat	Moisture	Ash	carbohydrate
Chlorpyrifos	33.16 ^d	22.43 ^c	12.03 ^a	6.03 ^a	4.06 ^c	28.08 ^b
Control	34.39 ^b	20.06 ^d	12.06 ^a	5.13 ^c	2.36 ^d	30.16 ^a
Nano <i>P. alliaceae</i> leaf	33.34 ^c	22.7 ^b	7.33 ^c	5.30 ^b	6.10 ^a	28.2 ^b
Nano <i>P. alliaceae</i> root	36.83 ^a	24.23 ^a	9.13 ^b	6.10 ^a	4.40 ^b	25.86 ^c

Means with the same superscript(s) are not significantly different

Table 3 shows the effect of insecticide on the mineral content of cowpea. Cowpea grains from plants treated with Nano *P. alliaceae* leaf and root had the highest Calcium content (300 mg/ha) meanwhile, harvested cowpea grains from plants treated with Nano *P. alliaceae* root had the highest potassium and magnesium content whereas, cowpea grains from untreated and chlorpyrifos treated cowpea plants resulted into the highest sodium content among the treated plants.

Table 3: Effect of Insecticides on the Mineral Contents of *V. unguiculata*

Treatment	Mineral Contents (mg/kg)			
	Calcium	Potassium	Magnesium	Sodium
Chlorpyrifos	200 ^b	300 ^a	160 ^a	100 ^b
Control	190 ^c	210 ^c	100 ^b	100 ^b
Nano <i>P. alliaceae</i> leaf	300 ^a	216 ^b	80 ^c	70 ^c
Nano <i>P. alliaceae</i> root	300 ^a	130 ^d	50 ^d	180 ^a

Means with the same superscript(s) are not significantly different

Discussion

This experiment proved that the tested nano-insecticides from *P. alliaceae* effectively prevented post-flowering insect pests from causing economic damage to the cowpea pods, this is due to the highest number of undamaged pods from treated cowpea plants. Consequently, a significantly higher yield was obtained from nano-insecticide-treated cowpea plants. This observation concurs with earlier research work by Mervat (2019) who reported that application of Silver nanoparticles resulted in a high yield of fenugreek plant. Also, ZnO nanoparticles were observed to have contributed positively to the growth of cowpea and okra under salt stress conditions. The applied treatments did not exhibit negative effects on root nodules of the target crop; however, this goes contrary to what was observed by Pallavi, (2016) who discovered that application of silver nanoparticles on cowpea significantly increased growth parameters and root nodulation.

The observed calcium content (1.9-2.99 mg/kg) from the harvested cowpea grains was within the range of calcium content reported by (Mamiro *et al.*, 2011). However, nano *P. alliaceae* leaf and root significantly improved the calcium content of the harvested cowpea grains when compared with other treatments. The magnesium content of harvested cowpea grains ranged from 1.0 to 1.8 mg/kg which was below the range reported by (Peter *et al.*, 2020). However, it was discovered that harvested cowpea grains from cowpea plants treated with *P. alliaceae* leaf had no magnesium content. The moisture content of harvested cowpea grains ranged from 5.13 to 6.1% which was below the moisture content reported by Peter *et al.*; (2020) and this is an indication that the applied treatments will prevent cowpea from been damaged due to low moisture content. The protein contents of the harvested cowpea grains ranged from 33.2 to 36.8%

these were higher than the protein contents reported by Therese *et al.*; (2019). Harvested cowpea grains from plants treated with nano *P. alliacea* root had the highest protein content (36.8%) when compared with other treatments, this implies that application of nano *P. alliacea* root can serve as protein enhancement. However, the fiber content of cowpea grains ranged from 20.1 to 26% which was higher than the observed fiber content by Peter *et al.*; (2020). Application of harvested cowpea grains from plants treated with *P. alliacea* leaf extract had higher fibre content 26%. This implies that application of *P. alliacea* leaf extract improved the fiber content of the harvested cowpea grains. The observed fat content of the harvested cowpea grains ranged from (7.3 to 12%) which was higher than the value obtained by Khalid *et al.*; (2012). The carbohydrate content (24.8 to 30.2%) from the harvested cowpea grains were below the carbohydrate value reported by Usman *et al.*; (2022). The ash content of harvested cowpea grains ranged from (2.36 to 6.1%) with the highest ash content (6.1%) from the cowpea plants treated with nano *P. alliacea* leaf. This suggests that nano *P. alliacea* leaf could be the major source of improving the ash contents of cowpea grains.

The effects on the nutritional contents of the harvested cowpea pointed to the fact that the applied nano *P. alliacea* were absorbed either through the leaf stomata or plant roots, consequently influenced the biochemical constituents of the treated plants. This observation is in line with the earlier research work by Ragavan *et al.*, (2017) who reported that selenium nanoparticles influenced biochemical constituents of cluster bean (Zhang *et al.*, (2001).

Conclusion

The result from this study shows that Nano formulations had significant effects on the nutritional contents of the tested harvested cowpea grains. However, further field studies should be conducted on the use of Nano insecticides of different concentrations for their use in preventing insects and improving plants' nutritional contents.

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Published by:





Effects of Recommended Cocoyam Production Technologies on Output of Farmers in Enugu State, Nigeria

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Keywords:

Adoption, recommended technologies, cocoyam production, farmers

Access online at:

www.africanorganicconference.net

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Abstract

The study assessed the effects of adoption of recommended cocoyam production technologies on the output of farmers in Enugu State, Nigeria. Five-stage sampling procedure was used to select 245 cocoyam farmers. Structured questionnaire was used to collect primary data which were analyzed using descriptive statistics and multiple regression analysis. The results obtained revealed that mean age of the farmers was 56 years and majority (84.1%) of them had formal education. Most of the farmers adopted all the recommended cocoyam technologies namely; application Organic fertilizer after planting (99.6%), timely planting between May–June (99.2%), planting method using internodes at 1-2cm thickness (98.8%) and harvesting by digging around cocoyam plant at about 30cm (98.8%). Regression estimates revealed that almost all the technologies had positive and significant effects except fertilizer which was negative but significant ($P < 0.01$) probability level. Thus, it was concluded that the recommended cocoyam technologies had significant effects on the farmers' output. The study recommends that more sensitization should be carried out by research institutions in order to scale-up the adoption of recommended cocoyam technologies in the region and beyond.

Effets des Technologies de Production de Cocoyam Recommandées sur la Production des Agriculteurs dans L'état D'enugu, Nigeria

Résumé

L'étude a évalué les effets de l'adoption des technologies recommandées pour la production de cocoyam sur la production des agriculteurs de l'État d'Enugu, au Nigéria. Une procédure d'échantillonnage en cinq étapes a été utilisée pour sélectionner 245 producteurs de noix de coco. Un questionnaire structuré a été utilisé pour recueillir des données primaires qui ont été analysées à l'aide de statistiques descriptives et d'une analyse de régression multiple. Les résultats obtenus ont révélé que l'âge moyen des agriculteurs était de 56 ans et que la majorité d'entre eux (84,1 %) avaient reçu une éducation formelle. La plupart des agriculteurs ont adopté toutes les technologies recommandées pour le cocoyaume, à savoir l'application d'engrais organique après la plantation (99,6 %), la plantation à temps entre mai et juin (99,2 %), la méthode de plantation utilisant des entre-nœuds d'une épaisseur de 1 à 2 cm (98,8 %) et la récolte en creusant autour du plant de cocoyaume à environ 30 cm (98,8 %). Les estimations de régression ont révélé que presque toutes les technologies avaient des effets positifs et significatifs, à l'exception de l'engrais qui avait un effet

Mots clés :

Adoption,
technologies recommandées,
production de cocoyam,
agriculteurs

négatif mais significatif ($P < 0,01$) au niveau de la probabilité. Ainsi, il a été conclu que les technologies recommandées pour le cocoyam avaient des effets significatifs sur la production des agriculteurs. L'étude recommande que les institutions de recherche fassent davantage de sensibilisation afin d'accroître l'adoption des technologies recommandées pour le cocoyam dans la région et au-delà.

Introduction

Agriculture remains substantially a family business in Nigeria. Inadequate use of modern agricultural technologies in addition to low resource status of the farmers have made Nigeria's agriculture to remain unimproved (Adeniji, 2002; Ajayi *et al.*, 2017). However, the challenges of inadequate food production and shortages in raw materials supply has led to development of improved technologies to enhance food production and living standard of farmers. Despite the various food crop production programmes embarked upon by Federal Government of Nigeria (FGN), there has been concern about the capability of Nigeria's agriculture to meet the food requirement of her fast-growing population (International Institute for Tropical Agriculture (IITA), 2013; Muhammed *et al.*, 2019).

In recent years, emphasis have been placed on production of root and tuber crops like cocoyam, which has the potentials of alleviating poverty by improving the income earning capacity and food security of farmers in Nigeria (Ephraim *et al.*, 2021). According to Olaniyan *et al.* (2013), tuber crops are among the most important staple food crops in many tropical African countries and constitute one of the largest sources of calories in the case of Nigeria. The average production figure in Nigeria is 5.4 metric tonnes which accounts for about 37% of total world's output of cocoyam (Food and Agriculture Organization (FAO), 2014). Chukwu *et al.* (2012) posited that cocoyam is nutritionally superior to yam in terms of its digestibility, crude protein contents and some important minerals like phosphorus, Calcium and Magnesium.

However, there has been decline in the yields of cocoyam which could be attributed to the use of low-impact technologies available to the farmers, inadequate improved planting materials, weed problems and poor soil conditions which resulted into reduced cocoyam productivity (National Agricultural Extension and Research Liaison Services (NAERLS), 2011; Nwakor *et al.*, 2015). The National Root Crops Research Institute (NRCRI), Umudike as a research agency saddled with the responsibility of providing research-based information on improved or recommended cocoyam production technologies for adoption has developed and extended frontier through various extension teaching methods to educate farmers (NRCRI, 2013).

Therefore, it becomes imperative to examine the extent to which the recommended cocoyam technologies have been adopted and their effects on farmers' output. It was against the backdrop of aforementioned this study was conceived and the following research objectives were put forward to describe the socio-economic background of cocoyam farmers; examine the adoption level of recommended cocoyam production technologies and determine the effects of recommended cocoyam technologies adoption on output of the farmers in the study area.

Methodology

Study Area

The study was conducted in Enugu State of Nigeria. The State lies between Latitude 7° 29' and 8° 55' North of the equator and Longitude 6° 26' and 7° 28' East of the Greenwich meridian. It has 17 Local Government Areas (LGAs) divided into three Agricultural zones (Enugu-North, Enugu-East and Enugu-West) and covers an estimated land area of 7,161 kilometre square (Enugu State Ministry of Information (ESMI), 2019). Enugu State has a population of 3,267,837 (National Population Commission (NPC), 2006) but the projected population as of 2020 using 3.2% growth rate (World Bank, 2019) was 5,078,975. The State experiences annual rainfall of between 1500mm – 2100mm and mean temperature of 30.6°C (ESMI, 2019). The rural people of Enugu State are predominantly farmers.

Sampling Procedure and Sample Size

A five-stage sampling technique was used to select respondents for the study. In the first stage, the Enugu-North agricultural zone was purposively selected due to the presence of many cocoyam farmers in the zone. There are six LGAs and eight extension blocks in the zone. In the second stage, four LGAs were randomly selected. The third stage involved the selection of one extension block from each of the LGAs selected. The fourth stage was the random selection of two extension cells from each of the extension blocks to get eight extension cells. The fifth stage was the proportionate selection of two hundred and forty-five (245) cocoyam farmers using the Taro Yamane (1967) formula based on the list of registered cocoyam farmers obtained from Enugu State Agricultural Development Programme (ENADEP).

Method of Data Collection and Analysis

Primary data used for the study were collected using semi-structured questionnaire complemented with an interview schedule to obtain information on socio-economic characteristics of the farmers, the recommended cocoyam production technologies adopted and effects of recommended cocoyam production technologies on output of the cocoyam farmers. Data collected were analyzed using descriptive statistics (such as the mean, standard deviation, frequency distribution count and percentage) and multiple regression analysis.

Results and Discussion

Socio-Economic Characteristics of the Respondents

As revealed in the Table 1, about half (49.8%) of the respondents were within the age bracket of 51–70 years with a mean age of 56 years. This implies that most of the cocoyam farmers were aged but still able to undertake farming activities. This finding is in contrast with the work of Uwandu *et al.*, (2018) who reported that majority of farmers in their study area were within the youthful and middle age. More so, more than half (55.1%) of the respondents were males, while 44.9% of them were females implying that males were more involved in cocoyam farming than female which could be due to the tedious nature of farming. Majority (82.4%) of the respondents were married which implies that cocoyam production in the study area was mainly undertaken by married individuals this could be attributed to the need to procreate and provide cheap family labour required for farming activities. This finding agrees with Odoemekun and Anyim (2019) who reported that majority of farmers married purposely for pro-creation of young ones. More than half (56.3%) of the respondents had household size between 5–10 people with a mean of 6 persons. This implies that the farmers had large household size which is an advantage in terms of farm labour supply.

Table 1: Distribution of respondents based on their socio-economic background (n = 245)

Variables	Frequency	Percentages (%)	Mean
Age (years)			
< 31	9	3.7	56
31 – 50	84	34.2	
51 – 70	122	49.8	
> 70	30	12.3	
Sex			
Male	135	55.1	
Female	110	44.9	
Marital status			
Married	202	82.4	
Widowed	32	13.1	
Single	4	1.6	
Divorced	7	2.9	
Household size			
< 5	98	40.0	6
5 – 7	87	35.5	
8 – 10	51	20.8	
> 10	9	3.7	
Educational status			
Primary	102	41.6	9
Secondary	79	32.2	
Tertiary	25	10.3	
Non-formal	39	15.9	
Experience (years)			
< 11	55	22.4	24
11 – 20	66	26.9	
21 – 30	54	22.0	
31 – 40	48	19.6	
> 40	22	9.1	
Farm size (hectares)			
< 1.1	217	88.6	0.82
1.1 – 2.0	28	11.4	
Access to credit			
Yes	50	20.4	
No	195	79.6	
Extension contacts			
Yes	119	48.6	
No	126	51.4	
Cooperative membership			
Yes	64	26.1	
No	181	73.9	

Source: Field Survey, 2022

Table 1 further revealed that majority (84.1%) acquired formal education (primary, secondary and tertiary) with a mean of 9 years of formal schooling. This implies that the farmers were literate which could help them to make better decisions as regards adoption of technologies. Most (68.5%) of the respondents had farming experience between 11 – 40 years with a mean of 24 years of farming. This implies that the farmers had been into farming for long period of time which could enhance their favourable perception about adopting recommended cocoyam technologies. This agrees with Olaosebikan *et al.* (2019) who reported that majority of the respondents in their study area had long years of farming experience which help them to make informed decisions about their farms. Majority (88.6%) of the respondents had farm size of less than one hectare with a mean of 0.82 hectare. This implies that majority of the cocoyam farmers were operating on a small-scale which could be attributed to competitive nature of farmland in the study area.

Just a few (20.4%) had access to credit. This implies that majority of the farmers had no access to credit which could negatively affect their adoption of recommended technologies. About half (48.6%) of the respondents had contact with extension agents, while 51.4% had no contact. This implies that some of the respondents had contact with extension agents which could influence their decision to adopt recommended cocoyam technologies. More so, majority (73.9%) of the respondents were not members of cooperatives, while only 26.1% were members. This implies that there was poor participation of the farmers in cooperative societies which could play a significant role in adoption of recommended cocoyam technologies in the study area.

Adoption of recommended cocoyam technologies by the respondents

The result in Table 2 presents the recommended cocoyam technologies adopted by the respondents in the study area. It revealed that there was higher adoption of all the recommended cocoyam technologies by majority of the farmers. The topmost recommended technologies adopted among others are manure application after planting (99.6%), timely planting between May – June (99.2%), planting method using heap and ridge top (98.8%) and harvesting by digging around cocoyam plant at about 30cm (98.8%). This implies that the farmer adopted all the recommended cocoyam technologies in the study area. This corroborate the report of National Root Crops Research Institute (NRCRI) (2013) that farmers adopted recommended cocoyam technologies developed and transferred to them to boost production.

Table 2: Distribution of respondents based on recommended cocoyam technologies adopted

Recommended cocoyam technologies*	Adopted (%)	Not Adopted (%)
Manure application after weeding	244 (99.6)	1 (0.4)
Timely planting between May – June	243 (99.2)	2 (0.8)
Planting method using heap and ridge top	242 (98.8)	3 (1.2)
Harvesting by digging round Cocoyam Plant at about 30cm	242 (98.8)	3 (1.2)
Biological pest control	240 (98.0)	5 (2.0)
Weed control (manual)	240 (98.0)	5 (2.0)
Cocoyam intercropping technique	228 (93.1)	17 (6.9)
Use of Cocoyam mini-sets of about 25g	224 (91.4)	21 (8.6)
Mulching using crop residues	222 (90.6)	23 (9.4)
Plant spacing of 1m x 1m	204 (83.3)	41 (16.7)

Source: Field Survey, 2022

Note: * Multiple Responses and numbers in parentheses are the percentages

Recommended Cocoyam Technologies Adoption on Respondents' Output

The result of regression estimate as presented in Table 3 revealed coefficients of determination (R^2) value of 0.7728 which implies that 77% variation in the output of the respondents were explained by the independent variables included in the model, while the remaining 23% unaccounted could be due to error or other variables not captured in the model. The F–statistic value of 16.84 was significant at 0.01 probability level implying perfect fit of the model and goodness at predicting the observed data. The result also revealed that out of sixteen (16) variables included in the model, thirteen (13) variables were significant at 0.01 and 0.05 probability levels, respectively. Twelve variables such as farm size, labour usage, timely planting, manure application, planting method, cocoyam inter-cropping, cocoyam mini-sett, weed

control, mulching, extension contact, membership of cooperative and access to credit were positive and significant, therefore had direct influence on the output of cocoyam farmers, while biological pest control was negative and significant, thus had inverse influence on the output of cocoyam farmers.

The coefficient for farm size (0.1150) was positive and statistically significant ($P < 0.05$) probability level. This implies that a unit increase in farm size because of adoption of recommended cocoyam production technologies will lead to 11.5% increases in the output of cocoyam farmers. This meet the a priori expectation because it is anticipated that complete adoption of the cocoyam recommended production technologies package will boost farmers' returns which will invariably lead to the expansion of farmland and thus increase in the output of farmers.

The coefficient for labour usage (0.0020) was positive and significant ($P < 0.05$) probability level. This implies that a unit increase in labour usage because of the adoption of recommended cocoyam production technologies will lead to about 0.2% increases in the output of cocoyam farmers. This meets the apriori expectation. As a result of the adoption of recommended cocoyam production technologies, it is envisaged that farmers may likely increase the size of farmland to accommodate increase in returns. This will necessitate more labour, which if properly utilized, will increase farmers output.

The coefficient for manure application (0.0644) was positive and significant ($P < 0.01$) probability level. This implies that a unit increase in the use manure will lead to 1% increase in the output of cocoyam farmers. This meet the apriori expectation as manure application can help in enhancing the performance and yield of the crop.

The coefficient for timely planting (0.7086) was positive and significant ($P < 0.01$) probability level. This implies that a unit increase in timely planting will lead to about a 71% increase in the output of cocoyam farmers. Timely of planting is a crucial cultural farming practice that can significantly affect crop performance and yield. This meet the a priori expectation because timely planting is expected to improve cocoyam's strong establishment, giving them ample time to grow to their full potential and lessen other environmental stress.

Table 3: Regression estimates on effects of recommended cocoyam technologies on output

Variables	Coefficient	Standard error	t-values
Farm size	0.1150	0.0560	2.05**
Labour usage	0.0020	0.0009	2.39**
Seed rate	3.15e-07	5.99e-07	0.53
Manure application	0.0644	0.0206	3.13***
Timely planting	0.7086	0.1015	6.98***
Planting spacing 1mx1m	-0.1393	0.0576	-2.42**
Planting method	0.2943	0.1399	2.10**
Cocoyam inter-cropping	0.1300	0.0610	2.13**
Cocoyam mini-sett 25g	0.1209	0.0592	2.04**
Weed control	0.2874	0.0717	4.01**
Mulching	0.2129	0.0643	3.31**
Pest control	0.0249	0.1356	0.18
Harvesting method	0.1466	0.1022	1.44
Extension contacts	0.2158	0.0541	3.99***
Cooperative membership	0.1527	0.0697	2.19**
Access to credit	0.1601	0.0761	2.10**
Constant	5.0223	0.2242	22.40***
R-squared	0.7728		
Adj R-squared	0.7388		
F-statistics	16.84***		

Source: Field survey, 2022

Note ***, ** and * implies significant at 1%, 5% and 10% probability level, respectively

The coefficient for the cocoyam mini-set (0.1209) was positive and significant ($P < 0.01$) probability level. This implies that a unit increase in cocoyam mini set adoption will lead to about a 12% increase in the output of cocoyam farmers. This meets the *a priori* expectation because adopting the recommended cocoyam mini-set techniques will help the farmer to produce large quantities of planting materials in the shortest possible time, which lessens the competition for cocoyam corms as food and planting materials. This is expected to improve their productivity.

The coefficient for cocoyam inter-cropping (0.1300) was positive and significant ($p < 0.01$) probability level. This implies that a unit increase in cocoyam inter-cropping adoption will lead to about a 13% increase in the output of cocoyam farmers. Adoption of recommended intercropping practices will help the farmers to diversify their sources of income while maintaining the same level of output per hectare.

The coefficient for weed control (0.2874) was positive and statistically significant at 0.01 probability level. This implies that a unit increase in weed control will lead to about a 29% increase in the output of cocoyam farmers. This meets the *a priori* expectation because weed competes with planted crops for nutrients, soil air, and water as well as harbouring pests. Therefore, the adoption of recommended weed control strategies by cocoyam farmers is expected to improve sanitary conditions towards pests and diseases thereby improving the productivity of the farmers.

The coefficient for mulching (0.2129) was positive and significant ($P < 0.01$) probability level. This implies that a unit increase in mulching will lead to about a 21% increase in the output of cocoyam farmers. Mulch on cocoyam is expected to enhance the activity of soil organisms and reduce evaporation of water from the soil. Thus, the result is in line with the expected *a priori*, because adoption of recommended mulching practices is expected to create favourable condition for cocoyam optimal growth.

The coefficient for extension contacts (0.2158) was positive and significant ($P < 0.01$) probability level. This implies that a unit increase in extension contact will lead to an increase of about 22% in farmers' output. Extension agent facilitates the dissemination of recent innovation in agriculture to farmer to improve their productivity. As expected, increase in extension contact can bring the result or method demonstration of cocoyam production technologies to farmer is expected to enhance the adoption of the technology which will invariably improve the output of farmers.

The coefficient for membership of cooperative (0.1527) was positive and significant ($P < 0.01$) probability level. This implies that a unit increase in membership of cooperative will lead to about 15% increases in the output of cocoyam farmers. This shows that cooperative membership could positively influence adoption decisions of a farmer in relation to improved technologies dissemination. Cooperative society is an instrument that facilitates access to credit and extension linkages that could help in adoption of recommended cocoyam production technologies.

The coefficient for access to credit (0.1601) was positive and significant ($P < 0.01$) probability level. This implies that a unit increase in access to credit will lead to about 16% increases in the output of cocoyam farmers. It is a general fact that access to credit by farmers is one of the most important means of improving farm productivity. Credit provides the means for innovation adoption, thus the higher a farmer has access to credit, the higher the capacity to adopt recommended cocoyam production technologies for increase output.

Conclusion and Recommendations

Based on the findings of the study, it was concluded that the cocoyam farmers were aged but still active in production, married and educated with at least secondary education. However, there was poor access to credit, fair contact with extension agents and poor cooperative membership. The farmers adopted all the recommended cocoyam production technologies with little variation. Thus, adoption level was high. There were significant effects of the recommended cocoyam production technologies on output of the farmers. It was recommended that drastic sensitisation should be carried out by relevant research institutes and extension agencies to scale-up adoption of recommended cocoyam technologies for increased output in Enugu state and Nigeria at large. The farmers should organize themselves into cooperative societies to harness the benefits accrued from cooperative participation such as access to credit, extension services and training in relation to cocoyam production.

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Published by:





Digital Mapping of Toxic Metals in Malete and Oke-Daaba Soils using Remote Sensing and Ancillary Data

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Keywords:

Toxic metals,
Spatial Modelling Indexes,
Soil Pollution,
Remote sensing,
Soil Parameter.

Access online at:
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Abstract

The use of remote sensing techniques to detect sources of pollution is a good tool to prevent possible environmental affections. After decades of cultivation/agricultural use of Malete Teaching and Research farm and mining activities in Oke-Daaba community, it is important to estimate their impact on soil pollution with toxic metals. Routine soil physio-chemical parameters were determined. The textural classes of the soil area are Loamy sand, sandy loam and sand. The pH (H₂O) ranged from 6.0-7.1. The total organic carbon ranges from 0.14-1.54%. Total nitrogen ranges from 0.41-0.73. The study utilized 170 top-soil (0-30 cm) samples, multi-spectral images (Landsat 8 OLI imagery of 2022), spatial modelling indexes and environmental variables to model and map the spatial distribution of Arsenic (As), Copper (Cu), Lead (Pb), Zinc (Zn) and Cadmium (Cd) in Malete and Oke-Daaba community soils. Topsoil maps of the five toxic metals were generated with the use of Soil-Adjusted Vegetation Index (SAVI), Weighted Difference Vegetation Index (WDVI), NDVI and Enhanced Vegetation Index (EVI), for lead, cadmium, Zinc and arsenic concentration respectively. The maps can be used to prioritize the choice of remediation measures and can be applied to other areas of similar environmental conditions and pollution causes. If the source of heavy metal is detected by remote sensing, the practices applied to the soil can be done according to those pollutants and avoiding the mobilization and transfer of heavy metal to other environmental compartments. The study therefore recommends that Continuous monitoring of soil pollution by heavy metals is desirable to ensure the sustainability of ecosystems.

Cartographie numérique des métaux toxiques dans les sols de Malete et d'Oke-Daaba à l'aide de la télédétection et de données auxiliaires

Résumé

L'utilisation des techniques de télédétection pour détecter les sources de pollution est un bon outil pour prévenir d'éventuelles atteintes à l'environnement. Après des décennies de culture/utilisation agricole de la ferme d'enseignement et de recherche de Malete et d'activités minières dans la communauté d'Oke-Daaba, il est important d'estimer leur impact sur la pollution du sol par les métaux toxiques. Les paramètres physio-chimiques habituels du sol ont été déterminés. Les classes texturales de la zone de sol sont le sable loameux, le loam sableux et le sable. Le pH (H₂O) est compris entre 6,0 et 7,1. Le carbone organique total varie de 0,14 à 1,54 %. L'azote total est compris entre 0,41 et 0,73. L'étude a utilisé 170 échantillons de sol (0-30 cm),

Mots clés :

Métaux toxiques,
indices de modélisation spatiale,
pollution du sol,
télé-détection,
paramètres du sol.

des images multispectrales (images Landsat 8 OLI de 2022), des indices de modélisation spatiale et des variables environnementales pour modéliser et cartographier la distribution spatiale de l'arsenic (As), du cuivre (Cu), du plomb (Pb), du zinc (Zn) et du cadmium (Cd) dans les sols des communautés de Maleta et d'Oke-Daaba. Des cartes de la couche arable pour les cinq métaux toxiques ont été générées à l'aide de l'indice de végétation ajusté au sol (SAVI), de l'indice de végétation par différence pondérée (WDVI), du NDVI et de l'indice de végétation amélioré (EVI), pour les concentrations de plomb, de cadmium, de zinc et d'arsenic, respectivement. Les cartes peuvent être utilisées pour hiérarchiser le choix des mesures d'assainissement et peuvent être appliquées à d'autres zones présentant des conditions environnementales et des causes de pollution similaires. Si la source de métaux lourds est détectée par télé-détection, les pratiques appliquées au sol peuvent être adaptées à ces polluants et éviter la mobilisation et le transfert des métaux lourds vers d'autres compartiments de l'environnement. L'étude recommande donc qu'une surveillance continue de la pollution des sols par les métaux lourds soit souhaitable pour assurer la durabilité des écosystèmes.

Introduction

Toxic metal contamination of soil occurs worldwide due to a variety of factors, including industrialization, fast urbanization, and military operations in certain regions (Alloway, 2013). Massive levels of toxic metal exposure in urban and industrial areas, particularly for arsenic (As), chromium (Cr), nickel (Ni), copper (Cu), lead (Pb), and zinc (Zn), can lead to a number of serious health disorders, including disruption of the nervous and digestive systems (e.g., acne, allergies, anemia, anorexia, arthritis, sciatica, schizophrenia), damage to the circulatory system (e.g., asthma and chronic bronchitis), abnormal blood composition, and many other unfavourable outcomes (Arfsten *et al.*, 2001).

The prediction of toxic metals accumulation in soils has been established for human and ecological risk assessment utilizing a range of geostatistical techniques and environmental data at different scales (Guo *et al.*, 2012). Lado *et al.* (2008) modeled and mapped the distribution of eight toxic metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Zn) for the topsoil across Europe using regression-kriging with a large number of auxiliary variables (1-km resolution) as predictors (e.g., land cover, geology, night-lights pictures). The cross-validation results demonstrated how inaccurate these maps were generally. Additionally, they offered two potential justifications for the poor accuracy: (1) Many hotspots (sporadic high values) cannot be handled by regression-kriging or regular kriging; (2) a somewhat narrow resolution.

Xie *et al.* (2011) mapped the spatial distribution of three toxic metals (Cd, Cu, and Pb) in soil in a limited area (605 km²) in Beijing using four different interpolation methods: inverse distance weighting, local polynomial, ordinary kriging, and radial basis functions. Based on cross-validation, the outcomes demonstrated that every interpolation technique offered a high level of accuracy.

In the last ten years, the potential of using remote sensing (RS) techniques (aerial or satellite data) for mapping toxic metals in soils has received more attention. Melendez-Pastor *et al.* (2011) comprehensively reviewed the role of RS in soil toxic metals' detection and found it to be an efficient tool for detecting sources of toxic metals' contamination in soils. This is despite the fact that toxic metals in soils appear in low or moderate concentrations (e.g., Cr and Cu <4000 mg·kg⁻¹) and are spectrally featureless, although they can easily bind to minerals and organic matter (Shi *et al.*, 2014).

Because the spectral designations of minerals can fluctuate with their chemical composition and surface activity, the reflectance spectral information of minerals in soils, in particular, is crucial for forecasting dangerous metals (Wu *et al.*, 2011). Since the information of Fe-oxides, clays, and organic matter in soils or vegetation cover can be retrieved from the RS spectra, this indirect process makes it possible to infer the correlations between spectral information and soil hazardous metals (Grunwald *et al.*, 2015).

Some plant species, like peach trees, cotton, citrus, and soybeans, may have slower growth and finally die as a result of heavy metals in the soil reducing their ability to sprout seeds and grow roots (Foy *et al.*, 1978). Furthermore, some crop plants have the ability to absorb and concentrate dangerous pollutants in their edible sections, which could damage people by way of food chains (Khan *et al.*, 2008). A thorough understanding of the heavy metal concentrations in soils can be used to protect the environment, reduce pollution, and ensure public health. Thus, this study aims to estimate heavy metal concentrations in soils using multispectral satellite imagery.

Materials and Methods

Experimental site

The study was conducted at Kwara State University (KWASU) Teaching and Research farm and Mining site, (OKE-DAABA) Malete. The farm lies between Latitude 8.71329; longitude 4.447263 while Oke-Daaba is located within Latitude 9 48 54" N and longitude 5° 37 51" E, both in Moro local government areas of Kwara state at 360 m above sea-level and relief is very gentle located in Southern Guinea Savannah ecological region of Nigeria.

The climate is characterized by the tropical wet and dry climate in the rainforest ecological region. The mean annual temperature of the area typically varies from 18°C to 35°C, rarely below 14°C or above 30°C. Relative humidity over the area varies from 45% to 95%.

Field Survey and Sampling Techniques

The farm was divided into four blocks based on Land-use in Teaching and Research Farm, Malete. The soil sampling of both Teaching and Research Farm and Oke- daaba depth was at top surface (0- 30cm) using the soil auger. For each main sampling point, One Kilogram (1 kg) of a representative soil sample were collected and logged into properly labeled sample bag for analysis. These samples were used to determine physical and chemical properties of the study areas, the parameters analyzed include: Particle size analysis, pH, Organic carbon, %Nitrogen, Available Phosphorus, Potassium, Exchangeable bases, Base Saturation and heavy metal concentrations like As, Cu, Pb, Cd in soils was estimated using multispectral satellite imagery. The total sampling points for the Teaching and research farm (KWASU) was 170 points from 4 blocks; Block-2A, Block-3A, Block- 4A, Block- OFY2 and for Mining site (OKE- DAABA) sampling points was MS-1 ,MS-2, MS-3, MS-4 . Field data collection and soil sampling were carried out by using GPS by navigating those points.

Laboratory Procedure

The collected soil samples were air dried, crushed and passed through 2 mm diameter sieves. Prepared soil samples were taken to the Laboratory for soil routine analysis. Then, Landsat 8 imagery, a digital elevation model, were used in estimating the concentrations of heavy metals like Cu, Pb, Zn, As, Cd, etc. in the topsoil.

Data acquisition

The data used for this research are tabulated below:

Table 1: Data and their sources

S/N	Data	Type	Description	Range	Scale/Resolution
1.	Farm Boundary	Categorical	Extraction from a high resolution satellite imagery with the help of the field locational observations	-	1:1000
2.	Soil Type Map	Categorical	Produced from the integration of available topsoil data and existing soil map of the area	-	1:25,000
3.	Elevation (m)	Continuous	Generated from the available 12.5m resolution AlosPals 2, from which slope and aspect were generated as one of the environmental variables	-	10m
4.	LandSat 8, 2022	Continuous	Satellite Imagery of 30m resolution	Band 2 - Band 7	30m

The farm boundary was used to delineate the farm as the main site of study and was used to clip other data for the study. The soil type map generated from the soil data and existing soil map was used to delineate various soil types within the farm.

Elevation generated from digital elevation model of ALOS PALSA 2 of 10 m resolution was used to produce slope and aspect through interpolation using triangulation.

Atmospherically-corrected LandSat 8 Object Land Imaging of 2022 (from U.S Geological Survey Agency) which represent land reflectance was used; it was believed that the presence of toxic (heavy metals) in soil can be predicted using vegetation cover. To provide this important information for soil toxic metals' spatial modelling, indexes like Enhanced Vegetation Index EVI, Land Surface Water Index LSWI, Normalized Differential Vegetation Index NDVI, Soil-Adjusted Vegetation Index SAVI, Transformed Vegetation Index TVI, Weighted Difference Vegetation Index WDV and tasseled cap transformation include brightness, greenness and wetness were all the spectral indices derived from the LandSat 8 OLI imagery of 2022 and the values of predicators was extracted at sample locations using ArcGIS 10.8. All the images are of 30 m resolution.

Table 2: Description of LandSat Images

S/N	LandSat 8 OLI Bands	Description
1.	Band 2	Blue (450-510nm)
2.	Band 3	Green (530-590nm)
3.	Band 4	Red (640-670nm)
4.	Band 5	Near Infrared (NIR) (850-880nm)
5.	Band 6	SWIR1 (1570-1650nm)
6.	Band 7	SWIR1 (2110-2290nm)

The Indices

The indices for this research to detect the presence of heavy metal on the soil are given below

Table 3: Description of indices used

Indices	Description
Brightness	$0.3561*B2+0.3972*B3+0.3904*B4+0.6966*B5+0.2286*B6+0.1596*B7$
Greenness	$-0.334*B2-0.354*B3-0.456*B4+0.6966*B5-0.024*B6-0.263*B7$
Wetness	$0.2626*B2+0.2141*B3+0.0926*B4+0.0656*B5-0.763*B6-0.539*B7$
EVI	$G \frac{B5 - B4}{B5 - C1B4 - C2B2 + L} (1 + L)$
LSWI	$\frac{B5 - B6}{B5 + B6}$
NDVI	$\frac{B5 - B4}{B5 + B4}$
SATVI ^c	$\frac{B6 - B4}{B6 + B4} * (1 + L) - \frac{B7}{2}$
SAVI ^c	$\frac{B6 - B4 * (1 + L)}{B6 + B4 + L}$
TVI	$\left(\frac{B5 - B4}{B5 + B4} + 0.5 \right)^{1/2} * 100$
WDVI	$B5-s*B4$

EVI, enhanced vegetation index; *LSWI*, land surface water index; *NDVI*, normalized differential vegetation index; *SATVI*, soil adjusted total vegetation index; *SAVI*, soil-adjusted vegetation index; *TVI*, transformed vegetation index; *WDVI*, weighted difference vegetation index; $b C1 = 6; C2 = 7.5; G = 2.5; L = 1, s = 1$.

Results and Discussion

Physical and Chemical Properties of the Study Area

Routine soil physio-chemical parameters, namely, texture, organic matter, pH and cation exchange capacity (C.E.C.) contents, base saturation, %silt, %clay, %sand, available phosphorous, exchangeable potassium, exchangeable calcium, exchangeable sodium, nitrogen were determined on the < 2.0 mm soil fractions. Some relevant soil Physio-chemical properties are presented in Table 4. The textural classes of the soil in this study area are Loamy sand, sandy loam and sand. The pH (H₂O) ranged from 6.0-7.1 indicating slightly acidic to neutral. The pH (KCL) ranged from 4.75 to 5.30, indicating strongly acidic properties. The total organic carbon ranges from 0.14-1.54% indicating that it is very low. The total nitrogen ranges from 0.41-0.73% indicating that it is very low.

Table 4: Physical and chemical properties of the study area

Parameters	Sample CM - OFY2	Sample CM-2A	Sample CM -3A	Sample CM -4A
pH (H ₂ O)	7.10	6.85	6.15	6.00
pH (Kcl)	5.30	4.80	5.10	4.75
Electrical Conductivity (μ S/cm)	29.2	12.47	34.30	13.07
Organic Carbon (%)	1.54	0.14	0.34	0.34
Organic Matter (%)	2.65	0.24	0.59	0.59
Sand (%)	88	90	90	80
Silt (%)	4	2	2	6
Clay (%)	8	8	8	14
Textural Class	Loamy sand	Sand	Sand	Sandy loam
Nitrogen (%)	0.041	0.060	0.073	0.049
Available Phosphorus (ppm)	11.08	11.76	9.95	9.04
Exchangeable Potassium (cmol/Kg)	0.20	0.25	0.33	0.28
Exchangeable Magnesium (cmol/Kg)	0.03	0.09	0.05	0.06
Exchangeable Calcium (cmol/Kg)	0.08	0.10	0.13	0.11
Exchangeable Sodium (cmol/Kg)	0.27	0.27	0.56	0.27
Exchangeable Acidity (cmol/Kg)	2.48	1.44	1.28	1.04
Cation Exchange Capacity (cmol/Kg)	3.06	2.15	2.35	1.76
Base Saturation (%)	18.95	33.02	45.53	40.91

Estimation of Heavy metals in Malete Teaching and Research farm soils

This predictive capacity of heavy metal was improved using multispectral satellite images from land 8 OLI. Five variables were present within the top 10 variables, which were calculated using different bands from LandSat 8, the unit of the measurement is in mg.kg^{-1} . In prediction of lead, Soil-Adjusted Vegetation Index (SAVI) was the dominant among the top ten variables used the map below predict the concentration of lead (pb) on the farm. It can be seen that the high concentration is found to the southern part of the farm (Figure 1). For cadmium, the most used indices are the Weighted Difference Vegetation Index (WDVI). This concentration of cadmium is high in west-most and some in eastern the part of the farm. The prediction map is show in Figure 2. NDVI was used for Zinc Concentration but it was in reverse version as there is a negative relation between plant health and presence of zinc because Zinc inhibits plant growth. The Zinc is more in area of low NDVI (Figure 3). Enhanced Vegetation Index (EVI), is the index used for the concentration of arsenic within the farm (Figure 4). From all the maps presented below, it is evident that the present of one element as plant growth inhibitor is confirmed by others.

The type of interpolated spatial of, As, Cd, Pb, Cu and Zn in the topsoil of the study areas presented variety of concentrations as shown in Figures/predicted maps. In prediction of lead, Soil-Adjusted Vegetation Index (SAVI) was used and it can be seen that the high concentration is found in the southern part of the Teaching and research farm. Malete, While the concentration of cadmium is high in west-most and some in eastern the part of the farm. NDVI was used for Zinc Concentration but it was in reverse version as there is a negative relation between plant health and presence of zinc because Zinc inhibits plant growth. The Zinc is more in area of low NDVI. Enhanced Vegetation Index (EVI), is the index used for the concentration of arsenic within the farm. High lead concentration is found in the eastern part of Oke-daaba location, and high concentration of Zinc occupied larger areas in the site. Based on these maps, we can easily specify relationships between agricultural soil and mining area and soil accumulation of toxic metals, as confirmed too in other studies. The important variability in toxic metals is related to different intensity levels of agriculture, urbanization and industrialization in different locations of both teaching and research farm Malete and Oke-Daaba.

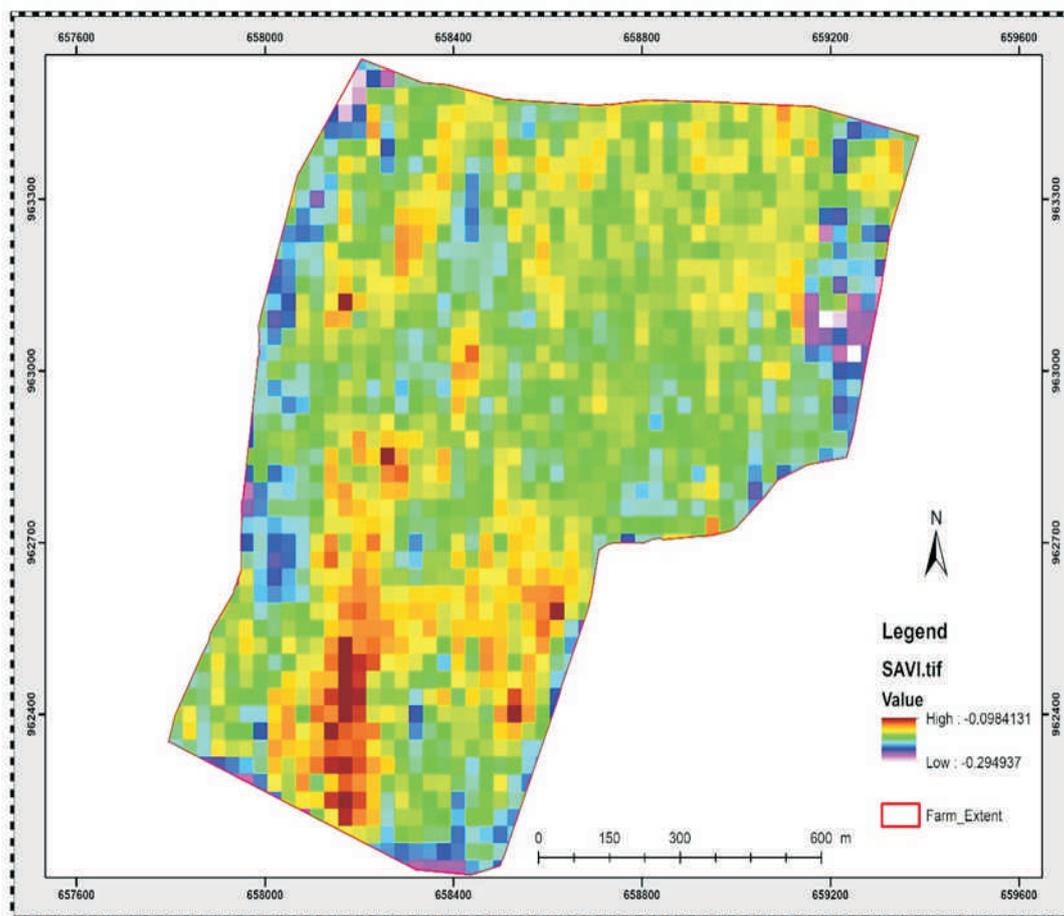


Figure 1: Concentration of Lead

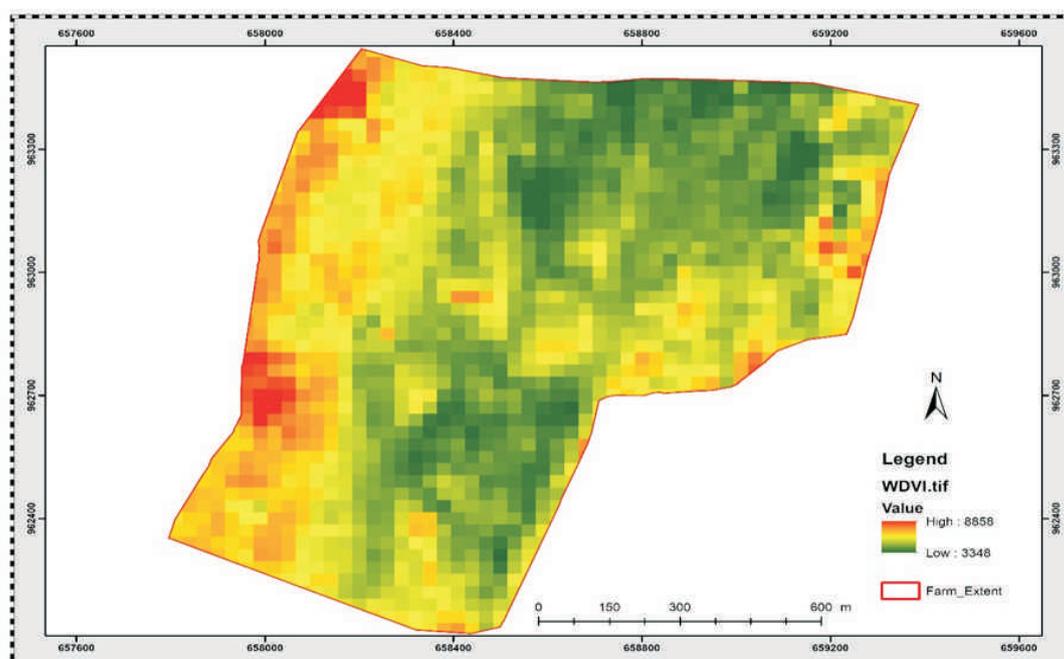


Figure 2: Concentration of Cadmium

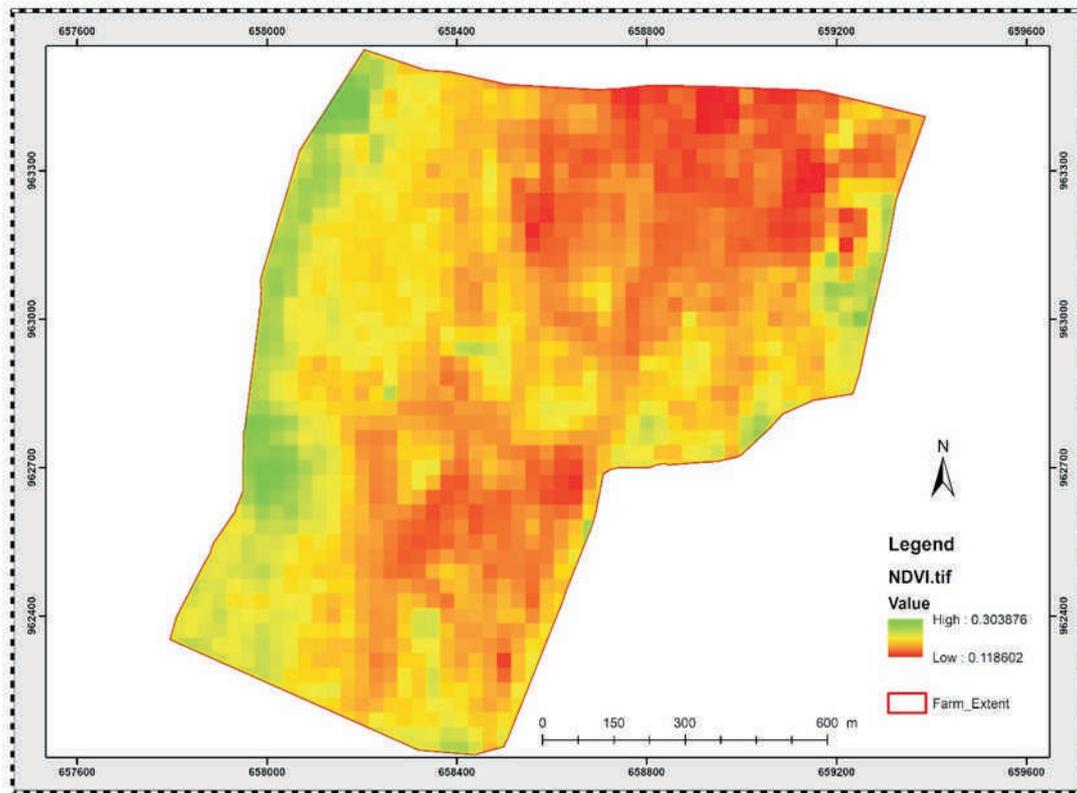


Figure 3: Concentration of Zinc

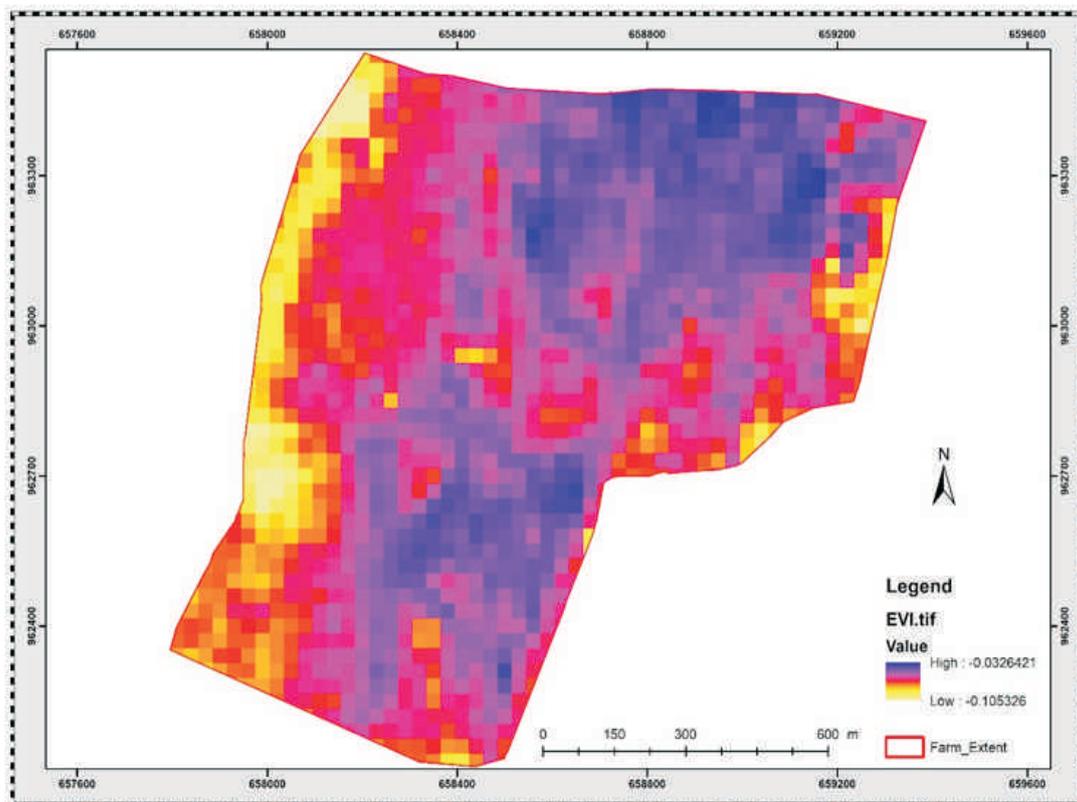


Figure 4: Concentration of Zinc

It is clear from the maps above that other elements confirm the presence of one element as a plant growth inhibitor. Because of their functions in the movement of minerals and soil particles through isostatic movement by agents of erosion, terrain models were chosen for this study over alternative models that have been shown to have an impact on the distribution of heavy metals. For example, a steep slope encourages heavy metals in the surrounding soil of a mining site to flow downward on higher ground. Additionally, by preventing heavy metals from flowing off mountainsides in runoff, the aspect of the slope influences the growth conditions of flora. The maps of the farm's aspect, slope, and soil are shown below.

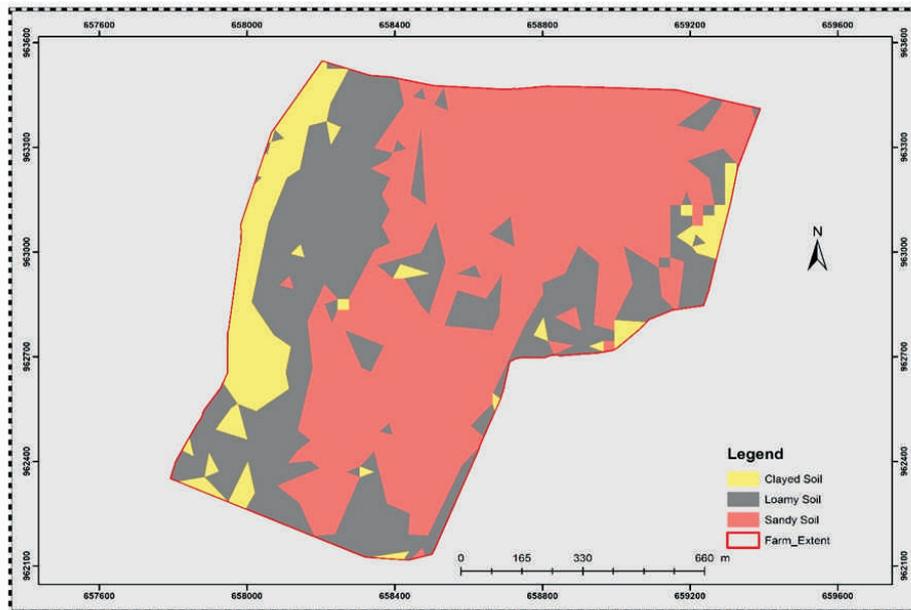


Figure 5: Soil Map

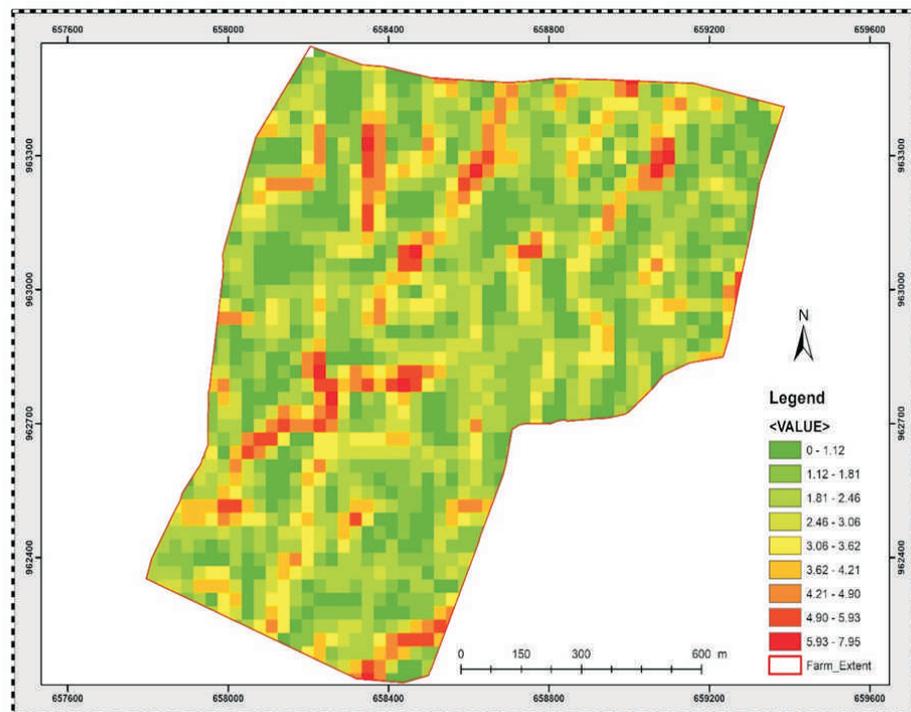


Figure 6: Slope Map

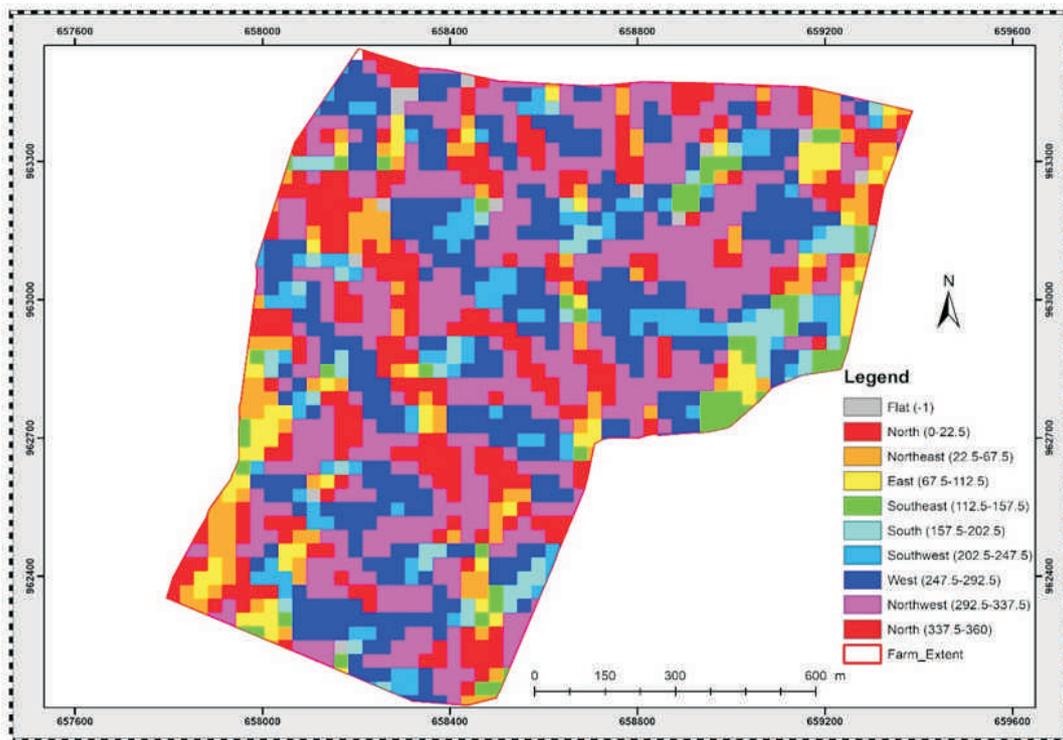


Figure 7: Aspect Map

Estimation of Heavy metals in Oke-Daaba (Mining site) Maleté

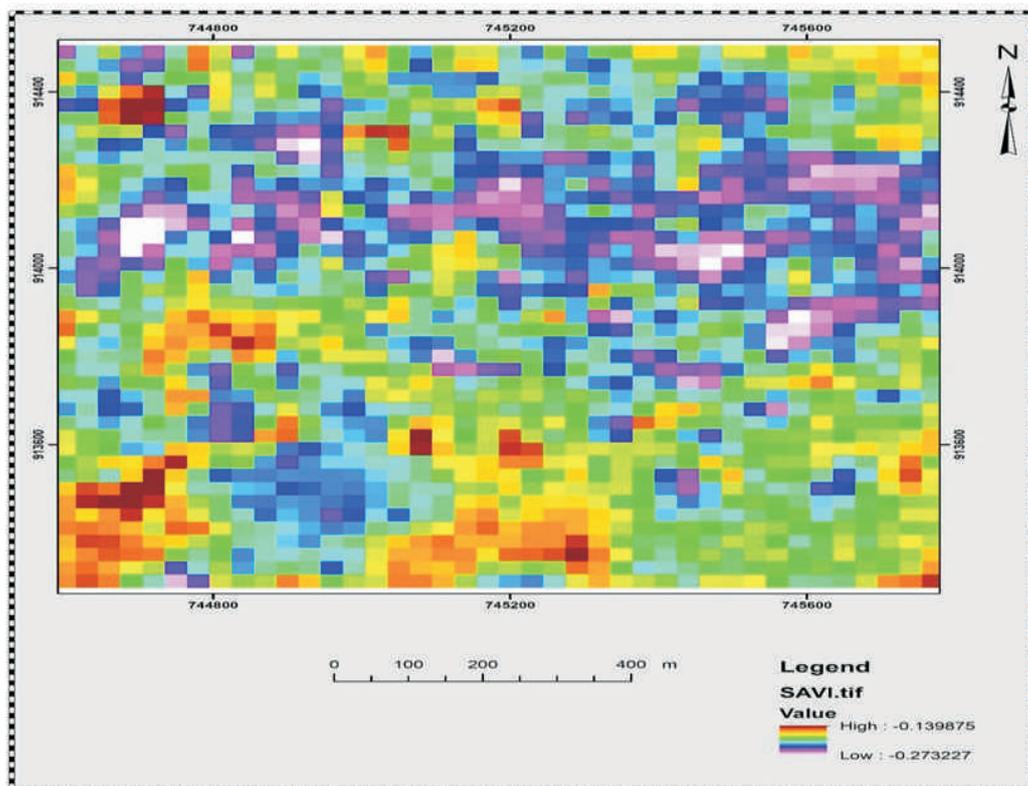


Figure 8: Concentration of Lead

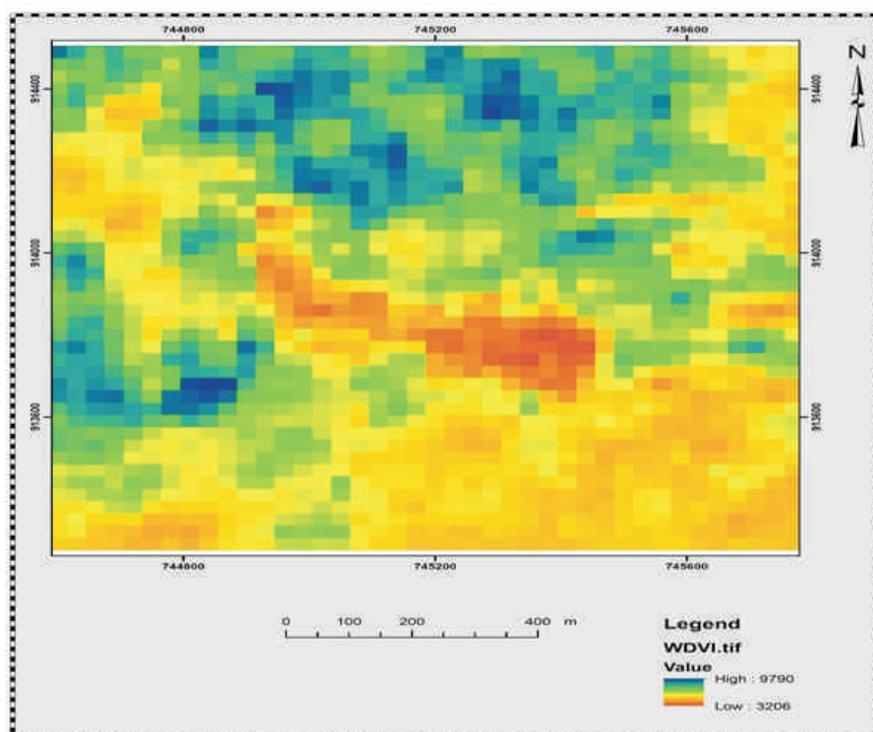


Figure 9: Concentration of Cadmium

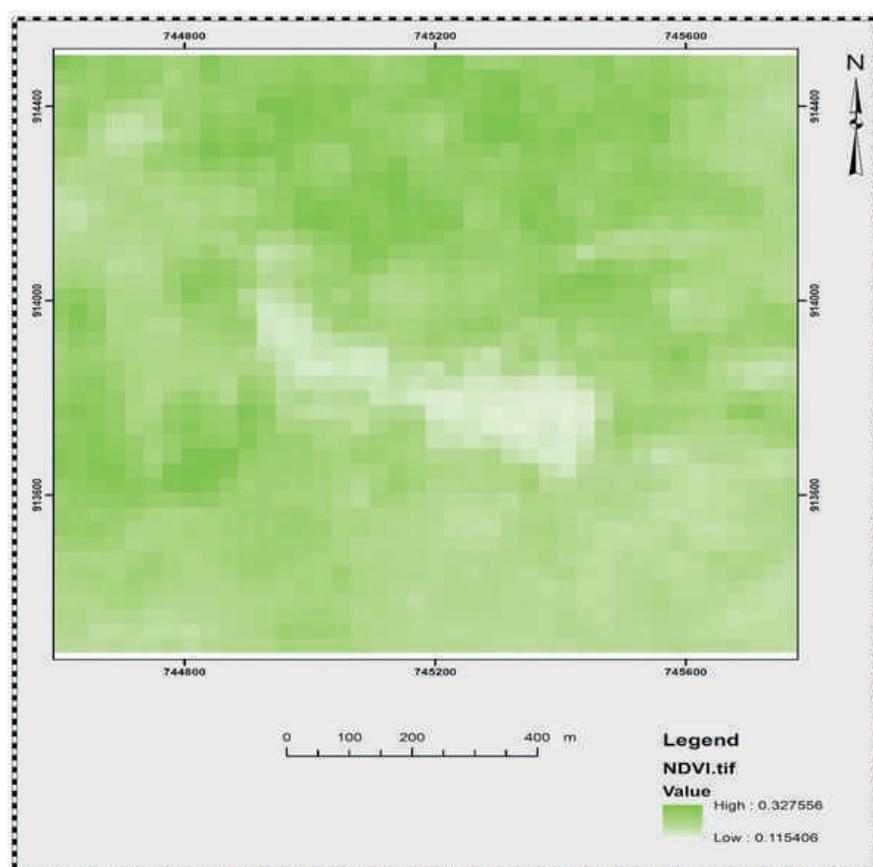


Figure 10: Concentration of Zinc

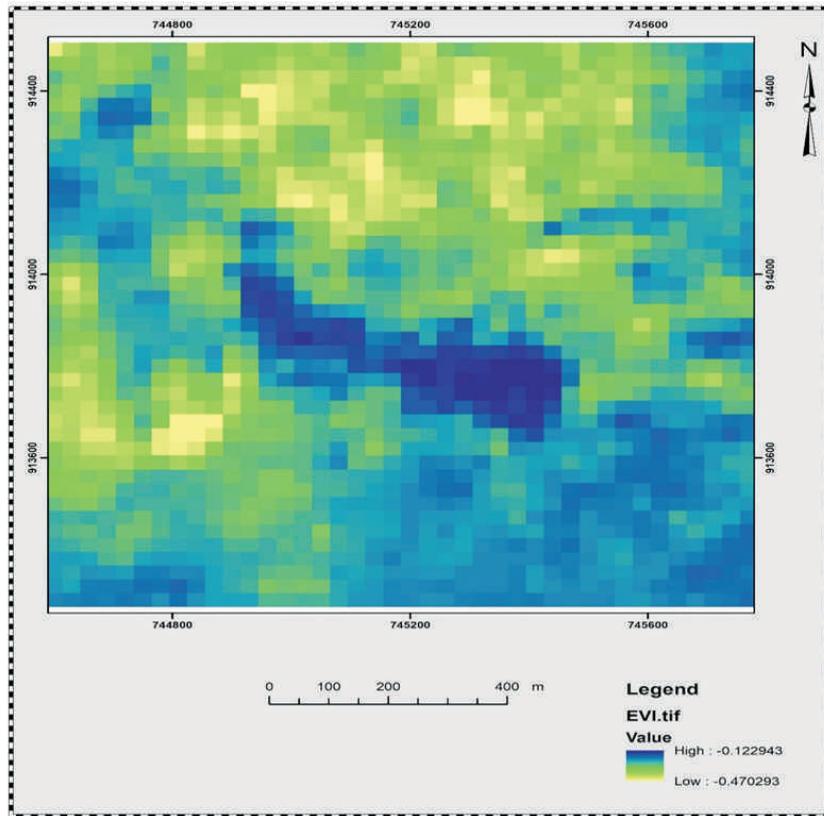


Figure 11: Concentration of Arsenic

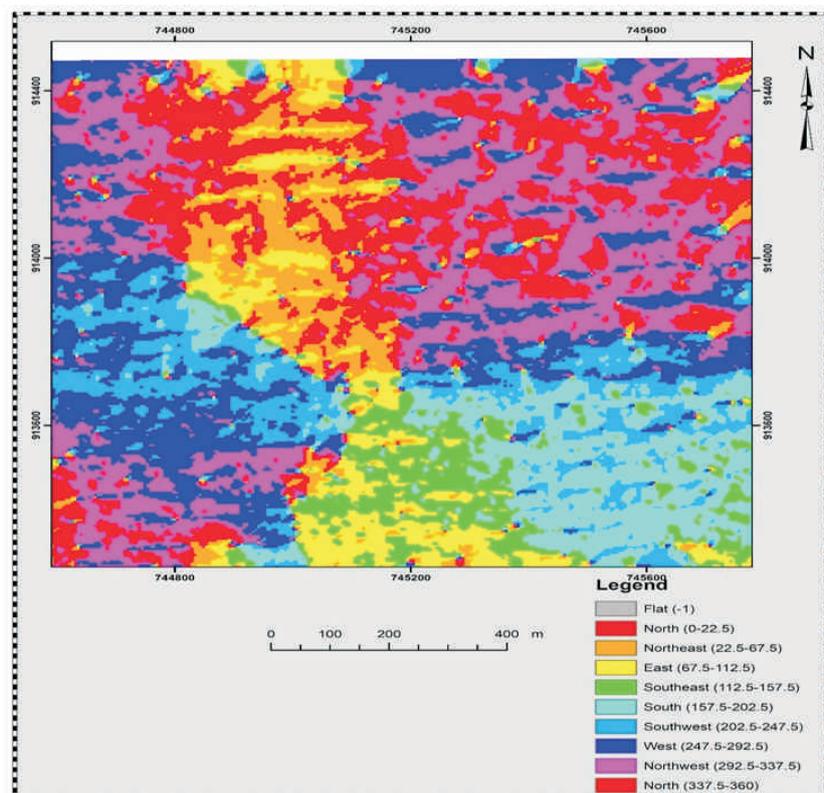


Figure 12: Slope Aspect

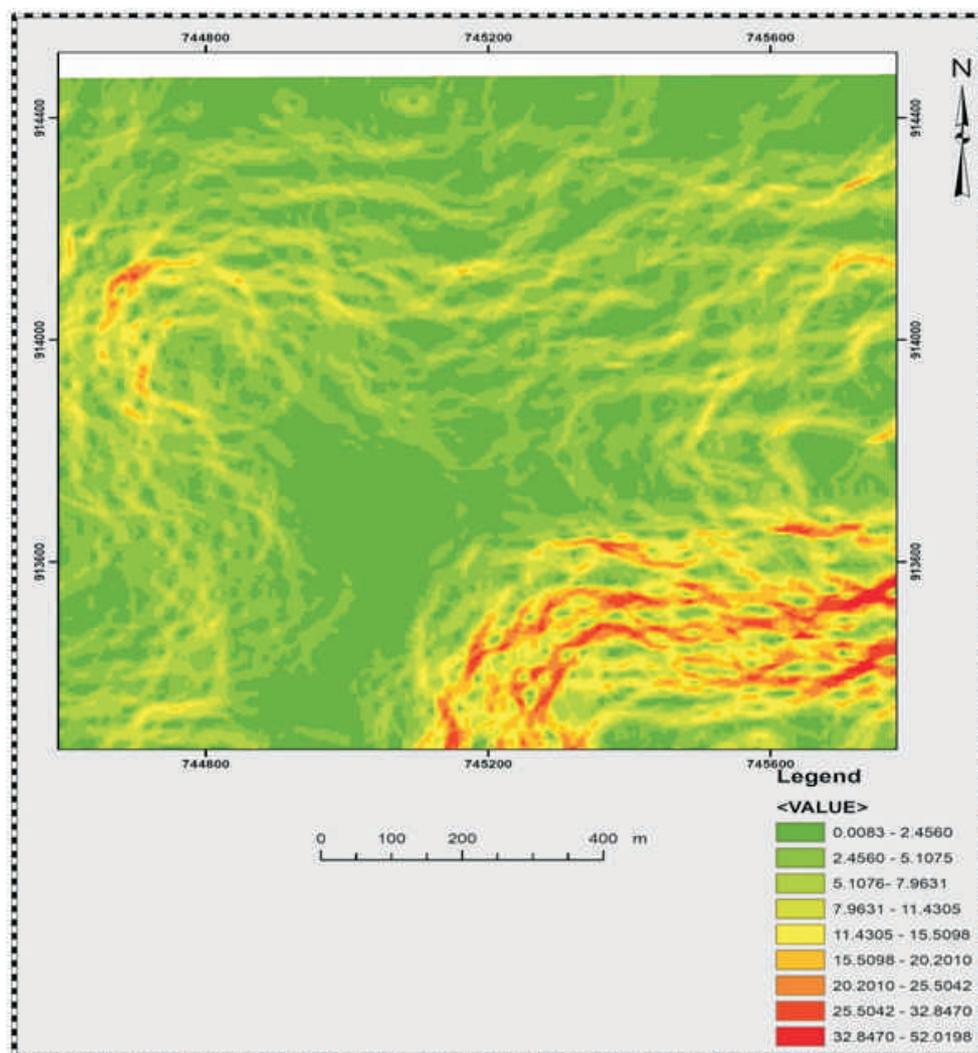


Figure 13: Slope

Discussion

The accumulation of potentially toxic metals (PTMs) in the human body through various pathways has been shown to be associated with toxicity and soil contamination, which have developed into significant environmental and health issues (Jarup, 2003; Chakraborty et al., 2017; Hagner et al., 2018). Studies have focused more on the spatial distribution of PTMs to evaluate their regional risks to the environment and human health. Anthropogenic activities, a significant source of PTMs, can be divided into four categories: industrial, agricultural, transportational, and others (Zhang et al., 2011). As seen in the Figures and projected maps, the interpolated spatial data for Pb, As, Cd, Cu, and Zn in the topsoil of the research sites revealed a range of concentrations. Because zinc slows plant growth, there is a negative correlation between plant health and zinc concentration, which is why the NDVI was utilized in reverse for zinc concentration. Zinc is concentrated in locations with low NDVI in the Maleté farm, while higher concentrations of zinc inhabited greater areas in the Oke-Daaba mining site. Given that zinc shortage tends to be the most frequent micronutrient deficiency in crop plants and is more common in high-pH soils, the high zinc concentration at both sites may be explained by the low pH in these soils. Although the weathering of rocks is the main way that humans add zinc to the soil, other methods include burning fossil fuels, mining waste, phosphate fertilizers, pesticides (such zinc phosphide), manure, sewage sludge, and particles from galvanized surfaces. Plants are poisonous to excess zinc, while zinc poisoning is far less common (Broadley et al., 2007).

In prediction of lead, Soil-Adjusted Vegetation Index (SAVI) was used and it can be seen that the high concentration is found in the southern part of the Teaching and research farm, Malete and High lead concentration is found in the eastern part of Oke-Daaba location. Around ten million tonnes of lead were produced annually worldwide in 2014, with more than half coming from recycling. Lead is a tremendously toxic metal that can damage practically every organ and system in the human body when consumed or inhaled. When 100 mg/m^3 is released into the air, it becomes immediately harmful to human life and health. The majority of lead that is consumed enters the bloodstream. Its propensity to obstruct enzyme activity is the main factor contributing to its toxicity. It accomplishes this by either imitating and dislodging other metals that function as cofactors in numerous enzymatic reactions or by attaching to the sulfhydryl groups present on a variety of enzymes. Lead interacts with calcium, iron, and zinc, among other important elements (Kharakwal, 2006). While low levels increase vulnerability to lead poisoning, high levels of calcium and iron tend to offer some protection against it.

Enhanced Vegetation Index (EVI), is the index used for the concentration of arsenic within the farm. The solubility of arsenic and Soil pH have an impact on its toxicity. Arsenite (AsO_3^-) is more poisonous and more soluble than arsenate (AsO_4^{3-}); at a lower pH, arsenate becomes more mobile. Arsenic phytotoxicity has been found to be significantly reduced by adding sulfur, phosphorus, and iron oxides to high arsenite soils. A variety of agricultural poisons and insecticides were also made with arsenic. Lead hydrogen arsenate, for instance, was a common insecticide used on fruit trees, but workers operating sprayers occasionally suffered brain damage from contact with the compound. In the latter half of the 20th century, less toxic organic forms of arsenic called monosodium methyl arsenate (MSMA) and disodium methyl arsenate (DSMA) replaced lead arsenate in agriculture; by 2013, all agricultural practices except cotton farming had been phased out.

Conclusion and Recommendation

Pollutants known as heavy metals are crucial to ecosystem health and human health. The use of remote sensing techniques to determine the presence of these pollutants in soils is a good tool for this purpose. However, not too many research and studies are done. To know the level of heavy metal pollution in soils is vital for most of the human activities in the Earth surface, thus the improvement of remote sensing techniques to study soil pollution are needed.

In order to ensure the sustainability of ecosystems, this study therefore, recommends that continuous monitoring of soil pollution by heavy metals be done. Additionally, the development of new sensors and the advancement of imaging analysis are critical components that enable us to locate heavy metals in large areas and support the making of the best decisions for land management and pollution control.

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Published by:







Organic Fertilizers and Biopesticides: Recycling, Eco-innovations, Circular Economy, Agribusiness Developed by Organic Farmers in Uganda

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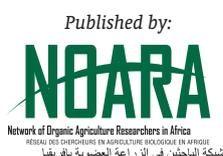
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Keywords:

Biopesticides,
circular economy,
organic fertilizer,
eco-innovations,
organic farming,
recycling, Uganda

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Abstract

Agriculture production now faces the challenge of reducing soil fertility and biodiversity components as a result of climate change and the use of large amounts of chemical inputs per unit of production. In order to reduce the negative consequences of using chemicals on human beings and ecosystems, farmers eco-innovate through agricultural practices, recycling residues and waste, and producing organic fertilizers and bio-pesticides. This study assesses the contribution of locally made organic fertilizer and biopesticides through recycling and eco-innovation to organic farmers and agribusiness in Wakiso, Massaka, and Jinja regions of Uganda. A multiple-stage stratified random sampling procedure was used to gather data from 150 organic farmers. The selected farmers had participated in organic farmer training and were making and using organic fertilizer and biopesticides. The results revealed that organic farmers make organic fertilizers and biopesticides from locally available wood ash, rice, milk, and plant leaves. It was observed that the farmers were able to recycle crop residues and waste for use as organic fertilizer. In the local market, a small proportion of farmers had established individual enterprises for selling organic fertilizers and biopesticides. This study underscores the importance of sustainable organic farming through recycling, eco-innovations, and circular economy.

Engrais organiques et biopesticides: recyclage, éco-innovations, économie circulaire, agro-industrie développée par des agriculteurs biologiques en Ouganda

Résumé

La production agricole est aujourd'hui confrontée au défi de la réduction de la fertilité des sols et des composantes de la biodiversité en raison du changement climatique et de l'utilisation de grandes quantités d'intrants chimiques par unité de production. Afin de réduire les conséquences négatives de l'utilisation de produits chimiques sur les êtres humains et les écosystèmes, les agriculteurs éco-innovent par le biais de pratiques agricoles, en recyclant les résidus et les déchets, et en produisant des engrais organiques et des bio-pesticides. Cette étude évalue la contribution des engrais organiques et des biopesticides produits localement grâce au recyclage et à l'éco-innovation pour les agriculteurs biologiques et l'agro-industrie dans les régions de Wakiso, Massaka et Jinja en Ouganda. Une procédure d'échantillonnage aléatoire stratifié à plusieurs degrés a été utilisée pour recueillir des données auprès de 150 agriculteurs biologiques.

Mots clés :

Biopesticides,
économie circulaire,
engrais organiques,
éco-innovations,
agriculture biologique,
recyclage, Ouganda

Les agriculteurs sélectionnés avaient participé à une formation sur l'agriculture biologique et fabriquaient et utilisaient des engrais et des biopesticides biologiques. Les résultats ont révélé que les agriculteurs biologiques fabriquent des engrais biologiques et des biopesticides à partir de cendres de bois, de riz, de lait et de feuilles de plantes disponibles localement. Il a été observé que les agriculteurs étaient capables de recycler les résidus de culture et les déchets pour les utiliser comme engrais organiques. Sur le marché local, une petite proportion d'agriculteurs a créé des entreprises individuelles pour vendre des engrais organiques et des biopesticides. Cette étude souligne l'importance d'une agriculture biologique durable grâce au recyclage, aux éco-innovations et à l'économie circulaire.

Introduction

Faced with the challenges of soil fertility reduction, soil and food contamination by chemicals, and environmental destruction, the farmers turned to the management of waste and residues in agricultural production as an eco-innovation. These eco-innovations have been a long time center for the conservation of agrobiodiversity in agricultural landscapes. Organic agricultural production is considered essential for restoring farming ecosystem losses. Do these eco-innovations participate in recycling waste and residues and circular economy in organic farming? How are these eco-innovations (organic fertilizers and biopesticides) marketed at the local and national levels?

Eco-innovation refers to new ideas, behaviors, products, or processes that, intentionally or not, reduce environmental impacts or resource use (Kemp and Pearson, 2007; Rennings, 2000). Eco-innovation refers to innovative activities that promote a sustainable environment by improving ecology (Shih *et al.*, 2018). Due to increased mass production, eco-innovation must draw on aspects of the economy, ecology, and society to impose limitations on the present state of environmental resource use (Xavier *et al.*, 2017). However, organic agriculture has been recognized as one of the practices that can improve the health and sustainability of agroecosystems (Giovannucci & Ponte, 2005; Pretty, 2008). As a holistic practice, organic agriculture reflects logical association and/or synchronization of systemic elements (Scofield, 1986), such as water, soils, crops, and livestock. Organic agriculture aims to create viable socially, environmentally, and economically integrated agroecosystems (Lampkin, 1994). Organic agricultural production bans synthetic agrochemicals to achieve sustainability in agricultural systems in general and biodiversity conservation. The dynamics of plant nutrient uptake are influenced by soil properties, which are conserved by organic farmers using organic inputs. As a result, the use of organic fertilizers and biopesticides is advantageous for socioeconomic and ecological improvements, particularly in soil quality amendments, which will contribute significantly to human health and safety, food quality, and environmental preservation. (Alfa *et al.*, 2014). The application of these organic fertilizers and biopesticides is very promising to increase food production and soil fertility while minimizing environmental damage (Silva *et al.*, 2016). Organic fertilization and biopesticides would improve crop yields and decrease the effects of groundwater contamination, which would otherwise be caused by using mineral fertilizers (Guo *et al.*, 2019). Organic agricultural production focuses on adding organic matter to the soil and, essentially, using locally available resources such as organic fertilizers and biopesticides. Organic farmers, on the other hand, combine agriculture production, agroforestry, and livestock for organic production using endogenous knowledge and experience from colleagues. This integration reflects the natural systems embedded; humans, plants, and animals contribute to safeguarding biodiversity. The wastes from animals or other elements of this natural system were recycled and served as organic fertilizers, biopesticides, or natural control pests. According to Uysal *et al.*, (2014), organic waste for utilization as agricultural fertilizers can be classified into several categories, namely: Animal-based organic waste (manure), compost (plant sources and food waste), and urban waste (sewage sludge and household waste). Thus, the reuse of agricultural products and waste as organic fertilizers, biopesticides, or natural pest control agents created a cycle in which agricultural waste is used to feed animals, and animal waste is used as manure, compost, and so on. The concept of circularity was elaborated within the context of natural resource use in productive processes denoting the reduction or avoidance of waste and trade-offs (Fidelis *et al.*, 2019; Sachs *et al.*, 2019). The circularity of reusing waste contributes to the

independence of organic farmers from external inputs and reduces the cost of production. Organic production generates a circular economy that participates conservation of soil fertility and biodiversity restoration. For Geissdoerfer *et al.*, (2017), the circular economy is a regenerative system in which the use and waste of resources, emission of gases, and leakage of energy are minimized through the deceleration, closing, and narrowing of material and energy loops (see also Geissdoerfer *et al.*, 2018). Murray *et al.* (2007) add a human dimension to the definition of circular economy, emphasizing that transformations in production systems must consider both the resilience of ecosystems and human well-being. However, the circular economy through organic inputs emphasizes agriculture resilience and biodiversity restoration by generating business and economic opportunities for farmers and providing environmental and societal benefits. The objective of this paper is to analyse organic fertilizers and biopesticides as eco-innovations for organic farmers to improve income and contribute to biodiversity restoration through recycling, circular economy, and agribusiness in organic production.

Methodology

Study area

The study area is constituted of five districts: Wakiso, Masaka, and Jinja. In the study area, the climate is tropical with a mean annual rainfall of 1614 mm, bimodal, and two seasons. The first season is from March to May, with a peak in April, and the second season is from October to December, with a peak in November. The temperature averaged between 18.14°C and 26.53°C; however, the years 2015 to 2020 registered an annual average of a minimum of 18.5°C and a maximum of 28.1°C (Majaliwa *et al.*, 2015; UBOS, 2020).

Data collection

The data collection was done through field research. The field research focuses on an on-site visit for each farm and at least one semi-structured interview with one or several members of the institutions. The selection of the organic farmers followed the multiple-stage stratified sampling procedure and was conducted to obtain a final sample of 150 organic farmers. In the first stage, three institutions (Agency for Integrated Rural Development and St. Jude Family Project, KSM Farm Limited) were purposively selected as an organization committed to organic agriculture at least 5 years ago, recognized by one Uganda national organic organization. Three institutions trained the farmers in making organic fertilizer, biopesticide, and organic practices following the agroecological approaches. In the second stage, the institutions, through some organic projects implemented, select randomly from a list of county beneficiaries of the organic fertilizer, biopesticide, and organic practices training. The visit and individual interviews were conducted with 150 organic farmers (Table 1). The data from these field visits, mostly in the form of photos or notes, were discussed after the visits by the authors and provided additional insights, especially regarding the residues and waste valorized, the innovativeness of organic fertilizer and biopesticide.

Table 1: Number of organic farmers interviewed

Institution	District	County	Number of Organic Farmers
Agency For Integrated Rural Development	Wakiso	Busiro	50
St. Jude Family Project	Masaka	Bukoto	50
KSAM Farm Limited	Jinja (Buikwe)	Kizigo	50
Total			150

Results

Recycling waste in organic production

Organic production in the study area combines agricultural production (agro-production), agroforestry, and livestock. The system of production, which integrates agro-production, agroforestry, and livestock, provides crops, vegetables, fruits, species, herbs, meat, milk, and eggs for consumption, demand, and diets. The residues and waste from the integrated system of production are recycled for manure, organic fertilizer, and biopesticides for organic production.

These organic fertilizers and biopesticides were sold at the farm level and at the local market for added value for organic production as an agribusiness. Figure 1 below depicts the interrelationship between all components of organic production and local markets as a circular economy.

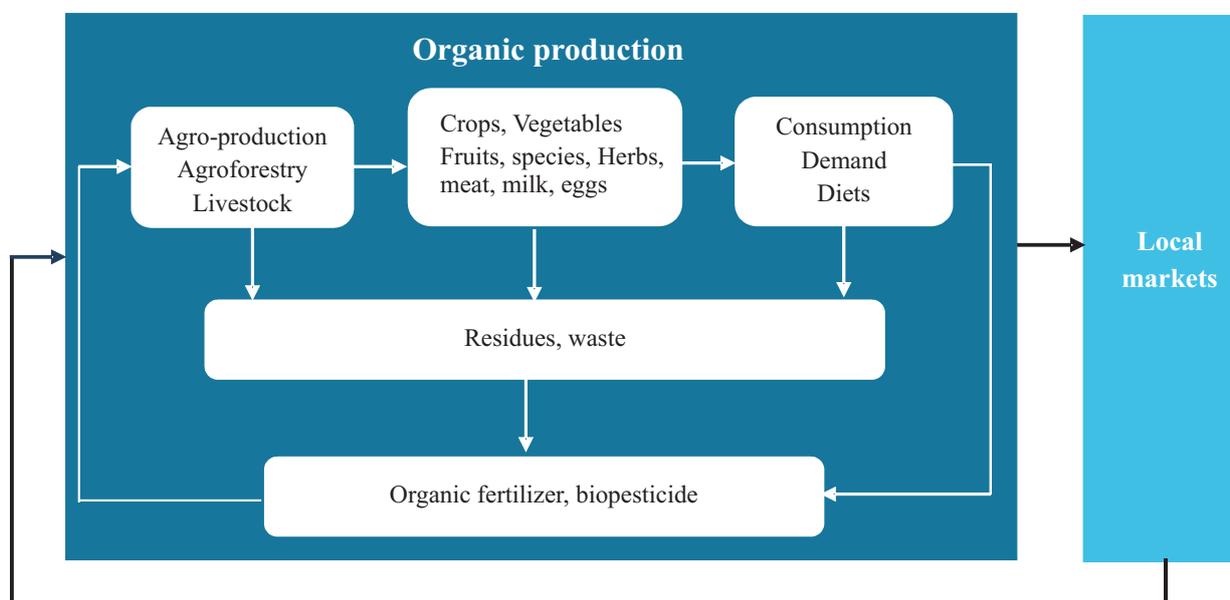


Figure 1: Organic production through recycling, circular economy, and agribusiness

Sample description

According to the findings of the study, organic farming practices were used by both men (36%) and women (64%). This means that women are overwhelmingly involved in organic production in Uganda. In organic farming, the householders are composed of on average 6 persons (minimum 1 person and maximum 20 persons) (Table 2). It is noticed that the average age of organic farmers is 53 years old, ranging between 20 and 90 years. This means that youth don't stay out of organic production despite facing more challenges than old farmers. In Uganda, on average, 2 male organic farmers and 2 female organic farmers were active in organic farming practices in the respondents' households. Meanwhile, organic production is characterized by small holdings, with an average holding size of 0.79 ha (± 0.67).

Table 2: Descriptive analysis of organic farmers

Variable		Frequency	Percentage (%)		
Sex	Female	96	64		
	Male	54	36		
		Mean	Std. Dev.	Min	Max
Age		53.1	14.16	20	90
Family size		6.34	2.96	1	20
Male actives		1.97	1.22	1	9
Female actives		2.36	1.54	1	14

Organic fertilizers and biopesticides used by organic farmers

Organic farmers benefit from the training provided by colleagues knowledgeable in making organic fertilizers or biopesticides by using local materials. Organic fertilizers or biopesticides such as Ash NPK, native, IMO, Lacto, green tea, and ash biopesticides are common organic inputs cited by organic farmer respondents. The photo shows some materials for organic fertilizers or biopesticides in the area studied.



Photo 1: Vermicompost from Coffee husk and maize cobs



Photo 2: Organic fertilizer NKP from wood ash

Recycling of residues and waste for agriculture production

The small size of organic farms in the area studied (0.79 ha; ± 0.67) provides small-quality residues and waste. In order to optimize the recycling of residues and waste, organic farmers used an innovation called "urban farming". Urban farming innovation contributes to optimizing the small size of organic farms by intercropping and increasing the yield of production. The picture below is an example of urban farming innovation.



Photo 3: Urban farming innovation through the recycling of residues and waste

Agribusiness of organic fertilizer and biopesticide in local markets

With endogenous knowledge and training at the national level, some farmers were able to create small enterprises for organic fertilizer and biopesticide. In the majority of cases, the enterprise for organic fertilizer and biopesticide is an individual enterprise in which the products are available at the local market. Some organic fertilizers and biopesticides are still in the process of certification at the national level in order to get the right of property for their innovations. The photo presents some organic fertilizers and biopesticides sold in the local market.



Photo 4: Biopesticide



Photo 5: Organic fertilizer



Photo 6: Organic fertilizer

Discussion

Organic production in Uganda is based on internal input utilization in the system of production. This system of production integrated agricultural production, livestock, agroforestry, silvopastoral, etc. However, organic farmers through experience and local training, eco-innovated by reusing the residues or waste combined with some plants to create organic fertilizers or biopesticides. For Ilham and Saktyanu (1999) and Pasaribu, (2006), farmers have experience in integrated farming systems has been proven to give synergy effect between crops, between food and horticultural crops, and livestock which has been mutually providing benefit to them as regard a circular economy. Recycle-reduce-reuse allows used resources and used materials to be part of the production and consumption process for a longer time, that is, until they are physically degraded (Shih *et al.*, 2018). a circular-based economy aimed at resource utilization, especially with the insertion of waste in the value chain, can help to reduce environmental pressure and mitigate dependence on non-renewable sources (Awasthi *et al.*, 2022; Ugwu *et al.*, 2022). Organic production through eco-innovation and circular economy presents the opportunity for organic fertilizers and biopesticides. Face this opportunity, some organic farmers launched Small and Medium Enterprises (SMEs) in order to satisfy the demand for organic fertilizers and biopesticides in the local market. However, agribusiness for organic fertilizers and biopesticides in Uganda has been promoted by the Ministry of Agriculture, Animals, Industry, and Fisheries (MAAIF), which defined the procedure for certification of organic fertilizers and biopesticides. At the market, the organic fertilizer "Blackoff" was certified by MAAIF. The organic fertilizers "Jimusa" and "Wonders" and biopesticide "Kilika" were in the process of certification. The interview with these entrepreneurs of organic fertilizer and biopesticides revealed that the raw material stems from local plants and herbs. Furthermore, vermicompost, ash biopesticide, Indigenous Micro-Organisms (IMO), Lacto produced from rice, green manure are the common organic fertilizers and biopesticides produced by individual organic farmers from agricultural and food residues and wastes. The nurturing of earthworms in organic waste has the potential to transform wastewater sludge, food waste, animal waste, municipal waste, and other wastes into valuable fertilizer (Yadav and Garg, 2019; Mahaly *et al.*, 2018; Soobhany, 2018).

Conclusion

This paper highlights organic production as an integrated system of production that combines agricultural production, agroforestry, and livestock. Organic farmers recycle the residues and waste to make organic fertilizers and biopesticides. Organic farming produces not only organic products (crops, vegetables, fruits, species, herbs, meat, milk, and eggs) but also organic fertilizers and biopesticides. The reuse of organic residues and waste contributes to a circular economy through the integration of production, livestock, and agroforestry. The circular economy in organic production reduces the cost of inputs (fertilizer and pesticide), which can positively affect the revenue of the farmers. Eco-innovation promotes local materials in organic agriculture production, which entails the opportunity for business. Organic fertilizers and biopesticides seen in the local market reflect organic farmers' agribusiness, which is based in large part on experience and local training. However, it is important for all stakeholders in an organic system to promote organic products by reducing the cost of organic product certification. This is essential for creating standards for organic input in order to reverse the conventional agriculture tendency.

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Published by:





Vulgarisation de la chaîne de valeur de l'agriculture biologique pour la sécurité alimentaire au Cameroun

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Mots clés :

Vulgarisation,
agriculture biologique,
sécurité alimentaire,
chaînes de valeur,
appui conseil

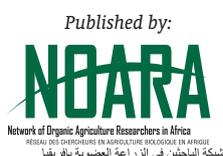
Résumé

L'objectif de cette recherche est d'analyser l'impact que la vulgarisation d'une chaîne de valeur de l'agriculture biologique peut avoir sur la sécurité alimentaire des camerounais. Plus spécifiquement, elle a pour objectifs de recenser et caractériser les différentes chaînes de valeur de l'agriculture biologique qui apportent une sécurité alimentaire autrement dit de qualité. Pour réaliser ces objectifs, un guide d'entretien et un questionnaire ont été administrés à 16 agriculteurs qui font dans l'agriculture biologique. Les informations collectées ont été analysées à l'aide du tableur Excel 2013. Les résultats indiquent que plus la vulgarisation est menée dans la chaîne de valeur de l'agriculture biologique. Plus, il y'a des consommateurs supplémentaires, plus il y'a des biens de qualité qui assurent la sécurité alimentaire. Le rôle joué par la recherche agricole, les formations des producteurs, l'encadrement est un atout. Ces enquêtes ont également permis de mettre en lumière les bonnes Pratiques Agricoles de production biologique pour permettre aux producteurs d'améliorer la qualité.

Introduction

"La vulgarisation agricole consiste à partager les résultats de la recherche et les savoir-faire avec les agriculteurs, mais aussi à les aider à exploiter une plus large part de la chaîne des valeurs." Michael Hailu, Directeur du Centre technique de coopération agricole et rurale ACP-UE (CTA), Pays-Bas sur le milliard de personnes les plus pauvres de la planète, les trois quarts vivent dans des zones rurales et une large majorité d'entre eux sont tributaires de l'agriculture pour leur subsistance et leur survie. Encourager la croissance du secteur agricole est donc l'un des moyens les plus efficaces de lutter contre la pauvreté et de réduire la faim et la malnutrition. Les petits exploitants agricoles, les pêcheurs et les éleveurs produisent 50 à 80 % des denrées de base consommées dans les pays en développement, mais nombre d'entre eux ne sont pas aidés de manière adéquate par les services de recherche, de vulgarisation et de conseil. Ces producteurs ruraux doivent être soutenus pour pouvoir améliorer leurs connaissances et leurs compétences, et ainsi tirer profit des nouvelles technologies, politiques et opportunités de marché. La revitalisation des services de vulgarisation et de conseil était le thème central de la Conférence internationale sur les innovations dans les services de vulgarisation et de conseil, qui s'est tenue à Nairobi, en novembre 2011, et a réuni plus de 450 délégués (agriculteurs, agents de vulgarisation, chercheurs, responsables

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politiques et représentants d'organisations de développement) en provenance de 85 pays. Les participants ont pu partager leurs connaissances et leurs expériences, et identifier les moyens de réformer les services de vulgarisation et de conseil au profit des petits exploitants agricoles. «L'une des causes profondes de la faible productivité en Afrique est le manque de performance des services de vulgarisation et de conseil agricoles, ainsi que le soutien financier limité qu'ils reçoivent.» Les catastrophes humanitaires attirent l'attention du monde entier mais les défis permanents auxquels les agriculteurs et les consommateurs sont confrontés revêtent une importance toute aussi grande pour notre bien-être futur. Pour ne citer qu'un seul exemple, les prix des denrées alimentaires ont connu des augmentations spectaculaires en 2010. Divers facteurs en sont la cause. De toute évidence, les mauvaises récoltes dues à la sécheresse, aux inondations et aux imprévus météorologiques dans les pays exportateurs de céréales ont entraîné une réduction de l'offre, et la facture des importations de denrées alimentaires des pays à faible revenu et à déficit alimentaire a par conséquent augmenté de 20 %. Des dizaines de millions de personnes se sont ajoutées au milliard d'individus souffrant déjà de la faim. Un an plus tard, les prix mondiaux des denrées alimentaires dépassaient de 19 % ceux enregistrés à la même période l'année précédente. Conséquence : une aggravation de la faim et de la malnutrition dans de nombreux pays en voie de développement. La croissance de la population rend le défi de la lutte contre la faim plus difficile à relever. Aujourd'hui forte de 7 milliards d'individus, la population mondiale franchira le seuil des 9 milliards en 2050. Pour répondre à la croissance démographique, la production alimentaire mondiale devra augmenter d'au moins 70 % au cours des quatre prochaines décennies. D'autres défis restent cependant à relever : le changement climatique, qui menace de diminuer le rendement des cultures, les pertes post-récolte élevées, la dégradation de l'environnement et le chômage galopant en milieu rural. Après des décennies de sous-investissement dans l'agriculture, les gouvernements et les donateurs s'accordent désormais à reconnaître la nécessité d'établir des politiques et institutions adéquates, d'accroître le soutien financier, d'améliorer l'accès aux nouvelles connaissances, aux compétences et aux marchés. La réforme des services de vulgarisation devrait faire partie intégrante d'une série de mesures pour aider les petits exploitants agricoles à améliorer leur productivité, accroître leurs revenus et contribuer à la sécurité alimentaire. «Il s'agit de changer la manière dont ils travaillent et de s'assurer que les réformes engagées sont rentables et durables». Il y'a lieu de se poser la question : La vulgarisation de la chaîne de valeur de l'agriculture biologique peut-elle contribuer à la sécurité alimentaire au Cameroun ?

Revue de la littérature

Pour (Samson et Clark, 1988), la vulgarisation agricole est assimilée à une démarche éducative qui vise à donner la possibilité aux ruraux d'améliorer leurs cadres et conditions de vie, celui de leurs proches à travers des savoirs et savoirs faire mis à leur disposition.

Cela rappelle le vieil adage qui dit : « *aider les gens à s'aider eux-mêmes* » et en langue anglaise : « *help people to help themselves* ». Il faut donc comprendre là tout simplement qu'aider des personnes à se démerder eux-mêmes pour s'en sortir et se forger un avenir soit la mission du vulgarisateur. Pour en arriver à entraîner, permettre ou favoriser les ruraux à cela, le vulgarisateur devra au préalable bien les comprendre dans leurs situations réelles et effectives. Le développement socioéconomique des pays sous-développés pourrait ainsi se faire d'une part importante par la vulgarisation agricole en passant par des résultats encourageants obtenus de l'augmentation des revenus à court, moyens et longs termes faisant suite à une progression notable de la production agropastorale.

Vu sur cet angle ou sur cet aspect, l'acquisition par des ruraux des savoirs et savoirs faire issus des progrès scientifiques et techniques pourront se faire au moyen de la vulgarisation. Dans le même sens, il en est pareil pour l'abandon subséquent des techniques et pratiques moins appropriées, voire archaïques et c'est pourquoi l'expression de système intégré est très souvent utilisé pour désigner ou caractériser la vulgarisation agricole. La vulgarisation est à l'origine normalement d'un changement de comportement du sujet. Le champ d'investigation de la vulgarisation s'élargit donc comme nous le disions tout à l'heure, car si l'on veut que le sujet modifie son comportement, il faut connaître:

- **son milieu** ou son «*écologie*», au sens large du terme; ce qui nous permet d'expliquer en partie le comportement du sujet et les contraintes que celui-ci induit,
- **son aptitude à accepter l'innovation** qui est sous l'influence des facteurs *endogènes* (le *milieu*) et *exogènes* (l'*action de vulgarisation*, entre autres).

En agriculture de subsistance par exemple, la pratique de la culture associée est liée au principe de sécurité alimentaire qui en est le fondement. L'aptitude à accepter l'innovation sera, dans ce cas, étroitement corrélée à l'évaluation par l'agriculteur des risques que comporte l'innovation en terme de garantie à la sécurité alimentaire.

Les systèmes de vulgarisation agricole existants sont nombreux et variés. Il n'est pas toujours évident d'en établir une classification rationnelle. On peut néanmoins opposer:

- *La vulgarisation individuelle et la vulgarisation de masse.*

La première implique une relation individuelle entre le vulgarisateur et l'agriculteur.

La vulgarisation de masse s'adresse, de manière unique, à un public qui, dans certains cas, doit être le plus vaste possible. On peut y ranger: l'animation rurale, la vulgarisation au moyen des supports médiatiques (revues, livres, émissions radiophoniques et télévisées...).

- *La vulgarisation basée sur une spéculation ou celle qui intègre l'ensemble de l'exploitation agricole.*

Dans la première catégorie, on rencontre souvent les systèmes de vulgarisation agricole des entreprises agro-industrielles (tabac, coton,...) alors que dans la seconde, il s'agit très souvent des systèmes mis en place dans le cadre de programmes intégrés de développement agricole.

- *La vulgarisation publique ou privée.*

On pourrait rapprocher cette différenciation de la précédente dans la mesure où, bien souvent, la vulgarisation basée sur une spéculation est de caractère privé alors que la vulgarisation intégrant l'ensemble de l'exploitation agricole bénéficie la plupart du temps d'un financement public. Il peut également exister des systèmes mixtes tels que ceux mis en place dans des pays producteurs de coton africains où la vulgarisation a élargi son champ d'action aux cultures vivrières de la rotation et bénéficie, à ce titre, d'un soutien financier des pouvoirs publics.

La vulgarisation agricole au Cameroun a connu plusieurs orientations et dispositifs qui peuvent être matérialisés en trois grandes phases depuis l'accession du pays à son indépendance en 1960. Il s'agit:

- du système d'encadrement descendant et normatif dans les années 1960-1986, avec des plans quinquennaux décidés "d'en haut" par l'Etat;

- des programmes d'ajustement structurel des années 80 et surtout 90, avec le désengagement de l'État, une Nouvelle politique agricole et un accent particulier sur le développement des organisations de producteurs;

- de la révision de la Nouvelle politique agricole et de nouveaux défis depuis 1999, avec la complexification du paysage d'acteurs et des initiatives menées dans le cadre de politiques agricoles plus reconnaissantes de la place des producteurs et leurs organisations, et le développement d'approches se voulant plus participatives et orientées vers du conseil agricole aux exploitations familiales.

Entre la fin des années 60 et le début des années 80, les pouvoirs publics, à travers les plans quinquennaux de développement, ont eu à concevoir et définir les politiques agricoles nationales sans impliquer les autres acteurs. Le secteur agricole était alors tributaire de l'économie administrée en vigueur. L'interventionnisme de l'État était supposé permettre le passage de l'agriculture de subsistance à l'agriculture moderne. Les orientations étaient alors : maintien et consolidation de l'autosuffisance alimentaire ; développement des cultures d'exportation ; amélioration du niveau et des conditions de vie en milieu rural.

Par le biais de divers mécanismes et sociétés (Coopmut, Sodécao, Zapi...), l'État assurait de nombreux services aux producteurs : fourniture d'intrants, crédits, production de semences et plants, encadrement, etc.

Les sociétés de développement étaient alors conçues et mises en œuvre pour être les principaux instruments du développement local et de l'amélioration de la compétitivité des filières basées pour l'essentiel sur des cultures industrielles et d'exportation (palmier à huile, hévéa, cacao, café...). Les plans étaient soutenus par des subventions en faveur du secteur agricole (notamment sur les intrants agricoles). Mais des blocages certains ont vite pointé aux différents niveaux : système d'encadrement peu performant - sur le terrain, pour la majorité des paysans, les agents de contact étaient peu nombreux et insuffisamment formés ; accès insuffisant des paysans aux intrants et autres facteurs de production ; stagnation de la productivité des exploitations; vieillissement des exploitations et des producteurs; retard accumulé par la recherche agricole en matière de cultures vivrières.

Au cours du 5^{ème} plan (1981-85), les orientations affichées ont évoluées avec notamment :

- l'établissement de relations « d'un type nouveau » entre l'administration et les paysans (planteurs plus responsabilisés à travers le renforcement du mouvement coopératif) ;

- la prise en compte des revenus des producteurs (et non plus des seuls intérêts des consommateurs urbains) dans la

fixation des prix agricoles ;

-la maîtrise (par l'État) de la production et de la transformation des produits agricoles ;

-la création d'une structure de développement dotée d'une autonomie administrative et financière dans chaque zone agricole ;

-l'intensification de la formation des agents de développement ruraux ;

-un encadrement des paysans opérationnel dans les zones couvertes par des sociétés de développement ;

-la subvention de l'accès à certains facteurs de production (notamment les intrants agricoles), dans le but de promouvoir l'autosuffisance alimentaire (engrais depuis 73 à 45-60 % ; pesticides à 100 %). Néanmoins, les orientations de ce dernier plan quinquennal ne seront pas suffisantes pour faire face à la crise économique au début des années 80.

La sécurité alimentaire? dans les pays en développement est loin d'être garantie, en dépit de la multiplicité et de la diversité des programmes mis en place dans le cadre des politiques agricoles nationales. Ces pays, qui ne produisent qu'une partie des denrées alimentaires de grande consommation, sont toujours tributaires de l'étranger pour assurer l'approvisionnement de leurs populations en aliments de base. Des facteurs multiples et interdépendants sont à l'origine de ce problème de la sécurité alimentaire dans les pays du Sud.

En 2021, selon la FAO, sur le continent africain, 1 personne sur 5 était touchée par la faim soit 278 millions de personnes. 425 millions de personnes en Asie soit 9 % de la population. L'Amérique du Sud et les Caraïbes 56 millions soit 8.6 %. Autrement dit 80 % des personnes souffrant de la faim vivent dans les zones rurales et le phénomène touche principalement les petites exploitations familiales qui fournissent pourtant la plus grande partie de l'alimentation mondiale. Le lien entre sécurité alimentaire, développement agricole et prospérité dans les zones rurales est donc particulièrement fort. Par ailleurs selon Antonio Guterres secrétaire général des Nations unies, la guerre en Ukraine menace de déclencher une vague sans précédent de faim et de misère. Les difficultés pour des millions de personnes d'accéder à une alimentation saine au quotidien ne sont pas une nouveauté. Elles ont été décuplées par les effets de la guerre et, avant cela, ceux de la pandémie de COVID-19 ébranlant les piliers d'un système alimentaire mondial déjà précaire. Il faut faire preuve de vigilance et bien séparer les effets conjoncturels, dramatiques au demeurant, du conflit en Ukraine, et les caractéristiques structurelles de l'insécurité alimentaire.

A cet effet, la souveraineté alimentaire pourrait être alors le pilier d'une politique publique globale de sécurité alimentaire. Elle repose sur la reconnaissance, pour chaque population, chaque État, chaque groupe d'États, du droit à se donner les moyens de produire, pour eux-mêmes, leur propre nourriture aux conditions qu'ils choisissent en toute autonomie, et ce à travers les politiques agricoles qui leur semblent les mieux adaptées pour garantir la sécurité alimentaire.

Selon une estimation de la FAO, le nombre de personnes sous-alimentées dans le monde s'élève à 852 millions pour la période 2000-2002, soit 815 millions de personnes dans les pays en développement, 28 millions dans les pays en transition et 9 millions dans les pays industrialisés (FAO, 2004). Si l'on considère l'Afrique Subsaharienne dans son ensemble, 37% d'Africains n'ont pas assez à manger, comparé à 17% de la population dans le reste du monde en développement. Cette même proportion s'élève à 55% en Afrique centrale [FAO (2004) cité par Oxfam, 2006]

Parmi de nombreux facteurs qui déterminent la sécurité alimentaire de ces millions de personnes, Madeley (2002) cite la pauvreté, l'appauvrissement des sols, la désertification, la méconnaissance du rôle des femmes agricultrices, les catastrophes naturelles, le sous financement de l'agriculture, la dette extérieure, les guerres, l'absence de démocratie, les changements climatiques, la croissance démographique et les difficultés d'accès aux terres, le manque d'eau, la réduction des services médicaux, les pêcheries locales prises d'assaut.

Comme réponse à cette question complexe d'insécurité alimentaire, le libre échange est la « baguette magique » proposée par la communauté internationale. En effet l'ouverture des marchés est au centre de la controverse de la question alimentaire et suscite actuellement beaucoup de débats, tant plusieurs voix s'élèvent pour encenser le processus et d'autres pour le stigmatiser.

En théorie, permettre à chacun d'avoir un revenu décent suffirait à garantir son alimentation puisque le problème n'est pas causé par le manque physique d'aliments (Guihéneuf et Pisani, 1996). Pour ces auteurs, le revenu est l'élément clé de la sécurité alimentaire et ce revenu pouvant être amélioré par la libéralisation des échanges, il va de soi, et en restant dans la logique de cette analyse, que la libéralisation commerciale peut avoir un impact globalement positif sur la sécurité alimentaire. La lutte contre la pauvreté devient ainsi le slogan fort de la recherche de la sécurité alimentaire car,

comme le souligne la FAO (1996a) dans la déclaration du sommet mondial de l'alimentation, « L'éradication de la pauvreté est essentielle à l'amélioration de l'accès à la nourriture. La grande majorité des personnes sous-alimentées ne sont pas en mesure de produire ou d'acheter des quantités suffisantes d'aliments. Elles ont un accès inadéquat aux moyens de production tels que la terre, l'eau, les intrants, les semences et végétaux améliorés, les technologies appropriées et le crédit agricole.

La FAO (1996a) relève également le paradoxe qui existe dans un contexte d'accroissement de la production alimentaire et l'augmentation du nombre de personnes prises au piège de la faim. Elle note que « Les disponibilités alimentaires ont considérablement augmenté, mais les difficultés d'accès à la nourriture, l'insuffisance chronique des revenus familiaux et nationaux pour l'achat d'aliments, l'instabilité de l'offre et de la demande, ainsi que les catastrophes naturelles ou causées par l'homme, empêchent la satisfaction des besoins alimentaires essentiels. La faim et l'insécurité alimentaire sont des problèmes aux dimensions planétaires qui risquent fort de persister, voire de s'aggraver de façon dramatique dans certaines régions, si des mesures énergiques et concertées ne sont pas prises de toute urgence, compte tenu de l'accroissement prévu de la population mondiale et de la pression exercée sur les ressources naturelles. »

La sécurité alimentaire se repose sur les racines de la pauvreté. Une croissance économique globale et durable constitue dès lors la première fondation qui garantisse un accroissement des revenus et un accès à la nourriture (Viatte, 1996). Les problèmes de sécurité alimentaires ne découlent pas obligatoirement d'une insuffisance des approvisionnements. Ils résultent plutôt d'un manque de pouvoir d'achat au niveau des pays ou des ménages. A long terme, la sécurité alimentaire passe par le relèvement du revenu réel des ménages, qui leur permet d'acheter assez à manger (Banque Mondiale, 1986).

De même Le Roy (1994) note que la cause de la faim n'est pas l'insuffisance de la production, mais la pauvreté et la précarité. Cet auteur pense également que la production agricole mondiale pourrait encore augmenter rapidement si les nécessaires étaient solvables. Pour lui, la faim n'est pas un problème agricole au sens strict du terme, ce n'est pas un problème de production. Pour venir à bout de la faim conclut-il, il ne s'agit pas nécessairement d'accroître les volumes de production agricole, il faut mettre en œuvre des politiques de développement.

La pauvreté étant diagnostiquée par tous comme la cause majeure de l'insécurité alimentaire, les politiques de développement que propose Le Roy, seraient-elles des politiques commerciales qui favoriseraient un plus grand accès des pauvres au marché ? Seraient-elles des politiques de l'emploi qui amélioreraient leur revenu afin de leur permettre de produire ou alors de se procurer des denrées alimentaires ?

En effet pour les théoriciens de la doctrine néo-libérale, les lois du marché assurent une meilleure allocation des ressources, favorisent la croissance tout en améliorant les revenus des plus démunis. La libéralisation des échanges à travers le commerce des denrées agricoles constitue donc pour eux la voie de sortie de cette impasse alimentaire.

Le PNUD (2005) fait remarquer qu'un commerce développé offre des possibilités incommensurables en terme de développement humain. Pratiqué dans les conditions adéquates, cette activité présente un potentiel non négligeable de réduction de la pauvreté, de restriction des inégalités et de victoire sur les injustices économiques. Oxfam (2002) observe également que le commerce peut constituer un puissant moteur pour la croissance économique et pour la réduction de la pauvreté mais à la seule condition que les pays pauvres aient accès aux marchés des pays riches. Cette observation d'Oxfam est corroborée par la CNUCED (2004) qui dans son rapport 2004 sur les Pays les Moins Avancés (PMA) note que le commerce international peut fortement contribuer à réduire la pauvreté dans les PMA ainsi que dans d'autre Pays En Développement (PED). Toutefois, pour que cette contribution soit efficace, « les politiques nationales et internationales qui peuvent faciliter cette contribution doivent s'appuyer sur une approche du commerce inspirée par le développement plutôt que sur une approche du développement dominée par le commerce » CNUCED (2004 : 69)

Le commerce des produits agricoles peut donc contribuer de manière efficace à la lutte contre l'insécurité alimentaire. La FAO (1998) affirme à cet effet que sans commerce, les pays ne pourraient compter que sur leur propre production ; cela diminuerait considérablement leur revenu global, réduirait le choix des denrées agricoles et augmenterait le nombre d'affamés. Il s'agit donc pour cette organisation en charge des questions d'alimentations « d'encourager la création d'emplois et de revenus, de favoriser un accès équitable aux ressources productives et financières, de poursuivre des politiques commerciales, dans tous les domaines et dans celui des denrées alimentaires, qui encourageront les producteurs et les consommateurs à utiliser les ressources disponibles de façon économiquement rationnelle et durable »

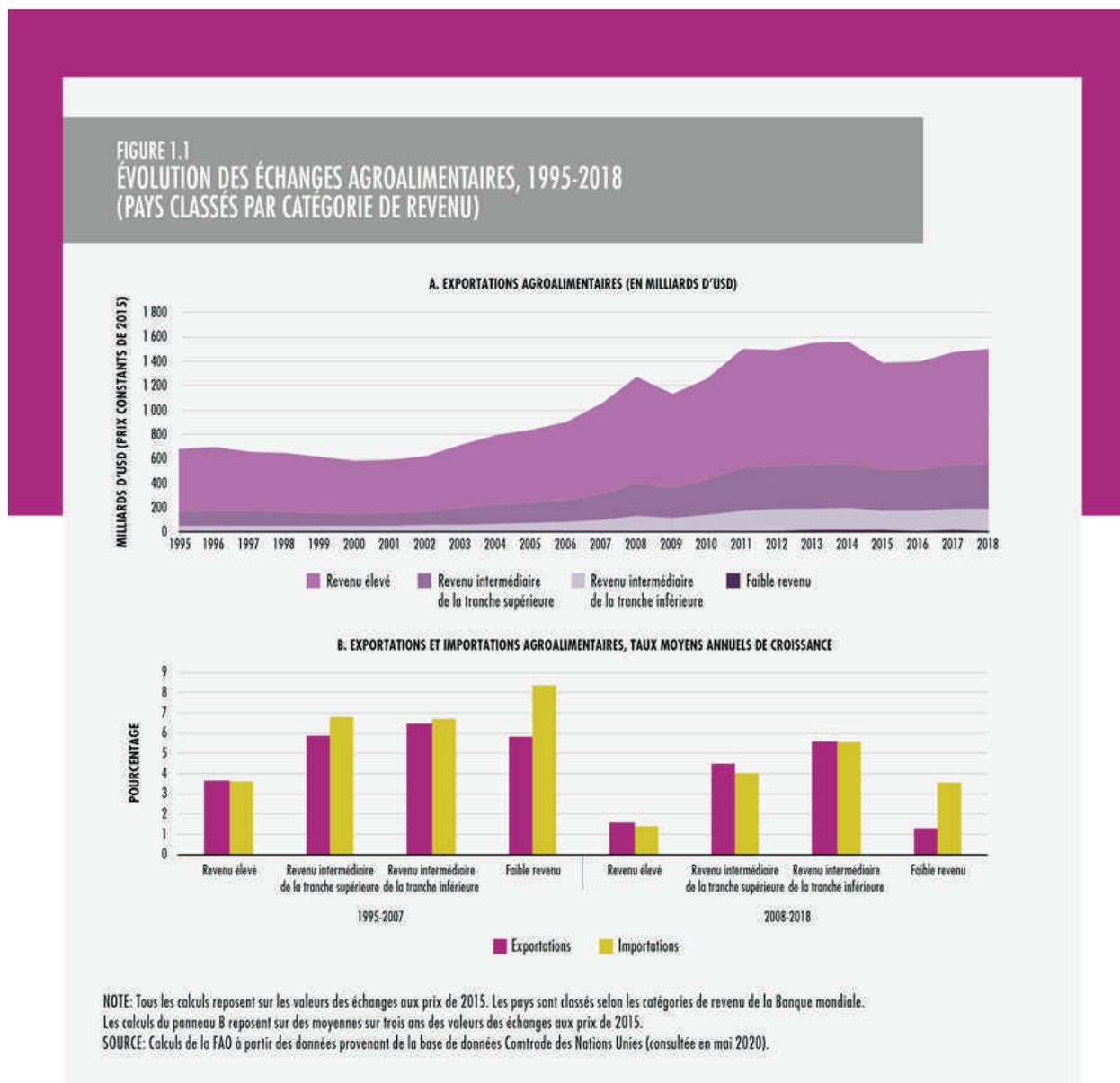
L'engagement quatre (4) de la déclaration de Rome sur le Sommet mondial de l'alimentation illustre à suffisance le rôle que doivent jouer les politiques commerciales. Il stipule : « Nous nous efforcerons de faire en sorte que les politiques concernant le commerce des denrées alimentaires et agricoles et les échanges en général contribuent à renforcer la sécurité alimentaire pour tous grâce à un système commercial mondial à la fois juste et axé sur le marché. »

Un pays qui accroît ses revenus grâce au commerce a théoriquement plus de ressources pour combattre la pauvreté (Madeley, 2002) et par voie de corollaire plus de ressources pour combattre l'insécurité alimentaire. Bien que le rapport entre le commerce et la sécurité alimentaire soulève des questions complexes et que l'accroissement du volume des échanges commerciaux s'est accompagné d'une détérioration des termes de l'échange pour les Pays en voie de Développement (PVD) et réduit leur gain potentiel, la libéralisation est un élément fondamental dans les trains de mesures qui favorisent la croissance (FAO, 1996b).

L'accès au marché à travers l'ouverture des échanges permet d'augmenter les recettes d'exportations qui permettront aux populations d'acheter moins cher de la nourriture qu'elles n'ont pas pu produire elles même sur place. Ainsi les exportations revêtent un caractère important, non seulement - ou même principalement - parce qu'elles sont un moyen de financer les importations des nouvelles technologies nécessaires à la création de croissance, de productivité et d'emploi, et l'amélioration des niveaux de vie et au maintien de la compétitivité au sein des marchés mondiaux (PNUD, 2005). Faisant la même analyse, Oxfam (2006) remarque que le commerce international des produits agricoles peut à la fois améliorer et dégrader la sécurité alimentaire. Du côté positif, elle note que « les importations peuvent permettre à des pays qui ont un déficit alimentaire de couvrir les besoins de leurs populations, alors que les exportations comme le coton et le café peuvent fournir aux agriculteurs un revenu en liquide très précieux pour compléter leur production alimentaire ».

Méthodologie et résultats

Pour réaliser cette étude, nous avons fait recours à un guide d'entretien et un questionnaire ont été administrés à 16 agriculteurs qui font dans l'agriculture biologique. Les informations collectées ont été analysées à l'aide du tableur Excel 2013. Il ressort de ces résultats que depuis le début du XXI^e siècle, le commerce mondial des produits agricoles et alimentaires (agroalimentaires) a singulièrement évolué. Il a plus que doublé en valeur réelle sur la période 1995-2018, passant de 680 milliards à 1 500 milliards d'USD (mesuré aux prix de 2015). Sur cette période, la part des échanges agroalimentaires dans le total du commerce de marchandises a été de 7,5 pour cent en moyenne. La tendance ascendante a atteint son point culminant lors de la crise des prix des denrées alimentaires de 2007-2008, avant d'être brutalement interrompue par la crise financière de 2008 et la récession mondiale qui a suivi. Malgré le rétablissement du commerce en 2010 et 2011 et le nouvel envol des prix des produits de base, le ralentissement de l'économie mondiale, en particulier dans les pays émergents tels que la République populaire de Chine, a eu des répercussions importantes, à la fois sur les échanges et sur les prix des produits de base. Depuis 2014, le recul en valeur du commerce agroalimentaire s'explique principalement par la baisse des prix des produits de base et les fluctuations des taux de change, les taux de croissance ayant recommencé à augmenter en partie entre 2016 et 2018 (Figure 1).



Les pays à revenu élevé réalisent la majeure partie du commerce agroalimentaire en valeur, mais les économies émergentes et les pays en développement prennent une part croissante aux marchés mondiaux. Depuis le début du nouveau millénaire, les pays à revenu intermédiaire des tranches inférieure et supérieure ont accru leur part des exportations agroalimentaires mondiales, de 25 pour cent environ en 2001 à 36 pour cent en 2018. Durant la même période, la part des pays à faible revenu dans les échanges agroalimentaires mondiaux est demeurée presque inchangée, autour de 1,1 pour cent.

À partir de 2008, compte tenu du ralentissement de l'économie mondiale, les exportations et les importations agroalimentaires ont connu une croissance poussive, comparée à celle de la période 1995-2007, et ce en particulier dans les pays à revenu élevé, dont l'économie a été plus durement touchée par la crise financière. Les pays à faible revenu, qui, pour beaucoup, exportent vers les marchés des pays à revenu élevé, ont également pâti du ralentissement de la demande sur ces marchés et de la baisse des prix des produits de base. Les exportations et les importations des pays à revenu intermédiaire des tranches inférieure et supérieure ont continué de croître rapidement entre 2009 et 2011, et ce n'est qu'ensuite qu'elles ont marqué le pas.

Durant toute la période 1995-2018, les importations agroalimentaires du groupe des pays à revenu élevé ont été supérieures aux exportations, tandis que le groupe des pays à revenu intermédiaire des deux tranches affichait une position d'exportateur net.

Les importations du groupe des pays à faible revenu sont restées légèrement supérieures aux exportations entre 1995 et 2000, avant d'augmenter nettement jusqu'en 2011, puis de se stabiliser. À l'échelle mondiale, la majeure partie des produits alimentaires sont échangés par des pays à revenu élevé. En moyenne, tous les groupes de pays, quelle que soit leur catégorie de revenu, importent davantage de produits alimentaires que de produits agricoles de base. Les pays à revenu intermédiaire des deux tranches exportent plus de produits alimentaires qu'ils n'en importent, ce qui témoigne, en moyenne là encore, d'une industrie de transformation bien développée et tournée vers l'exportation. Les exportations des pays à faible revenu se caractérisent par une plus large part de produits agricoles de base, car ces pays sont spécialisés dans la production de matières premières et leur secteur alimentaire est relativement moins développé (Figure 2 et 3).

L'orientation vers l'exportation varie nettement selon les pays. Alors que les pays des régions Europe et Asie centrale et Asie de l'Est et Pacifique commercent généralement avec d'autres pays de la même région, ceux des régions Asie du Sud, Amérique latine et Caraïbes, Afrique subsaharienne, Amérique du Nord, et Moyen-Orient et Afrique du Nord sont plus tournés vers des échanges mondiaux.

	Prévalence de l'insuffisance alimentaire (%)	Nombre de personnes sous-alimentées (millions)	Ampleur du déficit alimentaire (Kcal/personne/jour)
Cameroun	16,6	2,3	64
Congo-Brazzaville	40,2	1,3	196
Éthiopie	42,4	31,9	244
Haïti	59,1	5,5	530
Kenya	32,4	9,8	136
Maroc	8,3	-	33
Népal	13,3	2,2	49
Niger	14,6	1,8	58
Nigéria	11,3	11,9	40
Philippines	21,2	13,9	96
Sri Lanka	30,1	4,9	200
Tchad	43,6	4,8	276
Togo	19,4	12,9	85
Zambie	55,1	7,3	411
Yémen	35,7	6,5	180

Figure 2 : L'insécurité alimentaire au prisme de la sous-alimentation (2013-2022)
Source : (FAO, 2022)

	1990	2000	2012	2013	2014
Afrique du Sud	846	1 254	7 448	6 777	6 272
Algérie	2 306	2 578	9 998	10 467	11 784
Chili	308	1 228	5 911	6 076	6 114
Colombie	395	1 405	5 872	5 842	5 989
Égypte	2 903	3 519	15 666	11 674	14 898
Indonésie	1 104	3 336	15 828	16 395	17 028
Jordanie	672	851	3 598	3 691	4 042
Kenya	199	403	1 961	1 820	1 895
Koweït	561	1 249	3 676	4 435	4 917
Malaisie	2 021	3 526	16 518	15 610	16 537
Maroc	677	1 585	5 581	4 872	5 619
Mexique	4 326	8 485	22 859	25 113	25 811
Philippines	1 348	2 598	6 819	6 723	8 243
Sénégal	350	362	1 554	1 588	1 481
Thaïlande	1 672	2 677	12 638	12 851	12 590

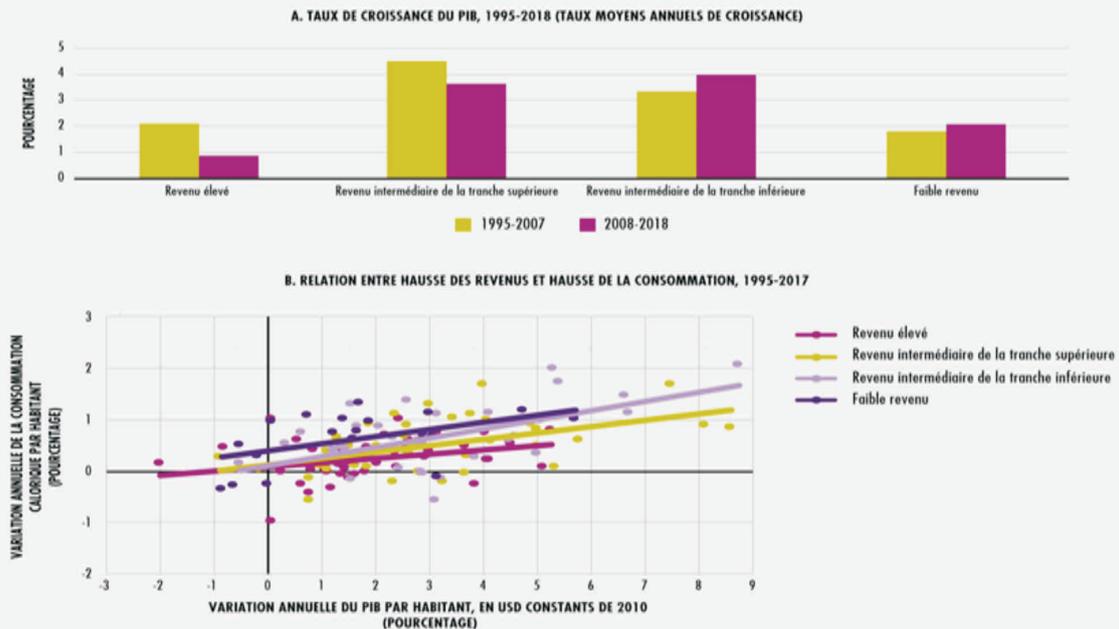
Figure 3 : Évolution du coût des importations alimentaires (en millions de dollars)
Source : (WTO, 2015)

De façon générale, le commerce est influencé par les revenus, mais il peut aussi être l'un des déterminants de la croissance économique dans la mesure où il favorise les gains d'efficacité et les retombées technologiques. La relation entre commerce et revenus est loin néanmoins de faire l'unanimité. Entre 1995 et 2018, c'est-à-dire une période caractérisée par une ouverture croissante des marchés et une intensification des échanges, la croissance des revenus dans les différents pays tend à montrer que la mondialisation ne sert que partiellement la convergence. Dans les pays à revenu intermédiaire des deux tranches, les taux de croissance des revenus ont été bien plus élevés que dans les pays à revenu élevé, ce qui indique que, sur la période 1995-2018, les premiers ont comblé une partie de leur retard sur les seconds. En revanche, les revenus n'ont crû que lentement dans les pays à faible revenu, ce qui suggère un défaut de convergence et un creusement des écarts.

La crise financière de 2008 aussi a eu des effets sur la croissance des revenus. Les pays à revenu élevé, où les systèmes financiers étaient plus endettés et l'expansion du crédit plus forte, ont été frappés de façon disproportionnée par la crise financière et ont subi de plus fortes révisions à la baisse de leur activité économique. Les pays à revenu intermédiaire de la tranche supérieure aussi ont enregistré un ralentissement de la croissance des revenus entre 2008 et 2018, mais dans une nettement moindre mesure. En revanche, un ensemble plus large de pays en développement, des pays à faible revenu et à revenu intermédiaire de la tranche inférieure peu intégrés dans les marchés financiers mondiaux, a été moins touché par la crise de 2008. Pour l'essentiel, ces évolutions des revenus se retrouvent aussi dans les échanges agroalimentaires

Les grands changements socioéconomiques associés à la croissance des revenus s'accompagnent de transformations notables des modes de consommation alimentaire un processus décrit sous l'appellation de «transition nutritionnelle». Aux premiers stades de cette transition, la croissance des revenus va de pair avec des niveaux d'apport alimentaire plus élevés et une moindre incidence de l'insécurité alimentaire. Les régimes alimentaires sont alors peu diversifiés et comportent une proportion relativement importante de féculents. Suit un stade de croissance accélérée de la consommation calorique, qui s'accompagne d'une augmentation de l'apport en protéines et en vitamines et minéraux, l'ensemble pouvant se traduire par une amélioration de la nutrition et des résultats en matière de santé. Bien souvent, toutefois, cette évolution se fait en parallèle, ou est rapidement suivie, d'un changement de régime alimentaire qui fait une plus large place aux graisses, au sucre et aux aliments transformés (Figure 4).

FIGURE 1.8
DYNAMIQUE ET CROISSANCE DES REVENUS ET DE LA CONSOMMATION ALIMENTAIRE
(PAYS CLASSÉS PAR CATÉGORIE DE REVENU)



voire hautement transformés. Au dernier stade de la transition nutritionnelle, et tandis que les revenus progressent encore, la croissance de la consommation calorifique par habitant ralentit et les régimes alimentaires évoluent vers des graisses de meilleure qualité, une part plus large faite aux fruits et légumes, et une augmentation de la consommation de céréales complètes. Pendant toute la transition nutritionnelle, la part de l'alimentation dans les dépenses des ménages décroît à mesure que les revenus augmentent (conformément à la loi d'Engel)^c.

^c La relation entre la part de l'alimentation dans le total des dépenses et le revenu porte le nom du statisticien Ernst Engel (1821-1896).

La transition nutritionnelle se retrouve également dans la loi de Bennett, qui établit qu'à mesure que les gens s'enrichissent, ils délaissent les régimes où prédominent des féculents de base et adoptent une alimentation plus variée dans laquelle entre une gamme plus large de fruits, de légumes et de protéines d'origine animale^d.

Les données agrégées font clairement écho aux stades de la transition nutritionnelle (figure 1.8, panneau B). Dans les pays à faible revenu, la hausse des revenus par habitant est associée à une hausse de la consommation calorifique par habitant. Lorsque la croissance des revenus s'accélère, cet effet se renforce dans les pays à

Conclusion

L'objectif de cette étude était d'analyser le lien entre la pratique de vulgarisation de la chaîne de valeur de l'agriculture biologique et la sécurité alimentaire au Cameroun. Cela dit, les caractéristiques de la cible, de son niveau d'implication, de sa motivation à entrer en apprentissage ont une influence considérable dans le choix des méthodes et des techniques à déployer. Une action de groupe dont la dynamique se veut à tout moment présente est indispensable pour la mise sur pied des ressources. Ainsi, exercice de terrain, de contact avec les ruraux, et non exercice de bureau, là sont les maîtres mots qui caractérisent le métier de vulgarisateur agricole. Le vulgarisateur devra sans préjugés ou jugements de valeurs étudier d'abord les populations et les apprécier à leur juste titre avant d'amorcer sa tâche. Les taux d'adoption des innovations, l'engouement manifesté par les ruraux pendant des séances d'apprentissage, les capacités de ces derniers à

reproduire les enseignements reçus aux autres sont là quelques paramètres qui pourront permettre de tester le niveau d'efficacité d'un vulgarisateur. Le développement de la vulgarisation de la chaîne de valeur de l'agriculture biologique est de toute évidence une condition de la sécurité alimentaire. Il passe par l'élaboration d'une politique agricole forte, efficace et adaptée à chaque pays. Les politiques agricoles doivent par ailleurs cesser d'être l'apanage des entreprises privées, des sociétés transnationales ou des institutions internationales, et devenir l'affaire des populations et de l'État. Il s'agit là de réaffirmer l'importance de l'État, dont les marges de manœuvre se sont vues significativement réduites, en tant qu'acteur numéro un des domaines de l'agriculture et de l'alimentation. La valorisation du rôle de l'État peut lui permettre d'assurer la mobilisation des ressources agricoles existantes, et garantir un approvisionnement alimentaire durable des populations.

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Profitability and Determinants of Profit Efficiency among Small Scale Organic Vegetable (Spinach) Farmers in Niger State, Nigeria

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Keywords:

Organic Vegetable, Profit Efficiency, Production, Farmer, Inefficiency Factors

Abstract

The study examined the profitability and determinants of profit efficiency among small-scale organic vegetable (spinach) farmers in Niger State, Nigeria. Descriptive statistics, farm budgeting technique, perception index and stochastic frontier profit function were used to analyze the data. A multi-stage sampling procedure was employed in selecting 148 organic vegetable farmers. Results show that most (82%) of the farmers were male and with mean of 40 years. It was revealed that 70% of the farmers had one form of education or the other with primary education constituting 57.3%. The farmers were experienced with mean of 5 years and 76.67 percent of them had not more than a hectare of farm size. The profitability result revealed that organic vegetable production was profitable with an estimated net farm income and Gross margin of N67,808.31 and N 70,273.56 per hectare respectively and the return on investment of N1.53 was realized as profit for every one naira invested in production of organic vegetable (spinach). The gross ratio of 0.46 and the operating ratio of 0.44 are indicators that organic vegetable production was profitable in the study area. The Tranlog Stochastic function result revealed that planting material, organic manure, labour, depreciation on equipment, farm size, age, household size, farming experience, awareness of organic farming and access to information on organic farming had significant effects on the profit efficiency of organic vegetable farmers in the study. The study recommended that efforts should be made by encouraging farmers to adopt organic vegetable farming in order to increase their output.

Rentabilité et Déterminants de L'efficacité des Profits Chez les Petits Producteurs de Légumes Biologiques (Épinards) dans L'état de Niger, Nigeria

Résumé

L'étude a examiné la rentabilité et les déterminants de l'efficacité des profits chez les petits producteurs de légumes biologiques (épinards) dans l'État de Niger, au Nigeria. Les statistiques descriptives, la technique de budgétisation agricole, l'indice de perception et la fonction de profit à frontière stochastique ont été utilisés pour analyser les données. Une procédure d'échantillonnage à plusieurs degrés a été utilisée pour sélectionner 148 producteurs de légumes biologiques. Les résultats montrent que la plupart (82 %) des agriculteurs sont des hommes, âgés en moyenne de 40 ans, et que 70 % d'entre eux ont suivi une forme d'enseignement ou une autre, l'enseignement primaire représentant 57,3

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Mots clés :

Légumes biologiques, rentabilité, production, agriculteur, facteurs d'inefficacité

%. Les agriculteurs étaient expérimentés, avec une moyenne de 5 ans, et 76,67 % d'entre eux n'avaient pas plus d'un hectare d'exploitation. Le résultat de la rentabilité a révélé que la production de légumes biologiques était rentable avec un revenu agricole net estimé et une marge brute de 67 808,31 N et 70 273,56 N par hectare respectivement et le retour sur investissement de 1,53 N a été réalisé comme bénéfique pour chaque naira investi dans la production de légumes biologiques (épinards). Le ratio brut de 0,46 et le ratio d'exploitation de 0,44 indiquent que la production de légumes biologiques est rentable dans la zone d'étude. Les résultats de la fonction stochastique Tranlog ont révélé que le matériel de plantation, le fumier organique, la main-d'œuvre, l'amortissement de l'équipement, la taille de l'exploitation, l'âge, la taille du ménage, l'expérience agricole, la sensibilisation à l'agriculture biologique et l'accès à l'information sur l'agriculture biologique avaient des effets significatifs sur la rentabilité des producteurs de légumes biologiques de l'étude. L'étude recommande que des efforts soient faits pour encourager les agriculteurs à adopter l'agriculture biologique afin d'augmenter leur production.

Introduction

Research shows that more than 75% of farming community in Africa, practiced subsistence and/or traditional agriculture. This is as a result of low skills, knowledge and asset base, agricultural productivity has declined over the years and is 2-3 times lower than the world average (FAO, 2009). There is, therefore, a growing need to provide food to an increasing population through innovative and adapted sustainable farming systems like organic farming. The United States Department of Agriculture (USDA) defines organic farming as a farming system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives to the maximum extent feasible, or the farming system that relies on crop rotations, residues, animal manure, legumes, green manure, off-farm organic wastes, and the aspects of biological pest control measures, soil productivity and tilt, to supply plant nutrients and to control insects, weeds and other pests (Alvares *et al.*, 1999). Organic agricultural production system is gaining popularity as one of the options which can enhance production of healthy food in a sustainable way (NEP-UNCTAD-CBTF, 2008). It contributes to the achievement of MDG (Millennium Development Goal) on eliminating Poverty and hunger; and enhancing environmental sustainability, respectively. Over time, it was realized that the effects of the chemicals used in the course of farming have lots of negative effects on both the environment and health of man, hence the need to discourage such practice and encourage the other alternative that is, organic farming (Kutama *et al.*, 2013). The vigorous growth of organic agriculture in the country is partially hampered by the perceived high economic risk leading to low adoption (UNEP-UNCTAD, 2007). This is contributed by limited empirical documentation of its economic benefits which also limits support by government and development partners. In order to support appraisal of organic agriculture as a viable alternative production system which contributes to livelihood there is need to evaluate its impact on profitability especially for smallholder farmers.

Sustainable agricultural system is crucial to ensuring food security, poverty alleviation, economic and environmental transformation of many developing countries Nigeria inclusive. This is based on the premise that small scale farmers, researchers and Non-Governmental Organizations (NGOs) have increasingly sought to identify, validate and implement practical farming technologies and methods which meets sustainability criteria, although the challenges of doing so having been enormous (Lumpkin, 2005).

Despite this advantage, the use of organic fertilizer is being advocated for because of its soil conservation property and its eco-friendliness over the inorganic fertilizer. It is a sustainable farming system that produces healthy crops and livestock without damaging the environment. It avoids the use of artificial chemical fertilizers and pesticides. It is mainly the cheapest sources adopted by vegetable farmers to supply nutrients for their vegetables to enhance growth and yield (Verena *et al.*, 2012; Fawzy *et al.*, 2016). It is on these bases that, this study tends to examine the profitability and determinants of profit efficiency of organic vegetable production in Niger State, Nigeria.

The objectives of this paper are to describe the socio-characteristics of organic vegetable farmers, examine the farmers' perception on organic vegetable production, estimate the cost and returns of organic vegetable production and analyzed the determinants of profit efficiency among organic vegetable farmers in the study area. The hypothesis was formulated for further empirical validation. H_{01} : The explanatory variables included in the inefficiency model do not significantly explain the profit efficiency of organic vegetable farmers.

Methodology

The Study Area

The study was conducted in Niger State which is located in the Guinea Savanna vegetation zone in the North Central part of Nigeria which lies between Latitudes $3^{\circ} 20'$ and $7^{\circ} 40' N$ and Longitudes 8° and $11^{\circ} 3' E$ (NAMDA, 2013). The State is bordered by Zamfara State, Kebbi State, Kogi State, Kwara State, Kaduna State and the Federal Capital Territory (FCT) Abuja respectively. The State shares a common boundary with the Republic of Benin along Borgu Local Government Area (LGA). This gives rise to common cross border trade with the State. Niger State is primarily called the "Power State" of Nigeria by virtue of the location of the three hydro-electricity dams in the State, namely, the Kainji, Shiroro and Jebba Dams. The State experience two distinct climatic seasons in a year (rainy and dry season). Rainfall (1,100mm – 1,600mm per annum) is steady and is evenly distributed falling usually between Mid-April and November, peaking in August. Average monthly temperature ranges from $23^{\circ}C$ to $37^{\circ}C$ (NAMDA, 2012).

The vegetation consists mainly of short grasses, shrubs and scattered trees, soils are predominantly light and well drained (NAMDA, 2013). According to National Population Commission, NPC (2006) Niger State has a population of about 3,950,249. Farming is the primary occupation of 85 percent of the State's population, which 15% are engaged in industrial and other businesses or vocational jobs like craft and arts. However, agriculture in Niger State is predominantly in the hands of rural dwellers. The major crops grown include rice, sugar cane, maize, millet, melon, yam, groundnut, sorghum and cowpea. Livestock reared include cattle, sheep, goats and poultry (NAMDA, 2013).

Sampling Procedure and sample size

Multi-stage sampling was used to select farmers for the study. In the first stage, one local government area (Chanchaga) was randomly selected. In the second stage, four communities were purposively selected (Barkin sale, Mechanic village, Mandella and Chanchaga) which are located at the river boundary channel across the LGA. These communities were selected because of the high concentration of organic vegetable farmers in the area. In the third stage, thirty-seven (37) organic vegetable farmers were selected from the selected communities because of the homogenous nature of the communities using simple random sampling techniques. A total of one hundred and forty-eight (148) organic vegetable farmers were selected and interviewed with the aid of structured questionnaire.

Analytical Techniques and Model Specification

Descriptive statistics such as frequency distribution, percentages, mean and Likert type scale was used to describe the socio-economic characteristics of the farmers and examine the farmers' perception on organic vegetable production. The farmers' perception towards organic vegetable production was determine using a 5-Likert scale as follows. Strongly Agree (SA) = 5, Agree (A) = 4, Undecided (U) = 3, Disagree (D) = 2 and Strongly Disagree (SD) = 1. The weighted mean score value of 3.0 or higher, means respondents Agree that organic vegetable production contributed to the statement while any weighted mean score value of less than 3.0 was regarded as respondents Disagree organic vegetable production not contributing to the statement.

Farm budgeting techniques was used to estimate the cost and returns of organic vegetable production. The model is specified in equations (1) and (2). Gross margin is the difference between the Gross Farm Income (GFI) and Total Variable Cost (TVC) as depicted in equation (1) following Olukosi *et al.* (2006).

$$GM = GFI - TVC \quad (1)$$

Where: GM = Gross Margin, GFI = Gross Farm Income, TVC = Total Variable Cost.

$$\text{The net farm income is defined as: } NFI = GM - TFC \quad (2)$$

Where: NFI = Net Farm Income, GM = Gross Margin, TFC = Total Fixed Cost.

The profitability of organic vegetable production was analyzed and compared using the various financial ratio as specified in equations (3), (4) and (5). Gross Ratio: This is a profitability ratio that measures the overall success of the farm. The lower the ratio, the higher the return per naira.

$$GR = \frac{TFC}{GI} \quad (3)$$

Where: GR = Gross Ratio, TFC = Total Farm Expenses and GI = Gross Income.

Operating Ratio: The operating ratio is directly related to the farm variable input usage. The lower the ratio, the higher the profitability of the farm business. OR =

$$\frac{TOC}{GI} \quad (4)$$

Where: OR = Operating Ratio, TOC = Total Operating Cost and GI = Gross Income.

Return on Capital Invested: Is a profitability index defined as a measure of the amount that accrues to the enterprise as net income for every naira invested.

The higher the return to investment, the more profitable the enterprise. RI = $\frac{GM}{TVC}$ (5)

Where: RI = Return on Capital Invested, GM = Gross Margin, and TVC = Total Variable Cost.

Trans-log Stochastic Frontier Profit Function was used to analyze the determinant of profit efficiency among organic vegetable farmers. Farm profit equals the difference between the Total Revenue (TR) and Total Cost (TC). That is,

$$GM(\pi) = \sum (TR - TVC) = \sum (PQ - WX) \quad (6)$$

To normalize the profit function, farm π is divided by P which is the market price of the output (vegetable). It is represented as

$$\frac{\pi(p, z)}{P} = \frac{\sum (PQ - WX_i)}{P} \quad (7)$$

$$= Q - \frac{(WX)}{p} \quad (8)$$

$$= f(X_i, Z) - \sum P_i X_i \quad (9)$$

Where: TR represents total revenue, TC represents total cost, P represents price of output (Q), X represents the quantity of optimized input used, Z represents price of fixed inputs used, $p_i = W/P$ which represents normalized price of input X_i , while $f(X_i, Z)$ represents the production function.

The Cobb-Douglas profit function in implicit form which specifies production efficiency of the farmers is expressed as follows: $\pi_i = f(p_i, z) \exp(V_i - U_i), i = 1, 2, \dots, n$ (10)

Where: π , p , and z is as defined above. The V_i s are assumed to be independent and identically distributed random errors, having normal $N(0, \sigma^2 v)$ distribution, independent of the U_i s. The U_i s are profit inefficiency effects, which are assumed to be non-negative truncation of the half-normal distribution $N(\mu, \sigma^2 u)$. The profit efficiency is expressed as the ratio of predicted actual profit to the predicted maximum profit for a best-practiced organic vegetable farmer and this is represented as follows: Profit Efficiency ($E\pi$) = π / π^{\max} (11)

$$= \frac{\exp[\pi(p, z)] \exp(\ln V) \exp(-\ln U) - \theta}{\exp[\pi(p, z)] \exp(\ln V) - \theta} \quad (12)$$

Firms specific profit efficiency is again the mean of the conditional distribution of U_i given by $E\pi$ and is defined as: $E_{\pi} = E[\exp(-U_i)/E_i]$ (13)

E_{π} takes the value 0 and 1. If $U_i = 0$, this means that farm is on the frontier, obtaining potential maximum profit given the price it faces and the level of fixed factors. If $U_i > 0$, the farm is inefficient and losses profit. The Cobb-Douglas Trans-log function model was estimated by a combination of the production and inefficiency factor in a single stage maximum likelihood estimation procedure to identify the determinants of profit efficiency. It is specified explicitly as:

$$\begin{aligned} \ln Y = & \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \frac{1}{2} \beta_{11} \ln X_1^2 + \frac{1}{2} \beta_{22} \ln X_2^2 + \frac{1}{2} \beta_{33} \ln X_3^2 + \\ & \frac{1}{2} \beta_{44} \ln X_4^2 + \frac{1}{2} \beta_{55} \ln X_5^2 + \beta_{12} \ln X_1 \ln X_2 + \beta_{13} \ln X_1 \ln X_3 + \beta_{14} \ln X_1 \ln X_4 + \beta_{15} \ln X_1 \ln X_5 + \beta_{23} \ln X_2 \ln X_3 + \\ & \beta_{24} \ln X_2 \ln X_4 + \beta_{25} \ln X_2 \ln X_5 + \beta_{34} \ln X_3 \ln X_4 + \beta_{35} \ln X_3 \ln X_5 + \beta_{45} \ln X_4 \ln X_5 + v_i - u_i \dots \dots \dots (14) \end{aligned}$$

Where:

- π = Net profit (N)
- X_1 = Unit price of planting material (N)
- X_2 = Unit price of waste (organic manure) (N)
- X_3 = Unit price of labour (N)
- X_4 = Depreciation on farm equipment (N)
- X_5 = Farm size (ha)
- $X_1 - X_5$ are factors assumed to affect the level of profit efficiency of the organic vegetable farmers and β_0 = constant,
- $\beta_1 \cdot \beta_{45}$ = are maximum likelihood estimates to be measured, \ln is natural Logarithm, v_i and u_i = composite errors

The inefficiency model (u) for the stochastic profit frontier is expresses in equation (15)

$$U = \delta_0 + \delta_1 z_1 + \delta_2 z_2 + \delta_3 z_3 + \delta_4 z_4 + \delta_5 z_5 + (v_i - u_i) \quad (15)$$

Where:

- Z_1 = Age of the farmers (years),
- Z_2 = Household size (number of persons),
- Z_3 = Educational level measured in number of years Spend in formal school,
- Z_4 = Extension contact (Number),
- Z_5 = organic farming experience (years)
- Z_6 = Awareness of organic farming (Dummy variables; Yes=1, No=0)
- Z_7 = Access to Information on organic farming (Dummy variables; Yes=1, No=0)
- δ_0 = constants
- $\delta_1 - \delta_7$ = coefficient to be measured

Results and Discussion

Socio Economic Characteristics of Organic Vegetable Farmers

The socio-economic characteristics variables of the organic vegetable farmers in the study area are presented in Table 1. The results revealed that majority (95%) of the organic vegetable farmers were male. This is a clear indication of complete dominance of male gender in vegetable production. This result affirms the popular belief in the study area that agricultural activities are dominated by male folks. This result is supported by Amos *et al.*, (2006), Ahmadu and Alufohai (2012) who in their separate study reported that crop production in Nigeria is dominated by male. More so, 62% of the sampled farmers were 50 years and below with a mean of 40 years. This reveals that majority of the farmers

were still in their economically active age and are likely to be productive in farming and improving their income earning capacities through adoption new technologies. Because age is an important factor to be considered in determining the quality of labour employed and it's prevalent in any given enterprise. This result is in agreement with that of Lawal *et al.*, (2014) who affirmed that as the age of farmers' increases, the adoption of agricultural technology will likely decrease while sensitivity to risk will increase as older farmers are more risk averse.

Table 1 further revealed that 58% of the organic vegetable farmers had some level of education to at least primary school. The implication is that, farmers with no formal education which constituted 30% might not be able to efficiently adopt new agricultural innovation and technology in organic vegetable farming. The mean farming experience was 5 years with over 47% of the farmers having more than 6 years of experience in organic vegetable farming. The implication is that longer years of organic vegetable farming experience may enable them to have adequate knowledge that will enable them make sound decisions that probably would increase their farm income as well as manage risk. Which might affect their level of adoption of improved technologies. This finding is corroborated by those of Tanko *et al.*, (2011) who observed that farmers with more years of farming experience can cope with the complexity of adoption of new technology. It enables the farmer set realistic time and cost targets by identifying production risks and constraints with greater ease. The result in Table 1 also showed that majority (81%) of the farmers were married and had household size of between 4 to 10 members (84%) as well as an average household size of 8 members. The result could be explained by the fact that most vegetable farmers in the region used the proceeds from the organic vegetable production to augment family income and employed relatively large and cheap family labor in vegetable production. These have a positive implication on farmers' welfare, sustainability of organic vegetable production and cost minimization objective of vegetable farms in the study area. This is in agreement with Olanipekun and kaponiyi (2009) who observed that a large family may serve as incentive for engaging in livelihood diversification in order to meet the obligations of the family.

Table 1: Socio-economic Characteristics of Organic Vegetable Farmers

Variables	Frequency (n=148)	Percentage	Mean
Sex			
Male	142	95.95	
Female	6	4.05	
Age			
Less 31	38	25.68	
31-40	46	31.08	
41-50	47	31.76	
Above 50	17	11.48	40
Marital status			
Single	27	18.24	
Married	121	81.76	
Level of education			
No formal education	45	30.41	
Primary education	86	58.11	
Secondary education	9	6.08	
Tertiary education	2	1.35	
Adult education	6	4.05	9.0
Farming experience			
< 5	77	52.03	
6-10	55	37.16	
11-15	12	8.11	5
Above 15	4	2.70	
House hold size			
4-10	125	84.46	
11-15	18	12.16	
16-20	5	3.38	8
Farm size(ha)			
0.4 - 1.00	113	76.35	
1.1 - 2.00	30	20.27	
Above 2.00	5	3.38	
Number of extension visit			
No Visit	43	29.05	
1-2 Visit	75	50.68	
3-4 Visit	30	20.27	
Member of association			
Yes	91	61.49	
No	57	38.51	
Monthly Income (₦)			
< 10,000	11	7.43	
10,001 – 20,000	88	59.46	
20,001 - 30,000	31	20.95	
30,001 - 40,000	6	4.05	
40,001 – 50,000	5	3.38	
Above 50,000	7	4.73	

Source: Field survey, 2020.

Furthermore, majority (76%) of the farmers had not more than 1 hectare of farm land for cultivation of organic vegetable. The result could be attributed to the continuous subsistence nature of cultivation of organic vegetable crop in Niger State imposed by increasing land fragmentation and urbanization. This means that the farm size possessed by a particular farm family is believed to determine the extent to which other resources (capital, labour etc.) will be utilized for optimum productivity. This Finding is in consonance with those of Akpan *et al.*, (2007), Abdullahi (2012).and Abdullahi and Mohammed (2012) who opined that farm size affects adoption of technology and that determines whether a farmer will use improved seed or not. It was also found that most (61%) of the farmers belong to at least one farmer's association. These farmers' associations are sources/channels of communicating information that will increase farmers' knowledge and skills on organic farming. This is supported by the finding of Amos *et al.*, (2014) that membership of association is of immense benefits to members, it gives opportunity for bulk purchased of inputs at discounted rates, encourages collective bargaining.

The result in Table 1 further shows that, half (50%) of the sampled farmers had between 1-2 extension visits in a year, while over 29% of the sampled farmers in the study area had no access to extension agents at all. This implies that, some of the organic vegetable farmers have no proper linkages with the extension services and this situation can result to little or no access to information by the farmers which will go a long way to affect their production skills in the study area. This accretion is in consonance with that of Oladele and Adu (2003) who are of the view that poor extension services may hinder farmer access to necessary information on production activities which decrease their profit margin. In addition, majority (87%) of the sampled farmers earned not more than N30,000 as monthly income.

Table 2 presents the distribution of farmers according to their perception on organic vegetable production in the area. The result shows that all the perception statements have their weighted mean of equal to or greater than 3 which is the mean cut. The result reveals a high positive and favourable perception of farmers toward organic vegetable production. This means that organic vegetable (O V) as contributed to strengthens the use of indigenous knowledge having ranked first with a mean of (4.57), followed by O V reduces inputs cost of production (4.30), then O V has no long-term effect on ecological health (4.16). Other responses were O V increase farmers income with low cost(4.06), O V provides social compatibility with its practices (3.96), O V reduces farmers exposure to health hazards (3.87), O V reduces all forms of environmental pollution (3.71), O V is prone to soil erosion (3.70), O V improve soil fertility and structure (3.68), O V is efficient in reducing pest and diseases infestation (3.64), O V is efficient in mitigating Climate Change effects (3.63), O V product enjoys poorer taste to conventional products (3.62) and O V ensures biodiversity (3.57). This suggests that the potential of organic vegetable practice in the maintenance of environmental biodiversity, mitigation of climate change effect and degradation, system stability and reduction of people exposure to health hazard which may be because of the consumers of organic vegetable product who want to reduce health care cost, increase their intake of minerals and vitamins void of pesticides and agro-chemicals grown. This finding corroborates the assertion of Giessman (2005) who reported that farmer practicing organic agriculture have healthier soil which can sustain plant growth higher nutrient content and it enables them to grow crops for longer period with higher yields and the conditions are marginal.

Table 2: Perception of the farmers towards organic vegetable production (n=148)

Perception Statements	SA	A	U	D	SD	Weighted sum	Weighted mean	Ranking
Organic vegetable (O V) is prone to soil erosion	21	55	18	10	5	404	3.70*	8 th
O V increase farmers income with low cost	40	52	6	6	5	443	4.06*	4 th
O V is efficient in reducing pest and diseases infestation	20	54	13	20	2	397	3.64*	10 th
O V has no long-term effect on ecological health	52	40	6	5	6	454	4.16*	3 rd
O V is efficient in mitigating Climate Change effects	15	55	26	10	3	396	3.63*	11 th
O V reduces inputs cost of production	51	46	7	4	1	469	4.30*	2 nd
O V product enjoys poorer taste to conventional products	12	65	18	7	7	395	3.62*	12 th
O V provides social compatibility with its practices	34	51	11	11	2	431	3.95*	5 th
O V ensures biodiversity	22	50	9	25	3	390	3.57*	13 th
O V strengthens the use of indigenous knowledge	66	42	0	0	1	499	4.57*	1 st
O V reduces all forms of environmental pollution	18	58	19	11	3	404	3.71*	7 th
O V improve soil fertility and structure	13	63	21	10	2	402	3.68*	9 th
O V reduces farmers exposure to health hazards	13	79	9	6	2	422	3.87*	6 th

SD= Strongly disagree, D= Disagree, U= Undecided, A= Agree, SA= Strongly agree

*Significant

Source: Field survey, 2020

Profitability of Organic Vegetable (spinach) Production.

Table 3 presents the costs and returns of organic vegetable farmers in the study area. The result reveals that organic vegetable production is quite profitable and it was also shown that labour cost accounted for almost 37 per cent of cost of production. This implies that high amount of labour is required for production of vegetable crops. This is in agreement with the findings of Abdullahi *et al.*, (2010), who reported that labour constitutes a large per cent of the cost of production. Per production cycle, a net farm income of N77,537.35 with an average gross margin of N89,371.58 was realized. The positive net farm income and gross margin show that returns exceeded the cost and also the gross and operating ratios of 0.60 and 0.39 were obtained respectively with returns on investment of N1.53 which indicates that organic vegetable production is profitable in the study area. This result is in line with those of Abdullahi *et al.* (2010), Abdullahi and Mohammed (2012) and Abdullahi (2012).

Table 3: Profitability analysis of organic vegetable (spinach) production

Cost Item & Revenue	Cost (₦/production cycle) n=148	% of Total cost
Variable cost		
Family labour (opportunity cost)	17,573.43	25.05
Hired labour	8,327.07	11.87
Organic manure cost	11,945.30	17.04
Seed/planting materials	6,553.50	9.34
Fuel (for pump)	5,875.00	8.38
Pump Maintenance/repairs	4,234.43	6.03
Marketing/transportation cost	3,793.00	5.40
Total variable cost(a)	58,301.73	83.13
Fixed cost		
Depreciation on farm tools	5,223.50	
Depreciation on pump	6,620.73	7.45
Total fixed cost(b)	11,844.23	9.43
Total cost (a and b)	70,145.96	
Returns		
Gross farm income	147,673.31	
Gross margin	89,371.58	
Net farm income	77,537.35	
Return on investment	1.53	
Gross ratio	0.60	
Operating ratio	0.39	

Source: Field survey, 2020.

Measurement of the Profit Efficiency of the Respondents Using the Stochastic Frontier Profit Model.

The maximum likelihood estimates of the stochastic frontier profit function are presented in Table 4 along with the interacting terms. The results reveal that the sigma-square (δ^2) was 0.3229 in the study area and significant ($P < 0.01$), indicating a good fit and the correctness of the specified assumptions of the distribution of the composite error term. The estimated gamma parameter (γ) of 0.96 in Table 4 was highly significant at 1 percent level of significance. This implies that one-sided random inefficiency component strongly dominates the measurements error and other random disturbance indicating that about 96 percent of the variation in actual profit from maximum profit (profit frontier) between farms mainly arose from differences in farmers' practices rather than random variability. Two out five estimated coefficients of the parameters of the normalized profit function based on the assumption of competitive market are positive.

The coefficient of planting material was negative and statistically significant at ($P < 0.01$), indicating an increase in the factor price of planting material will bring about a marginal decrease in profit efficiency of organic vegetable farmers. This implies that an increase in cost of planting material could reduce profit efficiency of the farmers, suggesting that good use of improved planting materials may increase the profit of organic vegetable production. The coefficient of organic waste (manure) was negative and statistically significant at ($P < 0.01$), which show that the organic manure had a

negative correlation with farm profit. This means that increase in the factor price of organic manure holding other variables constant will bring about a marginal decrease in profit efficiency of organic vegetable production by 0.31% in the study area. The reason would likely be that manure being a critical input in organic vegetable production, farmers were spending more on the purchase of this commodity from the open market as a result increase the level of patronage and usage of the commodity. This result corroborates Paul (2011) who reported that cost of organic material pose negative and significant effect on farmers' profit level.

The coefficient of labour was negative and statistically significant at ($P < 0.01$), indicating an increase in the factor price of labour will bring about a marginal decrease in profit efficiency of organic vegetable farmers. This means that since most family labour is unpaid for, farmers were using it to the extent of what is call economical visible point (over utilization of labour) and get to a point where returns to labour become negative. So, increasing price of labour above the present levels will decrease profit efficiency significantly. Similar finding was observed by Olowa *et al.* (2016) that cost of labour and cost of transportation were negatively attached to the profit of organic vegetable

The coefficient of depreciation on equipment was positive and statistically significant at ($P < 0.01$). Implying a one present increase in the factor price of equipment will bring about a marginal increase in profit efficiency by 0.37%. The coefficient of farm size was positive and significant at ($P < 0.05$), indicating that an increase in farm size will lead to an increase in profit efficiency. This also implies that farmers with large farm size are likely to generate more output and probably make more profit that those with small farm size. The result agrees with the report of UNCTAD (2008) and FAO (2012) that farm size is one of the major determinants of profitability and efficiency of vegetable production and that farm size was positively correlated with farmer profit.

Table 4: Maximum likelihood Estimates of Translog Profit Frontier Function

Variables	Parameters	Coefficient	T- Value
Constant	β_0	3.8769	24.24***
Planting material	β_1	-0.3529	-3.01***
Organic Manure	β_2	-0.3116	-2.32***
Labour	β_3	-0.2053	-3.31***
Dep. on Farm Equipment	β_4	0.3739	2.59**
Farm size	β_5	0.5214	6.28***
Squared Terms			
Planting material \times Planting material	β_{11}	0.0052	0.73 ^{NS}
Organic Manure \times Organic Manure	β_{22}	0.0089	2.49**
labour \times labour	β_{33}	-0.0049	-0.22 ^{NS}
Dep. on farm Equipt \times Dep. on farm Equipt.	β_{44}	0.1963	1.37 ^{NS}
Farm size \times farm size	β_{55}	0.2016	2.34**
Interaction Terms			
Planting material \times Organic Manure	β_{12}	-0.1731	-3.67***
Planting material \times labour	β_{13}	-0.0022	-0.58 ^{NS}
Planting material \times Dep. on farm Equipt.	β_{14}	0.0010	0.31 ^{NS}
Planting material \times farm size	β_{15}	0.1611	2.46**
Organic Manure \times labour	β_{23}	0.4148	5.12***
Organic Manure \times Dep. on farm Equipt.	β_{24}	-0.0052	-0.62 ^{NS}
Organic Manure \times farm size	β_{25}	0.0055	3.14***
labour \times Dep. on farm Equipt.	β_{34}	-0.3668	-3.49***
labour \times farm size	β_{35}	-0.2543	-4.38***
Dep. on farm Equipt. \times farm size	β_{45}	-0.0027	-0.36 ^{NS}
Diagnostic Statistics			
Sigma-Squared		0.3229	2.94***
Gamma		0.96	48.6395***
Log likelihood	Llf	37.014919	
	LRT	18.2146344	
Inefficiency effects			
Constant	δ_0	-2.2483	1.23 ^{NS}
Age	δ_1	-0.0038	-4.43***
Household Size	δ_2	-0.1316	-2.11**
Education	δ_3	0.0067	0.33 ^{NS}
Extension Contact	δ_4	0.3272	2.09**
Experience	δ_5	-0.1138	-3.34**
Awareness of organic farming	δ_6	-0.4724	-2.96***
Access to information on organic farming	δ_7	-0.3179	-2.58**

Note ***, **, * and NS implies statistically significant at ($P < 0.01$), ($P < 0.05$), ($P < 0.1$) and Not Significant, respectively.

Figures in parentheses are t-ratio

Source: Computed from Field survey, 2020.

The result of the inefficiency factors as shown in Table 4 further reveals that age was negative and statistically significant ($P < 0.01$). The negative coefficient implying that an increase in age would reduce profit inefficiency in the study area. This is because age has a significant influence on the decision-making process of farmers with respect to risk aversion, adoption of organic agricultural technologies, and production-related decisions that could reduce farmers' profit inefficiency. This result is in agreement with the authors of Tanko *et al.* (2010) and NISR (2017) who found a negative coefficient of age and profit inefficiency and that older or aged farmers embraced organic farming technology readily

and obtained a higher gross margin. Furthermore, the coefficients of the household size were negative and statistically significant ($P < 0.01$), meaning an increase in household size will result in the reduction in profit inefficiency. The reason could be that household with many productive members could benefit from the use of family labour at the right time when labour is needed. The result agrees with the finding of Tanko *et al.* (2010) which states that household size could reduce labour constraints, thereby leading to increase in productivity and increase in profit efficiency.

The estimated coefficient associated with experience, carries the expected negative sign and is statistically significant ($P < 0.01$). The result implies that those with experience are better performers than those without. In other words, organic vegetable farmers with more years of experience tend to operate at significantly higher level of profit efficiency. Experience in organic vegetable production could improve farmers' skills in farm operations, thereby reducing their profit inefficiency. The estimated coefficient associated with the extension contact is positive and significant ($P < 0.01$). The positive sign does not conform to a prior expectation; the reason is that farmers in the study area had limited access to extension services which reduces their profit efficiency. This means that limited extension contact with farmers hinders acquisition of new knowledge, skill and practices on improved technology by the farmers as well as their innovativeness. This result is also consistent with findings obtained by Ajibefun *et al.* (2002) who reported positive coefficient of extension contact.

The estimated coefficient awareness of organic farming is negative and significant ($P < 0.01$) indicating reduction in profit inefficiency. This means farmers' awareness of organic farming increases the tendency of farmer practicing and adopting the technology available to them which could go a long way to increase their vegetable productivity and this could have positive effect on profit efficiency. Again, the coefficient of access to information on organic farming is negative and statistically significant ($P < 0.01$). This means reduction in profit inefficiency. Which implied that farmers' access to information on organic farming is likely to enhance their probability to practicing it, hence adopt new technologies which translates to high organic vegetable output thereby leading to reduction in profit inefficiency in the study area.

The formulated hypothesis was subjected to empirical validation. Table 4 presents the result of maximum likelihood estimates from the inefficiency model for the stochastic frontier profit function for hypothesis. The result of maximum likelihood estimates from the inefficiency model for the stochastic frontier profit function revealed that explanatory variables included in the inefficiency model significantly explain the profit efficiency of organic vegetable farmers with estimated coefficients. The null hypothesis was therefore rejected while the alternative hypothesis is accepted and the study concludes that explanatory variables included in the inefficiency model significantly explain the profit efficiency of organic vegetable farmers.

Conclusion

The study revealed that in spite of the abundant potentials of organic vegetable production in Chanchaga Local Government Area of Niger State, available resources were not fully tapped. The farmers in the area were generally small-scale farmers that depended on small but scattered plots they acquire through rent/inheritance. It can be concluded that farmers had positive perception towards organic vegetable production to be more beneficial to the environment and for human consumption. The study further concludes that the area has great potentials to increase organic vegetable (spinach) production and farmer's income. This means that organic vegetable production is profitable with returns on investment of N1.53 in the study area.

The estimated parameters of the Trans-log profit frontier indicate that only few inputs have positive sign on the profitability of organic vegetable farming in area. The negative sign of prices of these inputs may be due to wrong or excessive application of such inputs by the farmers, thus leading to extra cost incurred on the part of the farmers. However, the study concluded that organic manure, labour, planting material, farm size, age, household size, education, farming experience, awareness of organic farming and access to organic vegetable information had significant effects on the profit efficiency of organic vegetable farmers in the study area. The policy implication of these findings is that inefficiency in organic vegetable production can be reduced significantly by improving the level of education among the farmers and awareness by extension agents. Most important are the extension services and the existing technological packages that need to be critically examined. The study therefore recommended that farmers in the study area should be encouraged by extension agents to form co-operative associations to enable them share their knowledge

and experience to facilitate their access to information on production technologies and credit facilities that will enable them to expand their organic vegetable (spinach) production. Since the study area has a great potential to increase organic vegetable production and farmers' income, government need to step out to beef-up the awareness level of the farmers by intensive utilization of appropriate technology this can be achieved through extension agents, mass media, town/village cry, agricultural show, symposium and the likes. This can be seen as a policy option for combating the endemic menace of unemployment among youths in study area and the country at large especially now that the present administration change mantra is geared towards agriculture. Extension agents and other relevant stakeholders should also organized sensitization programmes on health and environmental benefit of organic vegetable production.

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Published by:





The Potential of Sweet Sorghum (*Sorghum bicolor* (L) Moench) as an Alternative Source of Sugar: A Case Study in Kibos, Kenya

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Keywords:

Sweet sorghum, total sugar content, sucrose content, glucose content and purity percentage

Abstract

This Trial was conducted at Sugar Research Institute-Kibos, which is in LM2 zone in June 2019. The objective was to assess the potential of sweet sorghum (*Sorghum bicolor* (L) Moench) as an alternative crop source of sugar in Kenya. The treatment included six sweet sorghum varieties namely, *KM1*, *Kakamega white*, *Sila*, *Tabat*, *Gadam* and *smile* arranged in a randomized complete block design and replicated three times. Plots were 3 by 4.0 m planted at spacing of 0.75 by 0.2 m. The net plot was 1.5 by 4.0m. Twelve stems were sampled from the net plot at harvest of each experimental plot and taken to the laboratory for juice extraction and analysis. Pol percentage juice, brix percentage, glucose content, total sugar content and purity were determined. As a result of the analyses by ANOVA, *KM1* and *Kakamega white* showed the highest Brix value of 16.427% that differed significantly with *Smile* 9.02%, *Kakamega* had highest total sugar content 4,271 kg ha⁻¹ which differed significantly with *Smile* 573 kgha⁻¹ (P<0.05). *Tabat* indicated the best sucrose content of 10.16% that differed significantly (P<0.05) with *Gadam* 8.94%, *KM1* 6.21%, and *Smile* 4.25%. However, *Sila* showed the best glucose content of 3.28% that differed significantly (P<0.05) with *kakamega white* 3.13%, *Tabat* 2.39%, *Gadam* 2.17% and *Smile* 2.31%. There were significant differences noticed in purity percentage among the varieties with *Tabat* 70.63% being the best. Therefore, Sweet sorghum could be an alternative crop to sugarcane and can bridge sugar shortage gap in Kenya.

Le Potentiel du Sorghum Doux (*Sorghum bicolor* (L) Moench) Comme Source Alternative de Sucre: Une Etude de Cas a Kibos, Kenya

Résumé

Cet essai a été mené à l'Institut de recherche sur le sucre de Kibos, qui se trouve dans la zone LM2 en juin 2019. L'objectif était d'évaluer le potentiel du sorgho sucré (*Sorghum bicolor* (L) Moench) en tant que culture alternative pour la production de sucre au Kenya. Le traitement comprenait six variétés de sorgho sucré, à savoir *KM1*, *Kakamega white*, *Sila*, *Tabat*, *Gadam* et *smile*, disposées selon un plan en blocs complets aléatoires et répétées trois fois. Les parcelles mesuraient 3 x 4,0 m et étaient espacées de 0,75 x 0,2 m. La parcelle de filet mesurait 1,5 x 4,0 m. Douze tiges ont été échantillonnées dans la parcelle de filet. Douze tiges ont été prélevées dans la parcelle en filet lors de la récolte de chaque parcelle expérimentale et transportées au laboratoire pour l'extraction et l'analyse du jus. Le pourcentage de jus Pol, le pourcentage de brix, la teneur

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Mots clés :

Sorgho sucré,
teneur totale en sucre,
teneur en saccharose,
teneur en glucose et
pourcentage de pureté.

en glucose, la teneur en sucre total et la pureté ont été déterminés. Suite aux analyses ANOVA, KM1 et Kakamega white ont montré la valeur Brix la plus élevée de 16,427% qui diffère significativement de Smile 9,02%, Kakamega a eu la teneur en sucre total la plus élevée 4,271 kg ha⁻¹ qui diffère significativement de Smile 573 kg ha⁻¹ (P<0,05). Tabat a indiqué la meilleure teneur en saccharose de 10,16% qui diffère significativement (P<0,05) de Gadam 8,94%, KM1 6,21%, et Smile 4,25%. Cependant, Sila a montré la meilleure teneur en glucose de 3,28% qui diffère significativement (P<0,05) avec kakamega white 3,13%, Tabat 2,39%, Gadam 2,17% et Smile 2,31%. Des différences significatives ont été observées dans le pourcentage de pureté entre les variétés, Tabat 70,63% étant la meilleure. Par conséquent, le sorgho sucré pourrait être une culture alternative à la canne à sucre et pourrait combler la pénurie de sucre au Kenya.

Introduction

The sugar industry traditionally depends on sugarcane as the primary raw material for processing into sugar and allied products. However, the industry has been facing myriad of challenges, key among them is the sugar deficit. There is a shortage of sugar; Kenya produces 700,000 mt of sugar against a consumption of 1000,000 mt (AFA-Sugar Directorate, 2022) which leaves a deficit of over 200,000 mt that is currently imported, from the Common market of East and South Africa (COMESA) sugar producing countries, making the country a net sugar importer. The recovery of sugar from the milling factories has been reported to be very low and the cost of sugar production in Kenya is currently higher than those of other sugar producing countries within the COMESA trading bloc. In response to this problem, there exist an opportunity to venture into alternative sugar crop such as sweet sorghum among others.

Sweet sorghum [*Sorghum bicolor* (L.) Moench] is special purpose sorghum with a sugar-rich stalk, almost like sugarcane. Besides having rapid growth, high sugar accumulation, and biomass production potential, sweet sorghum has wider adaptability (Reddy et al, 2005). Given that water, availability is poised to become a major constraint to agricultural production in coming years cultivation of sugarcane becomes difficult.

In Kenya, sugar is mainly produced from sugarcane. However, sorghum, a close relative of sugarcane has the potential to serve as an alternative source of sugar. Two types of sorghum are grown in the world – sweet and grain sorghum. Grain sorghum is grown for the seeds which are milled and used unleavened bread, *ugali*. Sweet sorghum is grown for its sugar-rich stalks. Sweet sorghum accumulates large amounts of sugar in their stems. Near the time of grain maturity sweet sorghums have 10 to 25% sugar in stalk juice, with sucrose being the predominant disaccharide. The sugar in the stalk juice of sorghum can be used to produce crystal sugar.

The sugar content in the juice extracted from sweet sorghum varies from 16–23% Brix. Sweet sorghum is resistant to drought and flooding. Sugars in sweet sorghum has 85 % sucrose (Smith et al, 1987). Sweet sorghum sugar yields range between 1.6 and 13.2 tons ha⁻¹, with significant variations observed between different years and regions. The juice sugar content is depended on the plant stage of development. At the early development stage, fructose is more abundant and sucrose is dominant after heading. At maturity, the sweet sorghum juice sugar content can range from 10 to 25 brix (Reddy et al., 2005). At the global level, more than 35% of the sorghum produced is directly used for human consumption with the rest used for animal feed, production of alcohol and industrial products. The high demand for water coupled with climate change is limiting expansion of sugarcane production zones in many countries of sub-Saharan Africa. Near physiological maturity, sweet sorghums are distinct due to higher sugar content in the stalks (Brix 10– 18%) from flowering to maturity than that of grain sorghum (Brix 9–11%) during the same period (Rao et al. 2013).

Sorghum has lower nutritional and moisture requirements for growth than sugarcane, a traditional source of sugar and allied products. Sorghum's water requirement during a growing period of about 4 months is about 1,000 m³ per month, about one-third that of sugarcane's requirement of 36,000 m³ per crop that requires 12-16 months (Almodares and Hadi, 2009). While sugarcane is propagated from stem cuttings, sweet sorghum is sown with seed, that is. just 4.5 kg

is enough for a hectare of land, compared to 4,500-6,000 kg of sugarcane cuttings. The cost of cultivation of sweet sorghum is estimated to be one-third that of sugarcane.

Sweet sorghum could therefore be used as an alternative crop to sugarcane in drier lands for the production of sugar. Yet the exploitation of this valuable crop is limited by few accessions. The limited supply and increasing demand for sugar therefore indicates an urgent need to seek alternative sources of sucrose for industrial and domestic uses. Sweet sorghum can bridge that gap, especially in the Kenya sugar industry

Objective of the Study

To assess the potential of sweet sorghum as an alternative crop source of sugar in Kenya.

Materials and Methods

The experiment was planted in June 2019 at, Kenya Agricultural and Livestock Research Organization (KALRO)-Sugar Research Institute in Kibos, Kisumu County. Kibos site represents Nyando sugar zone, which includes Miwani, Chemelil, Muhoroni and Nandi. The area is categorized as agro ecological zone lower midland two (LM2) which is sub-humid. It lies at an altitude of 1200-1500m above sea level, latitude 0°04'S and longitude 34° 48' E. It receives a mean annual rainfall of 1200-1400mm with a mean annual temperature of 20.9°C-22.3°C. Soils include vertisols, nitosols, planosols and cambisols (Jaetzold et al., 2011).

Soil analysis

Chemical analysis of experimental soil was conducted before planting (Table 1). The soil analysis indicated that the soil was adequate in P₂O₅, low to medium in total nitrogen, medium in K₂O, CaO, MgO and good in cation exchange capacity.

Table 1: Soil chemical properties analysis before planting the crop during June 2019

Site: SRI-Kibos	P ^H (H ₂ O)	Pppm	Total N	Ca m.e	Mg m.e	K m.e	CEC m.e
F 10	6.05	15.3	0.20	21.3	20.9	1.3	10.2

Planting Material and Treatments

The six sorghum varieties Tabat, Gadam, Smile, KM1, Kakamega white and Sila were grown in field plots in a randomized complete block experimental design with three replications. Plots were planted in June 2019 on loamy fine sand (Nitosols) at the seed rate of 2kg/acre. Plots were 3 by 4.0 m planted at spacing of 0.75 by 0.2 m. The net plot was 1.5 by 4.0m. 50kg of P₂O₅ kg ha⁻¹ was applied at planting and 75kgNha⁻¹ fertilizer as a top dress at one month after planting. Weeds were manually controlled.

Harvesting was done in October 2019 when plants were in the hard-dough stage. 12 stems were sampled from the net plot of 1.5 by 4.0 m and taken from each experimental plot to the laboratory for juice extraction and analysis. The cut stems were crushed to determine, brix% juice, pol% juice by Saccharimeter. Sugar yield was determined by the equation: sugar yield = fresh stem yield x Brix/100 x 0.90.

Data was subjected to analysis of variance (ANOVA) using SAS vs 9.2 and means separated by Least Significant Difference (LSD) at 5% probability level.

Results and Discussion

Stem Juice yield

The juice stem yields varied between 38,217 Lha⁻¹ and 208,500 Lha⁻¹. However, significant differences were noticed between the varieties at ($P < 0.05$). The minimum stem juice yield was obtained from smile variety (38,217); the highest stem juice yield was obtained from Kakamega white variety (208,500) that differed significantly ($P < 0.05$). (Table 2).

Other studies conducted on sweet sorghum stem juice; Rao et al.; (2013) in India found the stem juice yield as between 1554 and 2084 l da⁻¹. Davilla-gomez et al (2011) in Texa determined the stem juice as between 1500 and 2830 da⁻¹. These differences could be attributed to varieties traits.

Brix

Brix percentage of varieties differed significantly at ($P < 0.05$). Smile variety (9.02) showed the lowest value and KM1 and Kakamega white (16.43) that were at par showed the highest brix % value (Table 2). The brix values determined were between 9.02 and 16.43%. Atokple et al (2014) in Ghana found the brix values between 11.1 and 17.3%. These differences could be probably due to varietal characteristics and temperature effect after flowering period.

Pol percentage (Sucrose) and Glucose values

Significant differences were noticed between the pol percentage and glucose of varieties at ($P < 0.05$). The pol percentage values varied between 4.25 and 10.16% while glucose values were between 2.16 and 3.280 %. The highest Pol %value was determined in Tabat (10.16) and lowest in Smile (4.25) (Table 2). Sila showed highest value (3.28%) while Gadam the lowest (2.17) (Table 2). The results reveal that sucrose is a dominant component in the stem of sweet sorghum. This is in agreement with (Almodares and Hadi, 2009).

Total sugar kg ha⁻¹

Total sugar kg ha⁻¹ between the varieties showed significant differences ($P < 0.05$). The values ranged between 577 and 4271 kg ha⁻¹ (Table 2). Smile (573kg ha⁻¹) showed the lowest content while Kakamega white (4271kg ha⁻¹) had the highest value. This difference is because of genetically structure that is effective firstly in sugar content of sorghum as reported by other researchers.

Purity Percentage

Significance differences were noticed between the varieties ($P < 0.05$). Tabat variety showed the best value (70.63%) and Sila variety the lowest (37.44%) (Table 2).

Table 2: Sugar quality of the six sweet sorghum varieties in the study at SRI-Kibos

	Brix%	Pol%	Purity%	Glucose%	Total sugar	Stem juice yield Lha ⁻¹	Totalsugar kgha ⁻¹	Protein
KM1	16.43 ^a	6.21 ^{ba}	39.64 ^b	2.52 ^{bac}	8.73 ^{ba}	162,887.00 ^{ba}	2265.00 ^{ba}	2.26 ^a
KAK_WHIT	16.43 ^a	9.83 ^a	59.74 ^{ba}	3.13 ^{ba}	12.96 ^a	208,500.00 ^a	4271.00 ^a	2.89 ^a
SILA	15.33 ^a	5.75 ^{ba}	37.44 ^b	3.28 ^a	9.03 ^{ba}	112,700.00 ^{bc}	3328.00 ^a	2.34 ^a
TABAT	14.36 ^a	10.16 ^a	70.63 ^a	2.39 ^{bc}	12.55 ^a	121,167.00 ^{bac}	2312.00 ^{ba}	3.61 ^a
GADAM	14.09 ^a	8.94 ^{ba}	58.04 ^{ba}	2.17 ^c	11.11 ^{ba}	162,983.00 ^{ba}	4099.00 ^a	2.44 ^a
SMILE	9.02 ^b	4.25 ^b	46.22 ^{ba}	2.31 ^c	6.55 ^b	38,217.00 ^c	573.00 ^b	2.91 ^a
Mean	14.28	0.52	51.95	2.63	10.15	134,409.00	2808.07	2.74
LSD _{0.05}	4.70	5.42	28.96	0.79	5.36	55.16	2512.70	2.10
P-value	0.05	0.16	0.17	0.05	0.15	0.03	0.06	0.72
CV%	18.10	39.63	30.64	16.55	29.01	37.60	49.19	42.15
R-sq	0.64	0.52	0.52	0.63	0.53	0.73	0.63	0.78
RMS	2.58	2.98	15.92	0.44	2.95	30.32	1381.18	1.16

Conclusion

In Kenya, sugar production has been from cultivation and processing of sugarcane since the 1920's to date. Currently trends in sugar production and consumption have also been changing and now annual local consumption has surpassed local production by over 200,000 metric tons. Therefore, the potential for sweet sorghum as an alternative source of

sugar is huge in that it is easy to establish through seed, matures in 4 months (two crops a year), and produces high sugar, tolerant to occasional moisture stress as is common in many zones of sugarcane cultivation

In the six sweet sorghum varieties tested, Kakamega white variety showed the highest total sugar 4,271 kg ha^{-1} followed by Gadam 4,099 kg ha^{-1} while smile variety 573 kg ha^{-1} had the lowest.

Recommendations

1. Sorghum a close relative of sugarcane has the potential to serve as an alternative source of sugar
2. More studies to be conducted in different agro-ecological areas to assess the effect of environment and varieties on sugar accumulation

Acknowledgments

The authors express sincere gratitude to the Institute Director, SRI for financial support. The SRI staff especially messers S.Mutai is greatly acknowledged for assisting in data collection.

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Published by:







Comparative Evaluation of Modified Pressurized Hot Water Extraction as a Green Extractant with other Conventional Phosphorus Extraction Techniques

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Keywords:

Green extraction,
Maize, PHWE,
Alfisol, Inceptisol

Abstract

Recent extraction trends have focused on finding solutions that minimize chemical usage, especially in phosphorus (P) determination. This has led to growing interest in using Pressurized Hot Water Extraction as a green and sustainable extraction means of soil-available phosphorus. Hence, a comparative evaluation of alfisol and inceptisol with Modified Pressurized Hot Water Extraction (MPHWE) with other conventional methods of phosphorus analysis using Maize (*Zea Mays L.*) as a test crop was carried out. The experiment's first phase was an incubation study conducted in the laboratory to determine the release of available phosphorus. In contrast, the second phase was a screenhouse study to determine the phosphorus uptake by maize. This study revealed a highly significant correlation between extracted phosphorus and the nutrient uptake in maize plants for MPHWE ($r = 0.61$ and $r = 0.54$, $p = 0.05$) for both Alfisol and Inceptisol, respectively. This was, however, lower than the conventional Mehlich III extractant ($r = 0.88$, $r = 0.66$, $p = 0.05$) for both Alfisol and Inceptisol, respectively. The result also demonstrated that the pH level of an extractant could determine the level of phosphorus that would be extracted. When Pressurized Hot Water Extraction is modified with citric acid (pH 2.5), higher levels of extractable phosphorus can be obtained compared to when PHWE (water at pH 7) was used. This indicates that the Modified Pressurized Hot Water Extraction method could be considered a suitable, sustainable, eco-friendly extractant for available phosphorus determination.

Évaluation comparative de l'extraction à l'eau chaude sous pression modifiée en tant qu'extracteur vert avec d'autres techniques conventionnelles d'extraction du phosphore

Résumé

Les tendances récentes en matière d'extraction se sont concentrées sur la recherche de solutions qui minimisent l'utilisation de produits chimiques, en particulier pour la détermination du phosphore (P). Cela a conduit à un intérêt croissant pour l'utilisation de l'extraction à l'eau chaude sous pression comme moyen d'extraction écologique et durable du phosphore disponible dans le sol. Une évaluation comparative de l'alfisol et de l'inceptisol avec l'extraction modifiée à l'eau chaude sous pression (MPHWE) et d'autres méthodes conventionnelles d'analyse du phosphore, en utilisant le maïs (*Zea Mays L.*) comme culture d'essai, a donc été réalisée. La première phase de l'expérience était une étude d'incubation menée en laboratoire pour déterminer la libération

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Mots clés :

Extraction verte,
maïs, PHWE,
Alfisol, Inceptisol

du phosphore disponible. En revanche, la deuxième phase était une étude en serre pour déterminer l'absorption du phosphore par le maïs. Cette étude a révélé une corrélation hautement significative entre le phosphore extrait et l'absorption des nutriments par les plants de maïs pour MPHWE ($r = 0,61$ et $r = 0,54$, $p = 0,05$) pour l'Alfisol et l'Inceptisol, respectivement. Ce résultat était toutefois inférieur à celui de l'extracteur Mehlich III conventionnel ($r = 0,88$, $r = 0,66$, $p = 0,05$) pour l'Alfisol et l'Inceptisol, respectivement. Le résultat a également démontré que le niveau de pH d'un agent d'extraction pouvait déterminer le niveau de phosphore qui serait extrait. Lorsque l'extraction à l'eau chaude sous pression est modifiée avec de l'acide citrique (pH 2,5), des niveaux plus élevés de phosphore extractible peuvent être obtenus par rapport à l'utilisation de l'extraction à l'eau chaude sous pression (PHWE) (eau à pH 7). Cela indique que la méthode d'extraction modifiée à l'eau chaude sous pression peut être considérée comme un extracteur approprié, durable et écologique pour la détermination du phosphore disponible.

Introduction

Soil testing helps in the estimation of plant-available nutrients for fertilizer recommendations (Meille *et al.* 2012). Extraction techniques combine analytical procedure with chemicals or other substances which serve as extractants, thereby determining the level of certain element in the soil. Proper extraction method provides a good correlation between the amounts of nutrient that it extracts to the uptake rate of the nutrient by the crop and each method can extract a different amount of nutrient from a given sample Smart (2017).

Laboratory soil tests including phosphorus (P) extraction, often involve the use of chemicals that could be toxic to the environment. However, recent trends in soil nutrient extraction techniques have largely focused on finding solutions that minimize the use of chemicals (Turner, 2010). This has necessitated the need to evaluate cheaper, easy to dispose of and environmentally safe extractants for effective soil nutrient extractions, while conducting soil tests for agronomic purposes. The most conventional methods of extracting phosphorus are Mehlich III, Bray 1 and Olsen (Wien, 2013). However, Hanks (1997) devised the use of Pressurized Hot Water Extraction (PHWE) method by using an espresso machine.

Pressurized Hot Water Extraction (PHWE) method is one of the most promising modern extraction techniques (Chemat *et al.* 2012). The PHWE is widely used in the preparation of samples for the analysis of soil and sediments (Kronholm *et al.* 2007). It is an extraction method which is fast becoming a well-known green chemistry method for the extraction of different classes of compounds that are available in many kinds of matrices like foods, plants or in the environments. It was reported that desired compounds from both foods and plant samples can be extracted in higher quantities when PHWE is scaled up with some modifications (Teo *et al.* (2009).

The amount of phosphorus extracted by water could be small for most soils, and may not reflect all forms of labile P. But, Mehlich III has been established to be the most acidic extractant (pH 2.5) of all extractants and it can partly remove water-insoluble Ca-P and Mg-P compounds by desorption process Vanderleen (2002). This has informed the modification of Pressurized Hot Water Extraction method with citric acid to pH 2.5 as in Mehlich III so as to see the correlation between both extractants. Citric acid, having been reported to be a good modifying agent, is able to increase extraction fluid solvation power, and as an organic acid, could protect the user and environment (Zheng *et al.* 2009; Wenrich *et al.* 2000). Thus, it's used as a modifying agent for this study.

Maize (*Zea mays*), the test crop is the third important cereal food crop in the world being exceeded by wheat and rice. FAO (2002). Hence, the aim of this study was to find out correlation of the Modified Pressurized Hot Water Extraction at (pH 2.5) as a green chemistry extraction technique which can aid sustainable environment with phosphorus uptake by maize and with other phosphorus extraction methods.

Material and Methods

Experimental Site

The experiment was conducted at the soil fertility laboratory and the screen house, Department of Agronomy, University of Ibadan, Ibadan Nigeria which is located in an area with coordinates 7° 24'N and longitude 3° 54' and latitude of 234 m above sea level. The experiment was in two phases. The incubation study was focused on the release of available phosphorus into the incubated soil over a duration of 6 weeks while the screen house study was focused on the nutrient uptake using maize as a test crop.

Soil Sample Collection

The two soil types (Alfisol and Inceptisol) that were used for this study were collected from the farmland of the Practical Year Training Programme and Parry Road respectively, with coordinates latitude 7° 27'N and longitude 3° 53' at 321.5 m above sea level, University of Ibadan, Nigeria. The soil samples collected were subjected to routine analysis at the Consultancy Laboratory in the department of Agronomy, University of Ibadan, Nigeria.

Experimental Designs, Treatment and Layout

- i. A commercial citric acid was used to modify the distilled water used for the determination of soil available phosphorus.
- ii. Extractants used to determine soil available phosphorus were Bray 1, Mehlich III, pressurized hot water extraction (PHWE) and modified pressurized hot water extraction (MPHWE).
- iii. The Espresso machine used for pressurized hot water and modified pressurized hot water procedures.
- iv. Experiment A involves the rate of release of phosphorus as determined by different extractants through incubation studies. Forty grams of soil were weighed into each of the 20 incubation cups and kept under dark condition in cupboard of the laboratory. The soil received N: P: K 15: 15:15 fertilizer at the rate of 60kg P₂O₅ / ha and was kept moist. The experimental design used was completely randomized design (CRD), with 4 treatments (methods of Phosphorus extraction), two soil types and two replicates. The soil available phosphorus of the incubated soils was determined at week 2, 3, 4, 5 and 6.
- v. Experiment B involves the determination of phosphorus uptake by maize over a period of time in the Screen-house. A pot experiment with a planting duration of 6 weeks was conducted at the screen house of the Department of Agronomy, University of Ibadan. Each of the thirty polythene bags was filled with the two-soil type's alfisol and inceptisol of 4 kg. Then, N: P: K 15:15:15 fertilizer was applied to the soil at the rate of 60 kg P₂O₅, the pots were kept moist, and the soil was left to equilibrate for about 4 days before maize was sown.

The polythene bags were arranged in completely randomized design (CRD) of two replicates. Two maize seeds were planted into each of the polythene bags at a depth of 3cm. The treated soil was constantly kept at 60% field capacity throughout the experimental period that lasted for 6 weeks. The plants were terminated for destructive analysis at weeks 2, 3, 4, 5 and 6 to coincide with the laboratory incubation part of the experiment.

Soil routine analysis

Particle size distribution was determined using the hydrometer method as described by Gee and Bauder (1986). The total nitrogen was determined using micro – Kjeldahl apparatus (Bremner and Mulvaney, 1982). Available phosphorus was determined by the Bray 1 method using colorimetric assessment according to (AOAC, 1990). The determination of Ca, Mg, KM, Na and CEC was done using ammonium acetate method (Thomas, 1982). Percentage organic carbon content was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1996) while the percentage organic matter (OM) was obtained by multiplying the % carbon (C) by 1.724, i.e % OM = % C × 1.724. The exchangeable acidity (EA) was determined using the conventional Van Bernmellermethod, i.e., leaching the soil with 1M KCl and titrating with 0.01M sodium hydroxide. The exchangeable aluminum was determined by adding one drop of 0.01M HCl to make the soil solution colorless, then 10 ml of 4 % sodium fluoride was added to return the pinkish

colour, and titrating with 0.01M HCL till the solution became colorless again. Micronutrients (Zn, Fe, Mn and Cu) were extracted using Mehlich III solution (Aubert and Pinta, 1977).

Laboratory Analysis

Available phosphorus was determined using the following extractants Bray 1 (0.025M HCl, 0.03M NH₄F), Mehlich III (0.2N acetic acid, 0.25N NH₄NO₃, 0.015N NH₄F, 0.013N HNO₃, 0.00M EDTA), Pressurized hot water (PHW) and Modified Pressurized hot water (Citric acid at pH 2.5). The ratio of soil to extractant in each case was 1:10.

Pressurized Hot Water Procedure

An espresso machine was calibrated by running two runs of distilled water without soil sample. The espresso machine has 2.5 bars pressure and 93°C temperature. The procedure involves weighing 5g of 2mm sieved soil into Whatman's 42 filter paper and placing in the espresso machine filter basket. Distilled water of 100ml was poured in the espresso's water reservoir at the top of the machine and the lid was tightened and allowed to heat for 2 minutes. The heated water was then released and passed through the soil sample until the boiler was empty. Extraction aliquots were allowed to cool. Aliquots of 10 ml from the extracted samples were analysed for phosphorus. Modified pressurized hot water was derived by acidifying the distilled water with citric acid until the desired pH of 2.5 was arrived at. A routine procedure for the above pressurized hot water was followed i.e., Espresso machine was still used for the extraction to ensure the temperature and pressure of the distilled water used is influenced.

Statistical Analysis

The data obtained were subjected to Correlation and Regression analysis at 5% level of probability.

Result and Discussion

Pre-planting chemical and physical properties of the two soil types

The values of the physical and chemical properties of the pre-planting soil samples are as shown in Table 1. The textural class of the untreated soils according to USDA was determined to be Loamy Sand (an Alfisol from Parry Road, University of Ibadan) and Sandy Loam (an Inceptisol from Valley Bottom University of Ibadan) respectively. The pH of the Alfisol in distilled water and potassium chloride was 6.21 and 5.87 respectively while for Inceptisol the pH in distilled water and potassium chloride was 6.17 and 5.89 respectively. Both soils were close to being neutral soils. The two soils used differ relatively in pH although they are close in value (6.21 and 6.17). The soils have exchangeable acidity 0.20 and 0.30 respectively (1).

Table 2 showed that Mehlich III, MPHWE and PHWE extracted low level of P in both Alfisol and Inceptisol used for the studies than Bray 1. Mehlich III had the highest correlation with plant uptake ($r = 0.88$, $p = 0.05$), while MPHWE also followed closely in high correlation with plant uptake ($r = 0.61$, $p = 0.05$) and Bray I had a moderate correlation with plant uptake ($r = 0.58$, $p = 0.05$) while PHWE had the lowest correlation with plant uptake ($r = 0.37$, $p = 0.05$) for Alfisol.

In Table 3 for the Inceptisol Bray 1 had the highest correlation with plant uptake ($r = 0.77$, $p = 0.05$), while Mehlich III also followed closely in high correlation with plant uptake ($r = 0.66$, $p = 0.05$) and MPHWE has a moderate correlation with plant uptake ($r = 0.54$, $p = 0.05$) while PHWE has the lowest correlation with plant uptake ($r = 0.42$, $p = 0.05$) for Inceptisol.

Table 1: Chemical and Particle- size Properties of the Experimental soil

Parameters	Alfisol	Inceptisol
pH (1:1) H ₂ O	6.21	6.17
pH (1:1) CaCl ₂	5.87	5.89
Organic Matter (mg/ kg)	5.34	7.42
Total Nitrogen (g/ kg)	0.7	2.4
Avail P (mg/kg)	62	112
Exchangeable cations Cmol/kg		
Ca	3.4	4.7
Mg	0.3	1.1
K	0.6	0.7
Na	0.4	0.5
Exchangeable acidity (Al and H)	0.15	0.35
Extractable micronutrients (mg/kg)		
Fe	1	6
Mn	14	2
Cu	1	1
Zn	2	6
Particle size distribution (g/kg)		
Sand	774	832
Silt	140	80
Clay	86	98
Textural class (USDA)	Loamy Sand	Sandy Loam

Table 2: Correlation values of Available P extracted by the four Methods and nutrient Uptake for Alfisol

Extraction Methods	R
MEHLICH–III	0.88*
MPHWE (pH 2.5)	0.61*
BRAY 1	0.58 ^{ns}
PHWE	0.37 ^{ns}

ns = not significant,

* = significant at 5 % n = 10

r = Correlation

Table 3: Correlation values of Available P extracted by the 4 Methods and Nutrient Uptake for Inceptisol

Extraction Methods	R
BRAY-I	0.77*
MEHLICH III	0.66*
MPHWE (pH 2.5)	0.54*
PHWE	0.42ns

ns = not significant,

* = significant at 5 % n = 10,

r = correlation

Relationship among the Extractants used.

The MPHWE had the highest correlation with Mehlich III with a correlation value of ($r = 0.53, p = 0.05$) and its lowest correlation with PHWE extraction ($r = 0.20, p = 0.05$) Mehlich III also had the highest correlation with MPHWE ($r = 0.53, p = 0.05$) while it lowest was with bray 1 ($r = 0.20, p = 0.05$) in the Alfisol used for the study. Bray 1 had its highest correlation with PHWE ($r = 0.93, p = 0.05$) and its lowest correlation MPHWE ($r = 0.47, p = 0.05$). The PHWE had its highest correlation with Mehlich III ($r = 0.67, p = 0.05$). While its lowest correlation was with MPHWE ($r = 0.20, p = 0.05$) as seen in Table 4 for the Alfisol.

The MPHWE had the highest correlation with PHWE with a correlation value of ($r = 0.77, p = 0.05$) and its lowest correlation with Bray 1 extractant ($r = 0.25, p = 0.05$) Mehlich III also had the highest correlation with PHWE ($r = 0.92, p = 0.05$) while it lowest was with bray 1 ($r = 0.32, p = 0.05$) in the Inceptisol used for the study. Bray 1 had it highest correlation with PHWE ($r = 0.93, p = 0.05$) and its lowest correlation MPHWE ($r = 0.26, p = 0.05$). PHWE had it highest correlation with Bray ($r = 0.69, p = 0.05$). While its lowest correlation was with MPHWE ($r = 0.53, p = 0.05$) as seen in Table 5 for the Inceptisol.

Comparative rate of release of P measured by the extractants for the two soils across the week of incubation.

Comparative rate of release of P across the 6 weeks of incubation is shown in Fig 1 for Alfisol, the result showed that Bray 1 extracted most value of P at 5 weeks of incubation time among the extractants and it extracted it lowest at 4 weeks of incubation time. While Mehlich follow closely after Bray 1 in the amount of P it extracted, and it had lowest level of P extraction at week 6 of incubation duration. The MPHWE had the lowest values of P among all the extractants from week 1 to week 6. The PHWE also extracted low levels of P throughout the incubation period.

Comparative rate of release of P across the 6 weeks of incubation for Inceptisol in Fig 2 showed that Bray 1 and Mehlich III both extracted the highest amount of P at 2 weeks of incubation respectively and also consistently extracted the same amount of P at 2, 4, 5 and 6 weeks of incubation. The MPHWE extracted its highest amount of P at the 6th week of incubation with its lowest amount of P at 4 weeks of incubation.

Table 4: The relationship between MPHWE and other extractants used for Alfisol

Extractants	MPHWE	MEHLICH III	BRAY 1	PHWE
MPHWE	1	0.53	0.47	0.20
MEHLICH III	0.53	1	0.20	0.37
BRAY 1	0.47	0.53	1	0.93*
PHWE	0.20	0.67*	0.46	1

ns = not significant, * = significant at 5%, n = 10

Table 5: The relationship between MPHWE and other extractants used for Inceptisol

Extractants	MPHWE	MEHLICH III	BRAY 1	PHWE
MPHWE	1	0.55	0.25	0.77*
MEHLICH III	0.55	1	0.32	0.92*
BRAY 1	0.26	0.53	1	0.93*
PHWE	0.68*	0.55	0.69*	1

ns = not significant, * = significant at 5%, n = 10,

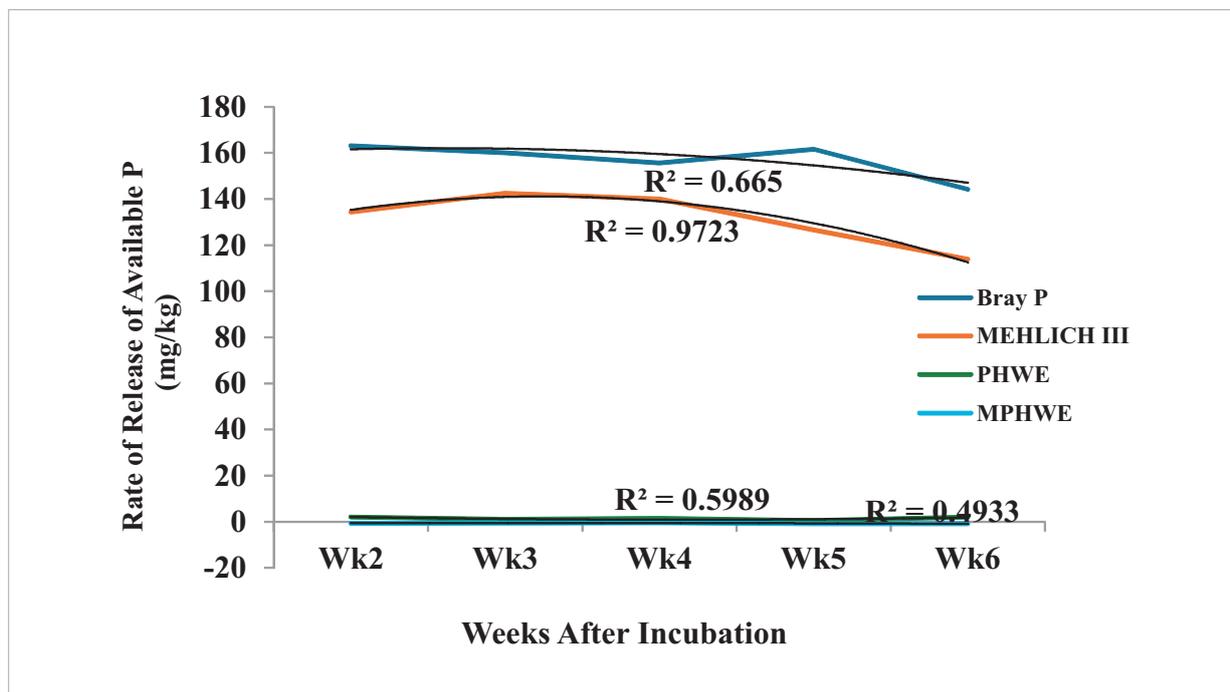


Figure 1: Available phosphorus release by extractants across weeks of incubation for Alfisol.

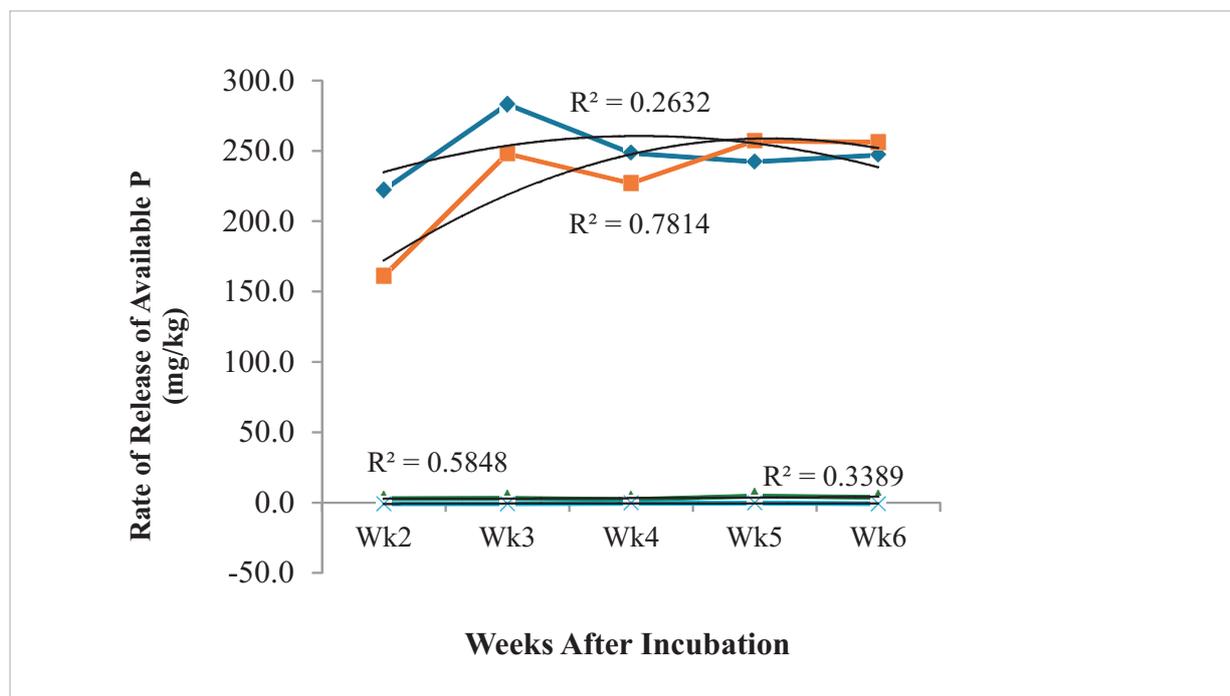


Figure 2: Available phosphorus release by extractants across weeks of incubation for Inceptisol.

Discussion

The results that was obtained from the analysis of the pre – treated soil shows that the pH of the soil is slightly acidic (6.17 and 6.21) for both Alfisol and Inceptisol respectively. Which is very suitable for the production of maize in the study area because the soil pH level for corn should be close to neutral or slightly acidic. According to the National Gardening Association, the recommended pH level for maize production is between 5.8 and 6.8. At pH below 5.6, the deficiencies of phosphorus, calcium, potassium, magnesium or molybdenum may occur if soil is too acidic (Brewbaker, 2003). Although, pH 6 and 6.5 will provide the best conditions for growth (Shorter et al., 2018). The textural classes of the untreated Alfisol and Inceptisol was determined to be Loamy Sand and Sandy Loam respectively.

The organic matter content of the Alfisol (5.34) and Inceptisol (7.42) was generally low because they were below the critical level of 10 – 14 g/kg according to FFD, (2012) and it is considered low for good soil management and crop production (Landon, 1991). The total nitrogen (N) content of the alfisol (0.7 g/kg) was lower than the critical level of 1.5 g/kg recommended for tropical soils by Enzenwor et al., (1979). These low contents of Total Nitrogen (TN) and Organic Carbon (OC) could be attributed to the effect of intensive and continuous cultivation that aggravated OC oxidation. Reports revealed that cultivation of the land results in reduction of organic carbon and total nitrogen (Negassa and Gebrekidan, 2003). It as been reported that the total nitrogen (N) for the Inceptisol (2.4 g/kg) is higher than the critical level (1.5 g/kg). The potassium (K) status of the Alfisol (0.6 cmol/kg soil) and Inceptisol (0.7 cmol/kg soil) was higher than the critical level of 0.2 cmol/kg soil reported by (FFD, 2012) for the soils of the Nigerian south-west.

Although, phosphorus was reported by Patel *et al.*, (1997) as the most important nutrient that affects maize production. But most Soils in the Tropics and Sub – tropics that account for over 97 % of the world maize production, shows a wide spread of P deficiency and high sorption capacity Rao *et al.*, (2004), hence, the need for good soil test and also a suitable extractant that would extract the available P in the experimental soil for accurate fertilizer recommendation.

The extracted P differs with the soil test methods used because extractant types removes different portions of inorganic P. Mehlich III and Bray 1 extracted more P from the incubated soil with fertilizer and the soil that was not treated with fertilizer, with Bray 1 extracting the most from both Alfisol and Inceptisol. This may be due to the fact that Mehlich III and Bray 1 are acidic extractants that could partly remove water-insoluble Ca-P and Mg-P compounds through desorption process which Pressurized Hot Water Extraction method does not have the ability to do. Mehlich III is an extractant that is highly buffered and more reliable in estimating available P in a wider range of soil pH according to Mallarino (2003).

Mehlich III is an extractant that has acidic constituents (acetic [HOAc] and nitric [HNO₃]), salts (ammonium fluoride [NH₄F] and ammonium nitrate [NH₄NO₃]), and the chelating agent ethylenediaminetetraacetic acid (EDTA) (Mehlich, 1984). This may be the reason why Mehlich III extracted more P than PHWE and MPHWE. Bray 1 is a combination of HCL and NH₄F that can easily remove soluble P forms, largely Al and Fe-phosphates as suggested by Bray and Kurtz (1945). Non-labile form of P may be solubilized by these chemical extractants overestimating the level of soil available P for plant absorption. Pressurized Hot Water Extraction was modified to the pH of Mehlich III which has a pH of 2.5 using citric acid. For the Alfisol Mehlich III ($r = 0.88$, $p = 0.05$) happens to have the highest correlation with plant uptake and this was closely followed by Modified Pressurized Hot water extraction and the lowest being Pressurized Hot Water Extraction which has a neutral pH of 7 as an extractant. This maybe due to the fact that the dissolution of apatite is very sensitive to the pH of the extracting solution with an exponential increase as pH decreases below 3 (Benbi et al., 1988) and since MPHWE was modified to the same pH as Mehlich with citric acid, it is expected that it would have a better correlation with plant uptake unlike Pressurized Hot Water Extraction (PHWE).

Phosphorus extraction tests often use chemicals that are toxic to the environment, which is why Pressurized Hot Water Extraction techniques is a green technique that is being used now because it involves the use of universal solvent which is water as an extraction fluid. Water being a non – toxic extractant with a neutral pH of 7 is ecofriendly, cost effective, easy to dispose of and environmentally safe extracting fluid that can protect both the laboratory users and the environment.

Among the four extractants that were used in the determination of available P in this experiment, correlation between extracted P and the nutrient uptake in maize plant showed that Modified Pressurized Hot Water Extraction (pH 2.5) had high significant correlation with nutrient uptake but lower than the conventional Mehlich III extractant.

Expectedly, the findings in these experiments show that citric acid Modified Pressurized Hot Water extraction has a high correlation with plant uptake in both Alfisol and Inceptisol than Pressurized Hot Water extraction in both soils. Both PHWE and MPHWE extracted low levels of P compared to the conventional methods, but MPHWE has a higher correlation with plant uptake than PHWE. Water is a universal extractant that can extract P from both acid and calcereous soils although it can only extract low level of phosphorus. However, when distilled water is acidified or modified it tends to extract higher levels of phosphorus.

Conclusion

This study revealed a highly significant correlation between extracted phosphorus and the nutrient uptake in maize plants for MPHWE ($r = 0.61$ and $r = 0.54$, $p = 0.05$) for both Alfisol and Inceptisol, respectively. This was, however, lower than the conventional Mehlich III extractant ($r = 0.88$, $r = 0.66$, $p = 0.05$) for both Alfisol and Inceptisol, respectively. The result also demonstrated that the pH level of an extractant could determine the level of phosphorus that would be extracted. When Pressurized Hot Water Extraction is modified with citric acid (pH 2.5), higher levels of extractable phosphorus can be obtained compared to when PHWE (water at pH 7) was used. This indicates that the Modified Pressurized Hot Water Extraction method could be considered a suitable, sustainable, eco-friendly extractant for available phosphorus determination.

We envision that future studies be carried out in the following areas:

- The pH at which PHWE was modified with citric acid should be varied at different levels so as establish this method as a suitable extractant for soil phosphorus analysis.
- On Modification of Pressurized Hot Water Extraction (pH 2.5) method of available phosphorus and calibration on the field for fertilizer recommendation should be done.
- There is a need for development of this PHWE technology so that scaled-up equipment can be manufactured to allow for extraction of large volume of samples at relatively short time period.

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Effect of Poultry Manure on Growth, Yield and Nutritional Composition of *Crassocephalum bialfræ*

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Keywords:

Crassocephalum bialfræ, poultry manure, proximate analysis, growth and yield

Abstract

Many indigenous vegetables are highly nutritious containing several micro-nutrients. Their appropriateness to marginal soil and low-input environments offers opportunities for low greenhouse gases emissions from an agro-ecosystem as well as their climate adaptive capacity. These indigenous vegetables also signify a broad gene pool for future vegetable crop improvement. Despite the identified numerous health and economic benefits of vegetables, low productivity in developing countries remains a serious obstacle in vegetable production. Field experiment was conducted at the Teaching and Research farm, Federal University Oye Ekiti to investigate the influence of poultry manure on growth, yield and nutritional composition of *Crassocephalum bialfræ*. The levels of poultry manure used were 0, 10, 20 tonnes/ha. The experimental design was randomized complete block design, replicated three times. Data collected were number of leaves, number of branches, vine length, leaf yield and proximate composition. Data collected were subjected to analysis of variance (ANOVA) and significant means were separated using Tukey Honestly significant difference at 5% probability level. The result indicated that application rate of 20 tonnes/ha of poultry manure had the highest plant height followed by 10 tonnes/ha while 0 tonnes/ha had the least. The same trend was observed for number of leaves, number of branches and leaf yield. The nutritional composition of *Crassocephalum bialfræ* plant harvested from plot treated with 20 tonnes/ha of poultry manure had the highest carbohydrate, protein, crude fibre, ash and fat content.

Effet du fumier de volaille sur la croissance, le rendement et la composition nutritionnelle de *Crassocephalum bialfræ*

Résumé

De nombreux légumes indigènes sont très nutritifs et contiennent plusieurs micro-nutriments. Leur adaptation aux sols marginaux et aux environnements à faible niveau d'intrants offre des possibilités de réduire les émissions de gaz à effet de serre d'un agro-écosystème, ainsi que leur capacité d'adaptation au climat. Ces légumes indigènes représentent également un vaste patrimoine génétique pour l'amélioration future des cultures légumières. Malgré les nombreux avantages sanitaires et économiques des légumes, la faible productivité dans les pays en développement reste un obstacle sérieux à la production de légumes. Une expérience de terrain a été menée à la ferme d'enseignement et de recherche de l'université fédérale d'Oye Ekiti pour étudier

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Mots clés :

Crassocephalum bialfræ,
fumier de volaille,
analyse proximale,
croissance et rendement.

l'influence du fumier de volaille sur la croissance, le rendement et la composition nutritionnelle de *Crassocephalum bialfræ*. Les niveaux de fumier de volaille utilisés étaient de 0, 10 et 20 tonnes/ha. Le plan d'expérience était un plan en blocs complets randomisés, répliqué trois fois. Les données collectées étaient le nombre de feuilles, le nombre de branches, la longueur de la vigne, le rendement en feuilles et la composition proximale. Les données collectées ont été soumises à une analyse de variance (ANOVA) et les moyennes significatives ont été séparées en utilisant Tukey Honestly significant difference à un niveau de probabilité de 5%. Les résultats indiquent que le taux d'application de 20 tonnes/ha de fumier de volaille a donné la hauteur de plante la plus élevée, suivi de 10 tonnes/ha, tandis que 0 tonne/ha a donné la hauteur la plus faible. La même tendance a été observée pour le nombre de feuilles, le nombre de branches et le rendement foliaire. La composition nutritionnelle de la plante *Crassocephalum bialfræ* récoltée dans la parcelle traitée avec 20 tonnes/ha de fumier de volaille présentait les teneurs les plus élevées en glucides, protéines, fibres brutes, cendres et matières grasses.

Introduction

Vegetables are grown worldwide and play major and multiple roles in human life. They are mostly grown for their nutritious, medicinal and economic importance. In human nutrition, they are good sources of vitamins, minerals, fibre and phytochemicals (Schreinemachers *et al.*, 2018). Consuming vegetables gives taste, palatability, increases appetite and prevents constipation. Currently many are conscious of their well-being; therefore, vegetable embellished diets are advocated for health benefits. Including vegetables in the daily diet has strongly improvement good vision, gastrointestinal health, and reduction in the risk of heart disease, stroke, diabetes and some forms of cancer (Keatinge *et al.*, 2010). Vegetable production is good source of income that is steady and regular to meet the daily expenditure. Production of vegetable is more lucrative compared to field crops (Dias and Ryder, 2011). Vegetables are of very short production cycle which facilitates multiple cropping round the year resulting in quick return on investment. It is also an important source of raw materials for many industries. There are numerous health and economic benefits of vegetables but low productivity is a major constraint on developing country such as Nigeria (Adeoye, 2020). Vegetables are sensitive to adverse climatic condition (Abewoy, 2018), this is because most vegetables are herbaceous plants with short production cycle and any adverse condition during this short period can result into a great loss (Prasad and Chakravorty, 2015; Naik *et al.*, 2017). A recent study of global vegetable and legume production concluded that if greenhouse gases emissions continue on their current trajectory, vegetable yields could fall by 35% by year 2100 due to high temperature, water scarcity and increased salinity and ozone (Scheelbeek *et al.*, 2018). Underutilized indigenous vegetables (UIVs) will likely play a key role in climate-resilient vegetables, although they currently constitute a small share of agro-food systems (Prasad and Chakravorty, 2015; Scheelbeek *et al.*, 2018; Nnamani *et al.*, 2009; Mabhaudhi *et al.*, 2016). Their appropriateness to marginal niche and low-input environments offers opportunities for low greenhouse gases emissions from an agro-ecosystem, production, and processing perspective, as well as their climate adaptive capacity. These indigenous vegetables also signify a broad gene pool for future vegetable crop improvement (Kuo *et al.*, 2020). Unfortunately, there is limited quantitative and qualitative information supporting the key role indigenous vegetables play in climate resilient pathway (Padulosi *et al.*, 2011; Pachauri *et al.*, 2014; Chivenge *et al.*, 2015). *Senecio bialfræ* (with local name: Yoruba - worowo or Sierra Leone - bologi) belong to this group of vegetables that grow in large quantity as undercover in tree crop plantation. Some of these leafy vegetables are also considered for their high medicinal value as the juice extracted from the leaves (Viana, *et al.*, 2003; Gullieice *et al.*, 2004; Okpara *et al.*, 2006; Dairo and Adanlawo, 2007). The high edible mucilaginous fibre, leaves and stem are used to treat indigestion or as laxative and as purgative (Fowomola and Akindahunsi, 2005).

Moreover, fresh succulent leaves of *Senecio biafrae* are used as a leafy vegetable in Sierra Leone, Ghana, Benin, Nigeria, Cameroon and Gabon. They are especially popular in south-western Nigeria. They are usually cooked with pepper, tomato and onions.

In Congo *Senecio biafrae* is used to treat cough and heart troubles, as a tonic and to relieve rheumatic pain, prurient allergies and localized oedemas (Stevels). In Congo it also has cultural uses in initiation and funeral rituals and in Yoruba culture it is associated with rituals to ward off smallpox (Adebooye, 2004). According to FAOSTAT, 2020, average vegetable yields across sub-Saharan Africa, Southeast Asia and South Asia are estimated to be only 36%, 48% and 64%, respectively (Adeoye, 2020; Xaba and Masuku, 2013a; Udimal *et al.*, 2017; Xaba and Masuku, 2013b). Environmental hazard through prolonged drought and increased insect infestations, increasing temperatures, changing precipitation patterns, and greater frequency of extreme weather events results in negative impact on vegetable production. (Pareek *et al.*, 2017, Seneviratne *et al.*, 2012, Sojobi *et al.*, 2016). In order to alleviate and strengthen the adaptive capacity of vegetables to the changing climate adaptive practices such as the use of organic manure which enhances the water holding capacity of the soil, increase activities of micro-organism, and make soil nutrient available to plant at a slower rate is imperative (Raghuvanshi *et al.*, 2001). The study aim at evaluating the influence of poultry manure on growth, yield and nutritional composition of *Crassocephalum biafrae*.

Materials and Method

Experimental Site

The experiment was carried out at teaching and research farm of Federal University Oye-Ekiti during the 2021 growing season. The area lies between latitude 7°48'N and longitude 005°29'E.

Land Preparation

The land was prepared manually and a vegetable bed of 2.5 m by 1.5m was prepared, seedlings were planted at a spacing of 50cm by 50cm. After four weeks of planting, poultry manure was applied to each plot.

Staking of *Crassocephalum biafrae*: The *Crassocephalum biafrae* plants were supported with a stick through a twine rope that was used to tie the *Crassocephalum biafrae* plant slightly to the stick.

Soil analysis

Pre-cropping soil sampling was done randomly at the depth of 0-15 cm for the analysis of physical and chemical properties of the soil.

Experimental design

The experiment was laid out in a randomized complete block design, replicated three times. The treatment comprised of three levels of poultry manure (0, 10, 20 tonnes/ha).

Data collection and analysis: The parameters measured were plant height (cm), Number of leaves, Number of branches, plant yield and nutritional composition. Data collected were subjected to analysis of variance (ANOVA) and significant means were separated using Tukey Honestly significant difference at 5% probability level.

Laboratory plant analysis

Plant analysis was done according to the procedure outlined in Selected Methods for Soil and Plant Analysis Manual of International Institute of Tropical Agriculture, Ibadan (IITA, 1979). Determination of Moisture Content was done according to Gharezi *et al.*, 2012) while Crude Fiber Determination was determined according to Adebooye *et al.*, 2006. Crude Protein Determination was done according to AOAC, 1990. Determination of Ash Content was according to (Owusu *et al.*, 2012).

Results and Discussion

Physical and chemical properties of the soil before planting

Table 1 showed the soil physical and chemical properties before planting. Percentage of sand is high indicating a sandy loamy soil. The organic carbon before planting was 1.95g/kg. Phosphorus (1:2 water) 6.64mg/kg. Total nitrogen content was 0.12g/kg.

Chemical composition of Poultry Manure

Table 2 showed the chemical composition of the poultry manure used. The pH of the poultry manure was 7.18 indicating slightly alkaline condition. The organic carbon was 20.48% and the calcium content was 37.12cmol/kg. The magnesium content of the poultry manure was 16.36cmol/kg while potassium was 42.30cmol/kg, the nitrogen content was 2.58% while total phosphorus was 0.87%.

Influence of Poultry manure levels on number of leaves of *Crassocephalum bialfræ*

Table 3 presented the influence of poultry manure on leaves of *Crassocephalum bialfræ*. At two weeks after planting, there were significant difference in number of leaves of *Crassocephalum bialfræ* for all the levels of fertilizer applied. At sixth, eighth, 10th and twelve weeks after planting, application rate of 20 tonnes per hectare had the highest number of leaves of *Crassocephalum bialfræ*. This was followed by 10tons/ha while the control had the least. This supports the result obtain by Modisane and Duplooy, 2009, Oyeniya and Agbede, 2009.

Table 1: Physical and chemical properties of the soil before planting

Parameters	Soil
Organic Carbon (%)	1.95
pH 1:2(water)	6.64
Nitrogen (%)	0.12
Available Phosphorus (mg/kg)	10.92
Magnesium (Cmol/kg)	2.30
Potassium (Cmol/kg)	0.26
Sodium (Cmol/kg)	0.02
Exchanged Acidity	0.70
Particle size analysis	
Sand %	87.4
Silt %	7.0
Clay %	5.6
Textural class	Loamy Sand

Table 2: Chemical composition of poultry manure used

SAMPLE	PARAMETERS						
	pH	O. C. %	Ca cMol/kg	Mg cMol/kg	K cMol/kg	TOTAL P %	N %
POULTRY MANURE	7.18	20.48	37.12	16.36	42.30	0.87	2.58

Influence of Poultry manure levels on number of branches of *Crassocephalum bialfræ*

Table 4 presented the influence of poultry manure on number of branches of *Crassocephalum bialfræ*. As from two weeks after planting, there were significant difference on number of branches of *Crassocephalum bialfræ* for all the levels of fertilizer applied. Application rate of 20 tonnes per hectare had the highest number of leaves of *Crassocephalum bialfræ*, followed by 10 tonnes per hectare while the control had the least.

Influence of poultry manure levels on vine length of *Crassocephalum bialfræ*

Table 5 presented the influence of poultry manure on vine length of *Crassocephalum bialfræ*. As from two weeks after planting, there were significant difference in plant height of *Crassocephalum bialfræ* for all the levels of fertilizer applied. Application rate of 20 tonnes per hectare had the highest number of leaves of *Crassocephalum bialfræ*, followed by 20 tonnes per hectare while the control had the least.

Influence of Poultry manure levels on fresh plant weight of *Crassocephalum bialfræ*

Table 6 presented the influence of poultry manure on fresh plant weight of *Crassocephalum bialfræ*. As from two weeks after planting, there were significant difference in fresh weight of *Crassocephalum bialfræ* for all the levels of fertilizer applied. Application rate of 20 tonnes per hectare had the highest number of leaves of *Crassocephalum bialfræ*, followed by 20 tonnes per hectare while the control had the least.

Table 3: Influenced of poultry manure on number of leaves of *Crassocephalum bialfræ*

TREATMENT	WAP	2	4	6	8	10	12
0 tonnes/ha		30b	70c	80c	102b	123b	160b
10 tonnes/ha		52a	140b	196b	215a	267a	319a
20 tonnes/ha		63a	173a	200a	233a	279a	327a

Mean in a column with the same letter(s) are not significantly different according to Tukey Honestly Difference at (P = 0.05)
WAP-Weeks after planting

Table 4: Influence of poultry manure Levels on Number of branches of *Crassocephalum bialfræ*

TREATMENT	WAP	2	4	6	8	10	12
0 tonnes/ha		3c	14c	18c	28c	40c	53c
10 tonnes/ha		6b	19b	28b	46ab	75b	111b
20 tonnes/ha		10a	29a	36a	53a	86a	112a

Mean in a column with the same letter(s) are not significantly different according to Tukey Honestly Difference at (P = 0.05)
WAP-Weeks after planting

Table 5: Influenced of poultry manure on plant vine length (cm) of *Crassocephalum bialfræ*

TREATMENT	WAP	2	4	6	8	10	12
0 tonnes/ha		38c	47c	64c	69c	75c	78c
10 tonnes/ha		40b	60b	80b	90b	98b	102b
20 tonnes/ha		42a	65a	86a	97a	112a	114a

Mean in a column with the same letter(s) are not significantly different according to Tukey Honestly Difference at (P = 0.05)
WAP-Weeks after planting

Table 6: Influence of Poultry manure levels on fresh weight of *Crassocephalum bialfræ*

TREATMENT	FRESH WEIGHT (kg)
0 tonnes/ha	0.27c
10 tonnes/ha	0.30b
20 tonnes/ha	0.35a

Table7: Influence of poultry manure Levels on Proximate composition of *Crassocephalum bialfræ*

SAMPLE	MOISTURE (%)	FAT (%)	ASH (%)	PROTEIN (%)	CRUDE FIBER (%)	CARBOHYDRATE (%)
20 tonnes	88.19a	0.22a	1.98a	2.88a	1.43a	6.67a
10 tonnes	87.52b	0.18b	1.93b	2.52b	1.33b	6.63b
Control	87.10c	0.14c	1.90c	2.34c	1.24c	5.80c

Influence of Poultry manure levels on proximate composition of *Crassocephalum bialfræ*

Table 7 presented the influence of poultry manure on proximate composition of *Crassocephalum bialfræ*. The application rate of poultry manure at 20tons/ha gave the highest fat, protein and carbohydrate levels. Application rate of 10tons/ha had the highest moisture and ash content. This implied that application rate of 20ton/ha is more beneficial on the nutrient composition of *Crassocephalum bialfræ*. The application rate of poultry manure at 20tons/ha gave the highest fat, protein and carbohydrate levels. Application rate of 10tons/ha had the highest moisture and ash content. This implied that application rate of 20ton/ha is more beneficial on the nutrient composition of *Crassocephalum bialfræ*. Adeniji (2014). Vegetables make up a major portion of human diet in many parts of the world and play significant role in human nutrition, especially as sources of Vitamins A, B, C, and E; minerals, dietary fibre and phytochemicals. Vegetables in the daily diet have been strongly associated with overall good health and improvement of gastro intestinal health, vision, risk of some forms of cancer, diabetics, and other chronic diseases (Janick, 2011). Africans have always used traditional vegetables to meet their nutritional needs. These vegetables are crops grown and consumed by local farmers along with the arable crops to serve as means of protein, minerals and vitamins in the diet of most African countries, and particularly in the Southwestern region of Nigeria. Salami (2011) revealed that these vegetables can greatly reduce the problem of malnutrition by providing adequate protein, minerals and vitamins to the body. Some of these vegetables are also used to manage diseases like high blood pressure, diabetes, urinary and stomach disorders, bronchitis and diarrhoea. Their medicinal efficacy can be guaranteed as they help in curing some minor sicknesses, thereby reducing the cost of seeking medical treatment. Many rural communities have developed sophisticated recipes based on the consumption of adequate amount of vegetables and fruits, which has been reported to enhance their immunity to diseases (Thomas, 2000). They are generally sold in local markets for economic empowerment; hence they could offer great opportunities for nutrient security and economic empowerment among the poor rural populace, especially the rural women. Unlike in the rural areas of Nigeria where most vegetable crops are obtained in the wild, the urban and semi-urban settlers obtain theirs from the open market and these serve as sources of nutrient sufficiency and income. Ojeniyi (2002). Oladeji and Ayeye (2008) reported that vegetable production forms a substantial percentage (25%) in the major food crops cultivated in Nigeria, and is a source of livelihood for a considerable section of the population, mostly women. The indigenous vegetables have unique advantages within the cropping systems. They grow quickly and are harvested within a short period of time. Adebooye *et al.* (2005) reported that some are usually gathered from the wild (with great drudgery) and indeed some of them are becoming scarce in the natural ecosystem of South-west Nigeria. In some cases, these vegetables are found in fallows, as under growth in tree crop plantations, watercourses, disturbed fields, and protected home gardens and refuse hills. A research by Adebooye and Opabode (2004), for example, was particular about the conservation of these indigenous crops in order to prevent them from going into extinction, especially as the reliance on a handful of major crops has inherent agronomic, nutritional, and economic risks, which is not sustainable in the long run (Ebert, 2014). Ayanwale *et al.* (2011), Aju *et al.* (2013) and Tanimonure *et al.* (2017) also studied the value addition and marketing potentials of some of these UIVs, and saw good business prospect in them, especially for women folks. It was equally found out that they are potential future crops for smallholder farmers, as sources of nutrition and income, especially in this era of climate change. natural systems to the impacts of climate change and climate-related risks, by maintaining or increasing adaptive capacity and systems resilience (OECD, 2011). As a result of adaptation measures, farmers are able to increase their resilience to the negative influence of climate change. Hence, adaptation increases the coping range of fresh fruits and vegetables play a significant role in human nutrition, especially as sources of vitamins (C, A, B6, thiamine, niacin), minerals, and dietary fiber (Wargovich, M.J. 2000). Their contribution as a group is estimated at 91% of vitamin C, 48% of vitamin A, 27% of vitamin B6, 17% of thiamine, and 15% of niacin.

Conclusion

The benefits of using organic manure have not been fully utilized, but this project showed positive Influence of Poultry Manure on Growth, leaf yield and proximate Composition of *Crassocephalum bialafrae* at the application rate of 20ton/ha which gave the highest fat, protein and carbohydrate content.

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Published by:







Influence of Planting Population of Onion and Soil Nutrient Mining on Post Planting Soil Fertility Status (*Allium cepa* L.)

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Keywords:
Nutrient,
Mining,
Treatment

Abstract

The nutrient requirement of onion (*Allium cepa* L.) largely depends on several factors, such as cultivar, plant population, crop environment, and soil fertility e.t.c. Nutrient mining generally refers to agricultural practices resulting in a negative nutrient balance: export (loss) of a nutrient is greater than import (input). When the quantity of soil nutrient removed by crop from agricultural field exceeds the amount of nutrient that is recycled back and/or less mobile in soil and have higher potential of remaining in the soil. Soil degradation due to nutrient mining, erosion and desertification is the major threat to food production in Nigeria. Thus, this study is to evaluate the influence of onion on post planting soil fertility status. The experiment was carried out at the Organic Agriculture section of the Teaching and Research farm of the University of Ibadan, between February to May, 2022. The treatments used were different population of onion plants at 40 cm x 20 cm, 30 cm x 20 cm, 30 cm x 15 cm, and 15 cm x 10 cm. post planting soil fertility test was carried out which was subjected to Descriptive Statistics data on the parameters obtained were subjected to Analysis of Variance (ANOVA) using GENSTAT 8th Edition and means were separated using Least Significance Difference (LSD). The study concluded that there was highest loss of micro-nutrients such as manganese, copper, and zinc in the post planting soil. Therefore, onions at optimum production lead to a considerable mining of soil nutrients which should be consistently replaced.

Influence de la Population D'oignons en Plantation et de L'exploitation des Nutrients du sol sur L'état de Fertilité du sol en Post-Plantation (*Allium cepa* L.)

Résumé

Les besoins en nutriments de l'oignon (*Allium cepa* L.) dépendent largement de plusieurs facteurs, tels que le cultivar, la population végétale, l'environnement de la culture et la fertilité du sol, etc. L'extraction de nutriments fait généralement référence à des pratiques agricoles entraînant un bilan négatif des nutriments: l'exportation (perte) d'un nutriment est supérieure à l'importation (apport). Lorsque la quantité d'éléments nutritifs du sol prélevés par les cultures dans les champs agricoles dépasse la quantité d'éléments nutritifs qui sont recyclés et/ou moins mobiles dans le sol et qui ont un potentiel plus élevé de rester dans le sol. La dégradation des sols due à l'extraction de nutriments, à l'érosion et à la désertification constitue la principale menace pour la production alimentaire au Nigeria. Cette étude vise donc à évaluer l'influence de l'oignon sur l'état de la fertilité du sol après la plantation. L'expérience a été

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Mots clés :
Éléments nutritifs,
extraction,
traitement

menée dans la section d'agriculture biologique de la ferme d'enseignement et de recherche de l'Université d'Ibadan, entre février et mai 2022. Les traitements utilisés étaient différentes populations de plants d'oignons à 40 cm x 20 cm, 30 cm x 20 cm, 30 cm x 15 cm, et 15 cm x 10 cm. Des tests de fertilité du sol après plantation ont été effectués et soumis à des statistiques descriptives. Les données sur les paramètres obtenus ont été soumises à une analyse de variance (ANOVA) en utilisant GENSTAT 8ème édition et les moyennes ont été séparées en utilisant la différence de moindre importance (LSD). L'étude a conclu qu'il y avait la plus grande perte d'oligo-éléments tels que le manganèse, le cuivre et le zinc dans le sol après plantation. Par conséquent, la production optimale d'oignons conduit à une extraction considérable des nutriments du sol qui devraient être remplacés de manière cohérente.

Introduction

Nigeria is the largest onion producer in Africa and the seventh-largest producer in the world, accounting for about 10% of the global onion production. According to the Food and Agriculture Organization (FAO, 2021), Nigeria produced about 1.4 million metric tonnes of onions in 2019, making it the second-largest producer of onions in Africa after Egypt. Following all these facts, there are still few challenges facing the effective production of onion, one of them is planting population and nutrient mining in the soil.

Onions (*Allium cepa* L.) belong to the genus *Allium* and are closely related to garlic, shallots, and leeks. Onion originated from Southwest Asia but it is cultivated all over the world today.

It is commonly known as "Queen of the kitchen" due to its highly valued flavor, aroma, unique taste and the medicinal properties of its flavor compounds (Griffiths *et al.*, 2002). Onion is a biennial crop propagated either by seeds, bulb or sets (small bulb) (Chakraborty, 2014). Most people consume roughly 20 pounds of this pungent vegetable per year, eating them raw, cooked, pickled, or powdered. There are many varieties of onions to choose from, including yellow, red, white, purple, Spanish, and *Vidalia* onions. Onions are a cool-season crop and can stand temperatures well below freezing. They may be planted from seeds, from small bulbs called sets, or from transplants.

There are many planting methods and configurations of plant spacing used for onion production in North America and other continent across the globe. Onions can be direct-seeded, transplanted with field-grown or greenhouse-grown transplants, or planted using onion sets, and onions are planted on flat ground and raised beds. The between-row and within-row plant spacings vary considerably depending on the region, soil type, type of onion, and target market. Within each of these systems, the plant density can be adjusted to manipulate the final bulb size, plant structure, time to maturity, and severity of foliar diseases.

Plant population refers to number of plants per square meter (plants m⁻²) or hectare (plants ha⁻¹) and is important in onion production since it has an influence on growth, yield and quality of onion bulbs (Brewster, 1994). Plant and row spacing are considered important to the optimum plant population which may be reflected in higher yield and quality.

Plant population or density is also an important factor determining onion yield and quality. In crop production, canopy development is very important to optimize light interception, photosynthesis and dry matter accumulation to harvestable parts. So, crop canopy can be managed by alternating row spacing and plant population; as the plant density increases, yield per unit area also increases (Silvertooth, 2001).

Generally, yield of onion increases with an increase in plant population because plant densities allowed the canopy to close quickly reducing the ability of weeds to compete, but only up to an optimal limit and yield will decrease beyond this optimum. Appropriate spacing enables the farmers to keep appropriate plant population in their field. Hence, a farmer can avoid over and less population in a given plot of land, which has negative effect on yield. Therefore, to avoid nutrient competition due to inappropriate use of plant spacing and N fertilizer, sufficient spacing between plants and rows and optimum amount N fertilizer application is vital to get highest yield in a given plot of land (AVRDC, 2004).

Nigeria like any other developing country is faced with rapid population growth and expanding urban population which increase demand on agricultural production (Nasiru, 2000). Therefore, it has witnessed increased population

pressure, industrialization and intensive land use causing depletion of natural resources, limiting the performance of land with respect to its functions such as soil fertility and crop production. Continuous cultivation for crop production often times resulted in poor management practices, leaving soil in most tropical area to become less fertile. This low nutrient status of most tropical soils necessitates the use of fertilizers for intensive cultivation (Adetunji, 1991).

Healthy soils are the foundation of the food system. Our soils are the basis for agriculture and the medium in which nearly all food-producing plants grow. Healthy soils produce healthy crops that in turn nourish people and animals. Indeed, soil quality is directly linked to food quality and quantity. Soils supply the essential nutrients, water, oxygen and root support that our food-producing plants need to grow and flourish. They also serve as a buffer to protect delicate plant roots from drastic fluctuations in temperature (FAO, 2015).

The imbalance in soil nutrient in agricultural sector has drawn a serious concern for soil fertility assessment, these can be traced back to various causes such as; the application of fertilizer to soil by uneducated farmers without making particular reference to the specific need of the soil or plant, uncontrolled continuous erosion, leaching, continuous cultivation on same piece of land on yearly basis and in the riverine areas, the issue of oil spillage on land, over grazing etc. Fertile land is defined as a land that is capable of producing consistently high yield in a wide range of crops (Esu, 1991) (Corbeels *et.al.*, 2000). Scientific understanding of soil fertility is also perceived as the status of the soil in relation to the quantity and availability of required nutrients needed by crops to enhance their growth life. Farmers usually understand fertility in a given soil through their native understanding and long-term experiences in a physical framework particularly color and texture as determinants. Apart from color and texture, other important salient characteristics are rebirths such as organic residues content in the soil, moisture retention capacity, drainage, workability and friability. The farmers in tigray (Ethiopia) use a various observable indicator to assess soil fertility. One of the indicators used for fertility assessment in tigray includes the appearance of specific weed species like *Echinops hispidus* in Ethiopia (Corbeels *et.al.*, 2000).

Therefore, soil nutrient depletion has grave implication leading to widespread deficiency of macro and micro nutrients of such as N, P, K, Ca, Zn, B, S, increased soil pH levels as well as cation exchange capacity (CEC); a weakened foundation for high yielding sustainability farming, and escalating remedial cost on rebuilding depleted soil fertility evaluation (analysis). The decline in soil fertility has imposed a national problem on food insecurity (Umar *et al.*, 2018).

Thus, the objective of this study is to:

Evaluate the influence of onion on post planting soil fertility status.

Materials and Methods

Experimental Sites Description

Seedlings were raised in the screenhouse, which were transplanted at eight (8) weeks to the organic section of the Teaching and Research Farm, University of Ibadan, Ibadan, Oyo State (7°27'05"N, 3°53'46"E), field was cleared manually, weeding and wetting was done. The research field is located in the derived savannah of Southwest Nigeria. The area has a bimodal rainfall distribution which peaks in June/July and September. The early rain occurs between late March and early April and ends in July while late rain occurs from August/September to November.

The experimental design was a randomized complete block design (RCBD) with four replicates. The size of each plot was 1.5m x 2m, beds were raised to allow good bulb development and also prevent bulb rot. All the 20 plots had seedlings planted at a spacing of Treatment 1 (control) – No plant, Treatment 2 – 40 cm by 20 cm, Treatment 3 – 30 cm by 20 cm, Treatment 4 – 30 cm by 15 cm, Treatment 5 – 15 cm by 10 cm, inter-bed spacing was 0.5 m.

Surface Soil Source for Seedling

Surface soil was collected from Agronomy research site, Parry road, University of Ibadan, Oyo State (7°27'07.3"N, 3°53'10.9"E) at 0–15 cm depth using a shovel which was sieved using a 5mm Sieve for tray experiment which was later transplanted into the organic farm, Teaching and Research Farm, University of Ibadan.

Cultural Practices

Manual weeding was done by using hoe to remove weed in furrow and by the side of the bed while weeds within the beds were handpicked. Plants base was always covered with soil to prevent exposure of the onion bulb.

Data Collection: Pre soil and Post soil analysis

Soil Analysis

Laboratory Analysis for Soil Samples

Soil pH: 10 gm of soil was weighed into an extraction cup and 10mls of distilled water was added and shaken for 10 mins on the mechanical shaker. After shaking, pH was read using the Hanna electrical pH meter.

Available Phosphorus in Soil: 2 gm of soil (2 mm sieve mesh) was weighed into an extraction cup, 20 mls of Bray P solution was added and placed on the Mechanical shaker for 15 mins, after which, the solution was filtered through 90 mm whatmann filter paper and allow it to drain completely., 5mls of filtrate was measured into a clean 50 mls volume beaker, then 5 mls of Murphy and Riley solution (color reagent) was added and made up to 25 mls with distilled water. the solution was allowed to stand for about 10 mins for color to develop into blue. Using a Spectrophotometer at 882 nm wavelength, the absorbance of each solution was determined.

Total Organic Carbon in Soil. 0.5 g of 0.5 mm sieved soil sample was weighed into a Conical flask and 10 mls of 1N potassium dichromate ($K_2Cr_2O_7$) with 20 mls of concentrated Sulphuric acid (H_2SO_4) was added respectively. Then, the mixture was allowed to cool for about an hour for oxidation to occur. After an hour, the solution was made up to 100 mls with distilled water and then allowed to cool for another one hour. 3 drops of ferroine indicator (1-10 phenanthroline mono hydrate) was added and titrated with 2.5M Fe_2SO_4 (ferrous sulphate) solution until a maroon brown color solution was obtained, titre values were recorded. ss

Total Nitrogen in Soil

Digestion: 0.5 gm of 0.5 mm sieved soil was weighed into a digestion tube and 5 mls of conc H_2SO_4 with 1 tablet of Selenium was added. After which the tube was placed in the digestion block and the content was allowed to digest at 360° c for about 3hrs until a light yellowish solution was obtained in the tube. The digest was allowed to cool and poured into a 100ml volume beaker, the digest was made up to 50mls using distilled water.

Distillation: 5 mls of digest was measured into the distillation chamber, 5mls of 40% NaOH was added and distilled into a 100 mls conical flask containing 5mls of Boric acid indicator until 50 mls of a greenish color solution was obtained.

Titration: The green color solution was titrated with 0.01 N HCl until a pink color was obtained, the final value was recorded.

Particle size distribution was analyzed using the hydrometer method (Bouyoucos, 1951).

Exchangeable bases (Potassium, Calcium, Magnesium and Sodium) were determined by adding 20 ml of 0.1 N ammonium acetate, stirred it for fifteen minutes and filtered and the reading taken using Atomic Absorption Spectrophotometer. The concentration of potassium and sodium in the filtrate was read using a flame photometer.

Plant Analysis

Determination of total phosphorus in plant: Sample was oven dried at 60-70°C and milled into a powder form. 0.5 g of the milled sample was weighed and digested with 10 mls of acid mixture of Nitric acid and perchloric acid on hot plate placed under a film cupboard at 60-70°C . A color change from brown to colorless was observed and the digest was allowed to cool down and made up to 25 mls with distilled water.

The digest was measured 5mls, then 5 ml of yellow reagent solution was added and made up to 50 ml with distilled water, giving a yellowish solution that was read on a U.V spectrophotometer at 400 nanometer wavelengths, the absorbance of machine reading was recorded.

Exchangeable bases (Potassium, Calcium, Magnesium and Sodium) were determined by adding 20 ml of 0.1N ammonium acetate, stirred it for fifteen minutes and filtered and the reading taken using Atomic Absorption Spectrophotometer. The concentration of potassium and sodium in the filtrate was read using a flame photometer.

Nitrogen: 0.20 g sample was weighed into a digestion tube, selenium catalyst tablet was added and 5 mls of conc H_2SO_4 was also added. The tube was placed on a digestion block under a film cupboard and allowed to undergo heating or digestion at a regulated temperature from 50°C to 250°C for about two hours. There was a color change from brownish black to colorless and it was allowed to cool after which it was made up to 50 ml mark with distilled water. 5ml of digest was titrated with 5 ml boric acid indicator and 5 ml of normal sodium hydroxide. There was color change to green and it was titrated with normal HCl and the greenish color turned pick and the titre value was recorded.

Results

Pre-planting Soil Analysis of the Experimental Soils

The physical and chemical properties of the soil prior to planting are shown in Table 1, the textural class was sandy loam according to United States Department of Agriculture (USDA). The soil had a pH of 6.80 indicating near neutral soil pH. The soil total nitrogen (0.35g/kg) and potassium (0.2 c/mol) are below critical level. The available phosphorus (9 m/kg) was moderate which was within critical range.

Post Harvest Soil Analysis

Table 2 shows the descriptive statistics of chemical parameters of the post planting soil fertility. The result shows that there was no significant difference in the following nutrients calcium, pH, sodium, potassium, iron, and total phosphorus while results obtained from organic carbon, magnesium, manganese, copper, zinc, and total nitrogen indicates a significant difference between the four treatments and control.

Post Harvest Plant Analysis

Table 3 shows that the result obtained from post plant analysis indicates that there was no significant difference in the following nutrients Calcium, Magnesium, Potassium, Manganese, Total nitrogen and available phosphorus which means that plant spacing had no significant effect on the treatment in terms of nutrients while;

There was significant difference between the following nutrient sodium, iron, copper, and zinc in the treatments which infers that plant spacing had a significant effect on nutrients availability in the treatments which can be said that onions are micronutrient lovers.

Table 1: Pre- planting Soil Analysis of the Experimental Site

Parameters	Values	Critical value (FFD, 2012)
pH	6.8	Neutral
Organic carbon (g/kg)	3.2	Very low
Av. Phosphorus (mg/kg)	9	Moderate
Total nitrogen (g/kg)	0.35	Low
Calcium (cmol/kg)	0.1	
Magnesium (cmol/kg)	0.1	
Potassium (cmol/kg)	0.2	Very low
Sodium (cmol/kg)	0.2	
Manganese (mg/kg)	3	
Iron (mg/kg)	1	
Copper (mg/kg)	1	
Zinc(mg/kg)	1	Medium
Sand (g/kg)	744	
Silt (g/kg)	200	
Clay (g/kg)	56	
Textural class	Sandy Loam	

Table 2: Post Harvest Soil Analysis

Trt	C (g/k g)	Mg (c mol/kg)	Na (cmol)	K (cmol)	Ca (cmol)	Mn (mg/kg)	Fe (m g/kg)	Cu (mg/kg)	Zn (m g/kg)	pH	Av.P (mg/kg)	T.N (g/kg)
T1	3.2	0.07	0.27	0.18	0.19	0.3	0.9	0.1	0.9	5.6	2.4	0.36
T2	4.4	0.02	0.32	0.19	0	0.8	1.2	0.7	10.9	5.6	2.9	0.46
T3	3.9	0.07	0.27	0.17	0.03	11.2	10.4	20.6	0.5	5.5	3.1	0.46
T4	4.1	0.07	0.3	0.17	0	1.8	0.9	1	9.6	5.6	2.8	0.49
T5	4.5	0.02	0.3	0.2	0	0.5	5.3	7	0.6	5.9	3.4	0.51
Mean	4.02	0.05	0.292	0.182	0.044	2.92	3.74	5.88	4.5	5.64	2.92	0.456
LSD	0.5	0.02	NS	NS	NS	0.9	NS	9	5.4	NS	NS	0.06

Legend: NS - Not Significant LSD – Least Significant Difference at 5%, Trt - Treatment

Note:

- T1 – Bare land
- T2 – 40CM X 20CM
- T3 - 30CM X 20CM
- T4 - 30CM X 15CM
- T5 – 15CM X 10CM

Table 3: Post Harvest Plant Analysis

Trt	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	T. N (g/kg)	Av. P (mg/kg)
T2	0.22	0.13	0.9	0.23	6.9	304.8	3.5	17.6	1.92	0.017
T3	0.15	0.12	1.27	0.27	6.7	148.9	3.9	26.8	2	0.013
T4	0.18	0.17	1.28	0.31	8.9	415.4	5.6	30.2	1.79	0.015
T5	0.23	0.12	0.99	0.26	13.6	337.2	5.2	53.5	1.81	0.012
LSD	NS	NS	NS	0.03	NS	124.1	1.5	11.3	NS	NS

Legend: NS - Not Significant, LSD – Least Significant Difference Trt - Treatment

Note:

T2 – 40CM X 20CM
 T3 - 30CM X 20CM
 T4 - 30CM X 15CM
 T5 – 15CM X 10CM

Discussion

Oyedemi *et al.* (2014) and Purseglove (1972) noted that onion is a heavy feeder plant and it gives good response to organic manure. Hatridge-Esh and Bennet (1980). Reported that bulb diameter decreased as plant population increased, this was caused by competition for nutrients and insufficient space restricting bulb enlargement when plant population increased in respect to 30 cm by 15 cm and 15 cm by 10 cm. The post planting soil analysis shows that micro-nutrients were mined.

Balraj *et al.* (1998) indicated that the spacing has a direct effect on the quality and production of onion. Appropriate spacing enables the farmers to keep appropriate plant population in their field. Hence, a farmer can avoid over and less population in a given plot of land, which has negative effect on yield. Therefore, to avoid nutrient competition due to inappropriate use of plant spacing, sufficient spacing between plants and rows is vital to get highest yield in a given plot of land (AVRDC, 2004).

Conclusion and Recommendation

Hence it can be concluded from the study that treatment 30 cm by 20cm mined the most nutrients from the soil, therefore continuous planting of onions on the same land could require fertilizer to supply. Soil test should be conducted before planting season so as to know nutrient level of the soil. It can be concluded that onions at optimum production leads to a considerate mining of soil nutrients which should be consistently replaced.

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Published by:





Contribution of Ecological Agriculture (EA) to Sustainable Food Systems and Climate Resilience in Rwanda

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Keywords:
Rwanda,
Ecological agriculture,
resilience,
food systems

Access online at:
www.africanorganicconference.net
www.noara.bio



Abstract

Rwanda, situated in East Africa, faces complex challenges in food security and agricultural sustainability despite its breathtaking landscapes and rich cultural heritage. Climate change impacts, soil degradation, limited resource access, and a rapidly growing population contribute to these challenges. Rwanda's agricultural sector, pivotal to its economy, struggles with vulnerability to climate change, soil degradation, and restricted resource access. Government initiatives like the National Agriculture Policy (NAP) and the Crop Intensification Program (CIP) aim to modernize agriculture and enhance productivity. The overall purpose of study was to explore and discuss how Ecological Agriculture (EA) practices contributes to food systems and climate resilience in Rwanda. The study used both quantitative and qualitative approaches, triangulation methods that included literature review, administering questionnaire to 200 smallholder farmers, 43 key informants from different ranges of stakeholders in four major agro-ecological zones of Rwanda. This study explores the role of Ecological Agriculture (EA) practices in promoting sustainable food systems and climate resilience in Rwanda. By analyzing existing challenges, opportunities, and policy implications, the study aims to inform evidence-based strategies for enhancing agricultural. However, gaps persist in policy implementation, and smallholder farmers encounter difficulties accessing seeds, land, and markets. Agroecological approaches offer promise in addressing these challenges but face barriers to widespread adoption. The study revealed that the majority of farmers highlighted that to adhere to ecological organic agriculture is to reduce the cost of inputs, sustain the productivity of their soils. Furthermore, this study identified EA practices which should be promoted so as to contribute to household nutrition and food security such as intercropping, agroforestry and fruit trees), push pull technology. The study recommend that EA practices would plays a critical role in building resilience in the face of climate change, improving the sustainability of food systems, improving soil health, conserving biodiversity, enhancing climate resilience, boosting the economy, ensuring food security.

Contribution de L'agriculture Écologique (AE) aux Systèmes Alimentaires Durables et à la Résilience Climatique au Rwanda

Résumé

Le Rwanda, situé en Afrique de l'Est, est confronté à des défis complexes en matière de sécurité alimentaire et de durabilité agricole, malgré ses paysages à couper le souffle et son riche patrimoine culturel. Les impacts du changement climatique, la dégradation des sols, l'accès limité aux ressources et la croissance rapide de la population contribuent à ces défis. Le secteur agricole du Rwanda, qui

Mots clés :

Rwanda,
agriculture écologique,
résilience,
systèmes alimentaires

joue un rôle central dans l'économie du pays, est vulnérable au changement climatique, à la dégradation des sols et à l'accès limité aux ressources. Les initiatives gouvernementales telles que la Politique agricole nationale (PAN) et le Programme d'intensification des cultures (PIC) visent à moderniser l'agriculture et à améliorer la productivité. L'objectif global de l'étude était d'explorer et de discuter de la manière dont les pratiques d'agriculture écologique (AE) contribuent aux systèmes alimentaires et à la résilience climatique au Rwanda. L'étude a utilisé des approches à la fois quantitatives et qualitatives, des méthodes de triangulation comprenant une revue de la littérature, l'administration d'un questionnaire à 200 petits exploitants agricoles, 43 informateurs clés issus de différentes catégories de parties prenantes dans quatre zones agro-écologiques majeures du Rwanda. Cette étude explore le rôle des pratiques d'agriculture écologique (AE) dans la promotion de systèmes alimentaires durables et de la résilience climatique au Rwanda. En analysant les défis existants, les opportunités et les implications politiques, l'étude vise à informer des stratégies basées sur des preuves pour améliorer l'agriculture écologique. Cependant, des lacunes persistent dans la mise en œuvre des politiques, et les petits exploitants agricoles rencontrent des difficultés pour accéder aux semences, à la terre et aux marchés. Les approches agroécologiques sont prometteuses pour relever ces défis, mais leur adoption à grande échelle se heurte à des obstacles. L'étude a révélé que la majorité des agriculteurs ont souligné que l'adhésion à l'agriculture biologique écologique permet de réduire le coût des intrants et de maintenir la productivité de leurs sols. En outre, cette étude a identifié des pratiques d'EA qui devraient être encouragées afin de contribuer à la nutrition des ménages et à la sécurité alimentaire, telles que les cultures intercalaires, l'agroforesterie et les arbres fruitiers, ainsi que la technologie « push pull » (pousser-tirer). L'étude recommande que les pratiques d'EA jouent un rôle essentiel dans le renforcement de la résilience face au changement climatique, l'amélioration de la durabilité des systèmes alimentaires, l'amélioration de la santé des sols, la conservation de la biodiversité, l'amélioration de la résilience climatique, la stimulation de l'économie et la garantie de la sécurité alimentaire.

Introduction

Background of the Study

The agricultural sector is contributing to food security is reflected in its prioritization in the global development agenda. The Ecological Agriculture (EA) practices contributes directly to multiple SDGs targets through integrated practices including as: SDG 1 (put an end to extreme poverty); SDG 2 (zero hunger, improved nutrition and sustainable agriculture), SDG 8 (decent work and economic growth); SDG 13 (climate action) and SDG 15 (terrestrial ecosystems, forests and land). One of the African frameworks for Agenda 2063 is the Comprehensive African Agricultural Development Programme (CAADP), is an integral part of the New Partnership for Africa's Development (NEPAD and the African Development Bank (AFDB) with targets of lowering poverty and malnutrition, increasing productivity, farm incomes, and enhancing the sustainability of agricultural production [1].

Rwanda, situated in East Africa, is renowned for its breathtaking landscapes and rich cultural heritage. However, amidst its natural beauty lies a complex tapestry of challenges, particularly in the realm of food security and agricultural sustainability. The country faces multifaceted issues such as climate change impacts, soil degradation, limited access to resources, and a rapidly growing population. Against this backdrop, the need for transformative interventions in the agricultural sector becomes increasingly urgent.

Over the last decade, the government of Rwanda has intensively embarked on investments in conservation and sustainable agriculture such as land husbandry, water harvesting and hillside irrigation to increase resilience to climate change, reduce water erosion and soil loss, halt land degradation, and increase land productivity. Several policies and

strategies of the Government of Rwanda have been adopted that encourage organic production practices such as National Agriculture Policy (NAP, 2017 to 2030, MINAGRI, 2017 [2] and Strategic Plan for the Transformation of Agriculture in Rwanda (PSTA4, MINAGRI, 2018 [3] makes it clear that developing resilient agriculture will require the agro-ecological knowledge of smallholder farmers to cope with progressive land degradation and climate change, while maintaining agricultural growth. According to Giusseppe (2018), Rwandan government's focus on export-oriented crops and the drive to increase overall productivity, risks neglecting the food security need of the population pushing the poorest rural households out altogether of the agricultural sector in the absence of credible off-farm employment opportunities. Moreover, the government push to implement monoculture, the increased use of chemical fertilizers and the mounting scarcity of organic fertilizers risk endangering Rwandans' most important productive asset, namely the country's land. However, amidst its natural beauty lies a complex tapestry of challenges, particularly in the realm of food security and agricultural sustainability. The country faces multifaceted issues such as climate change impacts, soil degradation, limited access to resources, and a rapidly growing population. Rwanda's agricultural sector forms the backbone of its economy, providing livelihoods for the majority of its population, particularly in rural areas. However, the sector grapples with various challenges that hinder its potential to contribute effectively to food security and sustainable development. One of the primary concerns is the vulnerability of Rwandan agriculture to the adverse effects of climate change. Against this backdrop, the need for transformative interventions in the agricultural sector becomes increasingly urgent. Access to resources such as seeds, land, and markets also presents a formidable challenge for smallholder farmers in Rwanda. Limited access to quality seeds and planting materials restricts farmers' ability to adopt improved agricultural practices and diversify their crops. Additionally, land scarcity, coupled with insecure land tenure systems, undermines farmers' land rights and inhibits investments in sustainable land management.

Furthermore, Rwanda has embraced agroecological approaches as part of its commitment to sustainable agriculture and environmental conservation. Agroecology, which emphasizes the integration of ecological principles into agricultural systems, offers promising solutions to address the challenges facing Rwandan agriculture. However, despite these efforts, gaps and challenges persist in the implementation of existing policies and initiatives. Coordination among various stakeholders involved in agroecological interventions remains fragmented, hindering effective collaboration and knowledge sharing. Limited awareness and capacity among farmers regarding agroecological practices also impede adoption and scaling-up efforts. Moreover, institutional barriers, bureaucratic hurdles, and inadequate financial resources constrain the effective implementation of agroecological initiatives at the grassroots level.

Food and nutrition are the most important and high priorities for a human being to survive in the world. The recent report released by World Food Programme (2022) revealed that globally about 828 million people go to bed hungry every night. Since 2019, the number of people experiencing severe food insecurity has increased from 135 million to 345 million. A total of 49 million people in 49 different nations are on the edge of famine [4]. Rwanda like other sub-Saharan countries is facing challenges and issues inherent to food policy and the related food system. The issues include environmental degradation, malnutrition, the rise in Non-Communicable Diseases (NCDs), and loss of biodiversity. In addition, people's ability to feed themselves is vulnerable not only to weather-related shocks such as periodic droughts and floods. Poverty declined from 77% in 2001 to 55% in 2017, while life expectancy at birth improved from 29 in the mid-1990s to 69 in 2019[5]. Malnutrition is also exacerbated by early childbearing, anemia and obesity. The issue of poor nutrition is also magnified by household food insecurity due to low agricultural productivity. While the status of nutrition made considerable progress between 2010 and 2015, rates of chronic malnutrition among children under 5 years is still high (33%). The Comprehensive Food Security and Vulnerability and Nutrition Analysis Survey (CFSVA, 2021, shows that 20.6 percent of the Rwandan population is food insecure, with 18.8 percent moderately food insecure and 1.8 percent severely food insecure.

In light of these challenges, there is a pressing need for comprehensive research and interventions that address the underlying drivers of food insecurity and agricultural sustainability in Rwanda. This study seeks to contribute to this endeavour by examining the role of Ecological Agriculture (EA) practices in promoting sustainable food systems and climate resilience in Rwanda. By exploring the existing challenges, opportunities, and policy implications, the study aims to inform evidence-based strategies for enhancing agricultural sustainability and improving food security for all Rwandans.

Objectives of the study

The aim of this study was to contribute valuable insights into the role of Ecological Organic Agriculture in enhancing both the sustainability of food systems and the resilience of agriculture to the challenges posed by climate change in the specific context of Rwanda. Specifically, document the specific EA practices that are being implemented in Rwanda, provide recommendations for policy adjustments or support mechanisms that could further promote EA practices and analyse how EA practices contribute to the overall food systems in Rwanda.

Methodology

In order to achieve the intended objectives and deliverables of the assignment, extensive interactions and consultations with different stakeholders from public, private, producers and local and International NGOs were an integral component in the planning and implementation of the current study. The research used different qualitative and quantitative research methods in order to deliver a comprehensive analysis of primary and secondary data regarding the EA in Rwanda with a special attention for youth in rural areas.

Study area

Rwanda was subdivided into 12 Agro-Ecological Zones (AEZs) (Verdoodt and Van Ranst, 2003). To ensure an extensive analysis at the national level with representation of different key agro-ecological zones (Congo-Nile Watershed Divide, Volcanic Highlands, Central Plateau, and Eastern Savannah) we selected one district per agro-ecological zone for the study sample. These districts were chosen due to the high engagement of rural households in farming and related activities, including the practice of ecological agriculture. This selection ensures a comprehensive understanding of the adoption and impact of ecological agriculture practices across different agroecological contexts within Rwanda. The district map is also presented in Figure 1.

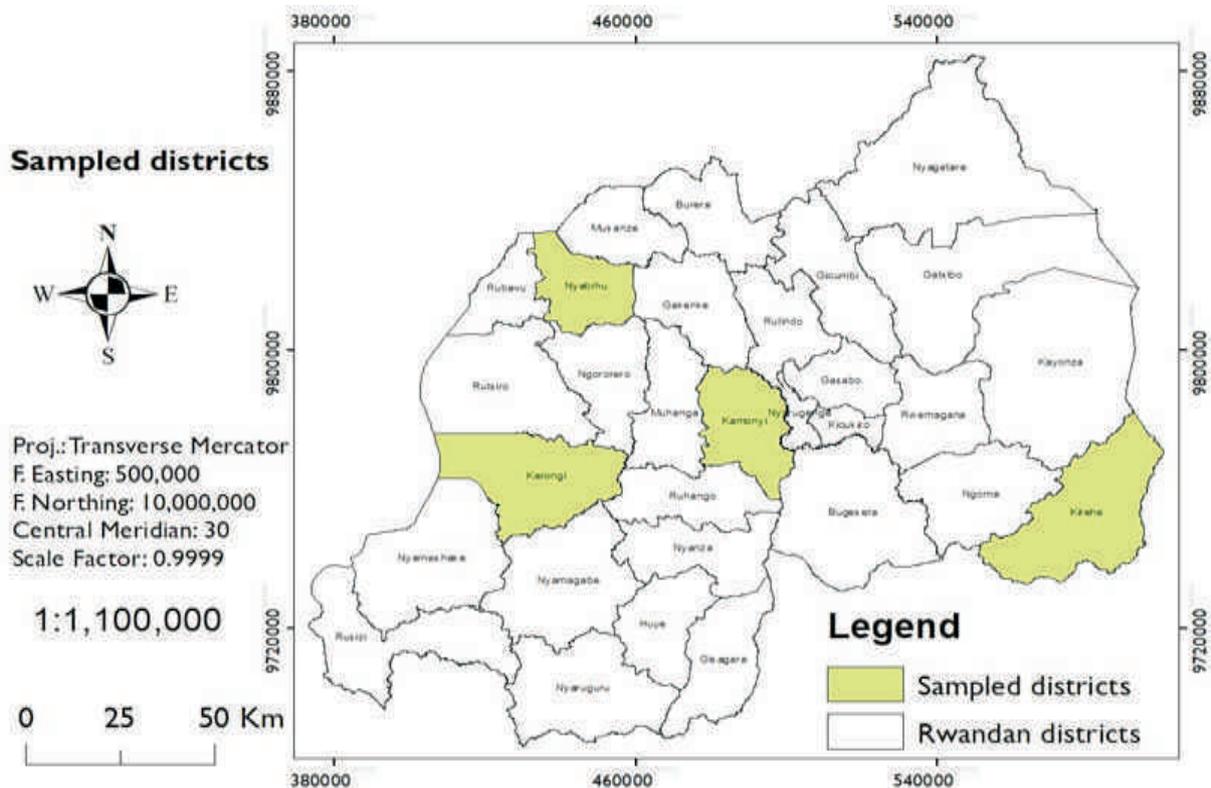


Figure 1: Map of the study area map

Data collection, sampling procedures and sample size

The random sampling was used while selecting respondents for households' questionnaire and targeted primary producers. For the total population was 269,503, for a confidence level 95%, a margin of error of 6.94%, the calculated sample size was 200 smallholder farmer as shows in the Table 1. The study managed to interview 200 smallholder farmers. A structured questionnaire designed to generate quantitative data to capture the current situation on the subject matter, youth engagement and organic market opportunities in the four districts namely Kirehe, Nyabihu, Kamonyi, and Karongi.

Table 1: Sample size in two group categories

No	AEZs	Province	District	Total	Weight	Sample (n)
1	Eastern Savanna+ Eastern Plateau zones	East	Kirehe	91,754	34	68
2	Volcanic + Buberuka+ Congo Nile Watershed Divide	North	Nyabihu	45,083	17	33
3	Central Plateau	South	Kamonyi	63,893	24	47
4	Kivu Lake Borders + Congo Nile Watershed Divide	West	Karongi	68,773	26	51
	Total			269,503	100	200

Source: Primary data, 2021

Qualitative survey

We collected qualitative data through Key Informants Interviews (KIIs) and Focus Group Discussions (FGDs). In-depth interviews with 43 key informants from a variety of stakeholders who support the development of EA. A 10 Focus Groups Discussions (FGDs) was organized in the 4 districts.

Data Analysis and reporting

After data collection, data was extracted into a statistical software in an analysable format. The data was cleaned for errors and inconsistency. STATA software was used for tabulation based on statistical analysis and anticipated data interpretation, and thereafter the results were presented in forms of tables and figures.

Study Findings

Potential EA practices that contribute to Household Nutrition and Food Security

The study identifies several major challenges hindering household nutrition and food security in Rwanda. Limited access to quality inputs such as seeds and fertilizers impedes smallholder farmers' ability to achieve optimal yields. Moreover, farmers often lack knowledge of effective farming techniques, compromising productivity and economic well-being. The lack of dietary diversity and access to nutrient-rich foods contributes to high rates of malnutrition, particularly among young children, impacting both agricultural productivity and nutritional outcomes negatively. Economically, farmers vulnerability to natural hazards like floods and adverse weather conditions leads to significant agricultural production losses, impeding their ability to increase production and improve livelihoods. This underscores the need for resilience-building measures in the face of climate change and environmental risks.

Additionally, the study highlights a deficiency in comprehensive nutrition education, particularly among women, exacerbating prevalent health issues related to malnutrition and food insecurity. Existing communication efforts may fail to engage the target audience effectively or address their specific needs, complicating efforts to improve nutrition outcomes. Furthermore, cultural barriers and limited access to educational resources pose significant challenges to disseminating vital nutrition information, hindering efforts to promote healthier dietary practices and achieve sustainable

improvements in food security and nutrition outcomes. Addressing these challenges is crucial to enhancing household nutrition and food security, requiring comprehensive interventions that address knowledge gaps, improve access to resources, and promote culturally appropriate dietary practices.

To overcome the above challenges. This study identifies several ecological agriculture (EA) practices that have the potential to contribute significantly to household nutrition and food security in Rwanda. These practices are categorized into thematic areas, including conservation agriculture, agriculture water management, agroforestry, sustainable pest and disease management, and the promotion of nutrient-rich crops.

Conservation agriculture practices, such as intercropping, crop rotation, and mixed cropping, are highlighted as effective strategies for improving soil fertility, reducing erosion, and enhancing crop diversity. Additionally, agriculture water management practices, such as rainwater harvesting and irrigation, are crucial for ensuring adequate water supply for crops, especially during periods of drought. By capturing and efficiently utilizing rainfall, farmers can mitigate the impacts of water scarcity and improve crop yields, thereby enhancing food security.

Agroforestry emerges as another important EA practice, offering multiple benefits such as soil conservation, biodiversity enhancement, and the provision of nutritious fruit trees. By integrating trees into agricultural landscapes, farmers can improve soil structure, provide shade and shelter for crops, and diversify their sources of food and income. Sustainable management of pests and diseases, exemplified by technologies like push-pull, is also recognized as essential for reducing crop losses and increasing agricultural productivity. By utilizing natural pest predators and repellents, farmers can minimize the need for chemical pesticides, thus promoting environmental sustainability and human health.

Furthermore, the **promotion of limited crops and varieties, coupled with biofortification efforts**, emerges as a strategy to address the challenge of reduced diet diversity. By focusing on nutrient-rich indigenous crops and biofortified varieties, such as Fe-rich beans and vitamin A-rich sweet potatoes, farmers can improve the nutritional quality of their diets and enhance household food security. Additionally, crop diversification and the provision of seeds and planting materials for biofortified food crops are highlighted as important interventions for improving dietary diversity and nutritional outcomes.

Additionally, the study suggests **promoting indigenous or traditional gene bank systems for access and sustainability of seeds**, along with the promotion of push and pull technologies for cereal crops. High-level dialogues on organic inputs and creating space for EA in farmer field schools are also proposed as avenues for promoting and implementing these practices effectively. By addressing these challenges and implementing these strategies, Rwanda can harness the potential of EA practices to improve household nutrition and food security, contributing to the overall well-being and resilience of its population.

Enabling environment for EA in Rwanda

A quick review of Rwandan policies and strategies for EA show that the following policies and strategies play a major role in guiding the subsector. Key policies and strategies are summarized in the Table 2.

Table 2: Key aspects of EA in the current policy and strategies framework in Rwanda

Policies	EA Aspects
i. Rwanda Vision 2050	Considers promoting sustainable agricultural practices and resilient value chains.
ii. National Strategy for Transformation (NST1), 2018	Prioritizes integrated water resources management, erosion control, and agroforestry
iii. National Agriculture Policy (NAP), 2017	Mentions priorities related to bio-fertilizer technologies, organic fertilizers, and climate smart agriculture.
iv. Strategic Plan for Agriculture Transformation (PSTA4), 2018	Mentions importance of EA knowledge, erosion control, & biological soil conservation practices
v. National Environment and Climate change Policy, 2019	Promotes erosion control, sustainable farming, climate resilient practices,& ecosystem-based approach
vi. Rwanda Green Growth & Climate Resilience Strategy (GGRS), 2020	Reduce dependence on inorganic fertilizers, conservation agriculture, and resource re-use and recovery
vii. National Determined Contributions (NDCs) updated 2020	Agroforestry, climate resilient practices, integrated water resources management
viii. National Gender Policy, 2021	Calls for gender mainstreaming in agriculture
ix. National Youth Policy (2015)	Addresses issues of youth unemployment through empowerment in agri-business
x. Gender and Youth Mainstreaming Strategy (2019)	Enables MINAGRI to mainstream gender and youth into agriculture programmes

Source: Primary data, 2021

It should be noted, that Crop Intensification Program (CIP) mainly drives the current agriculture practices in Rwanda program introduced in 2007 with the objective to respond to a growing demand on food security (IRDP, 2018). Since the introduction of CIP, much focus has been on land use consolidation, promotion of the intensive use of agricultural inputs such as chemical fertilizers, pesticides, access to improved seeds through provision of financial subsidies as well as bulking marketing. However, the government of Rwanda has recently been shifting the focus to more sustainable production systems to safeguard the environment and natural resources in the face of the challenges induced by climate change such as high erosion in the west and frequent droughts in the East. The study also assessed the SWOT factors for EA policies in Rwanda as reported by key informants.

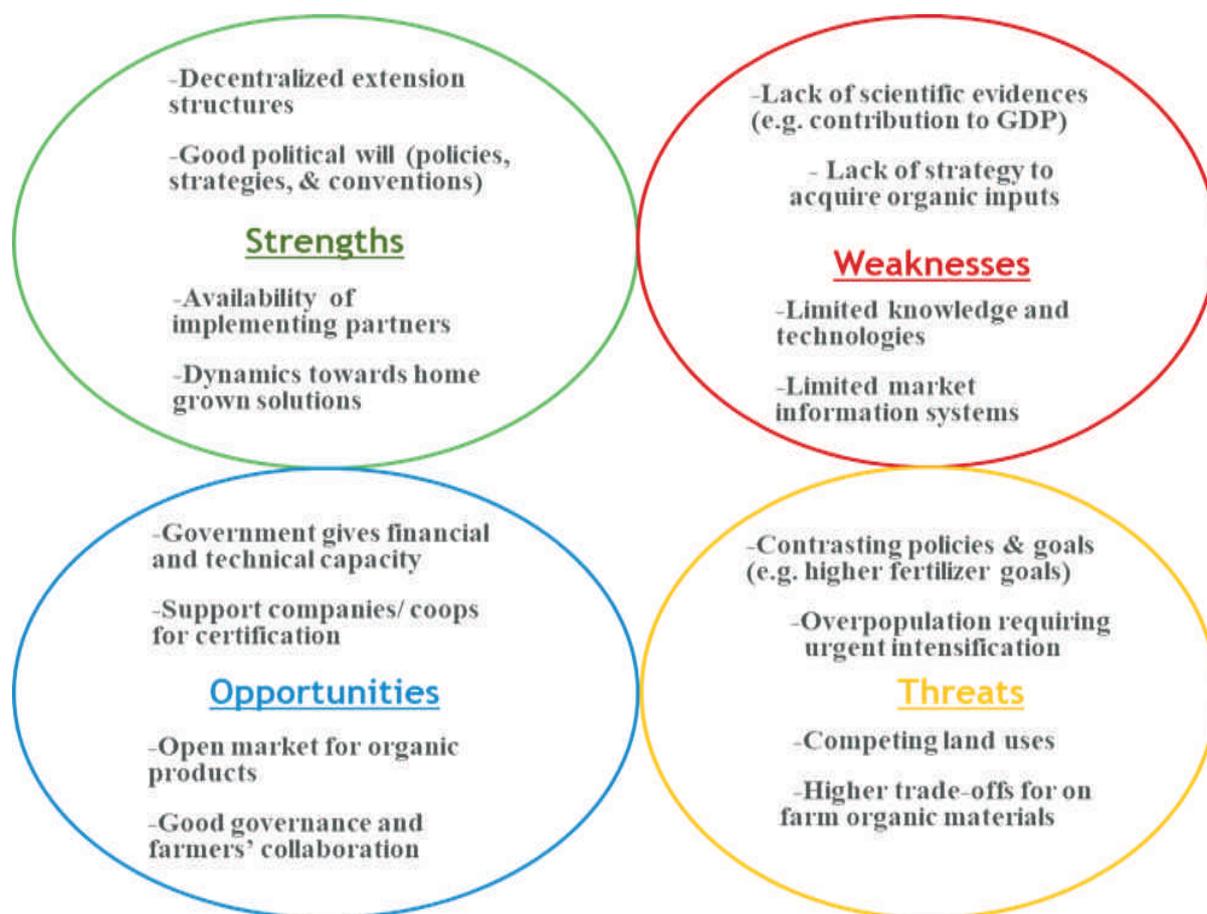


Figure 2: SWOT analysis for the EA policies implementation

Stakeholders Analysis for EA in Rwanda. Wide range of stakeholders is involved in the governance of the EA system in Rwanda, with various stakes and interests as show in the Table 3. A brief summary of key stakeholders is presented in the table below categorized according to their interests and influences as perceived by the KIIs in this study.

Table 3: Stakeholders’ interests and influence as perceived by key informants Interviews

	Low interest	Medium Interest	High interest
High Influences	ENVIROMGREEN HOLDING AFRICA, RWASHOSCCO, SORWATHE + Hillside Organic Tea Cooperative ADECOR	MINALOC, RDB, AEER, YALTA, RICA, REALMS, Ikirezi Natural products, Rwanda Mountain Tea- RUTSIRO Tea factory	MINAGRI, RAB, NAEB, ROAM, ACORD, Greencare Rwanda Ltd, MoE, Districts, MINECOFIN
Medium influences	NISR, RBS, PSF, MINALOC, UR	CCOAIB, SINA General Urwibutso	CAPCN, HORECO, YEAN
Low Influences	IPRC, AGRIRESEARCH, Local Market (Marriot).	RYAF, FAO, IFAD, WB	Finance institutions (Equity bank, BK, or KCB)

Source: Primary data

Knowledge and practice of EA among farmers

The study compared the EA knowledge that farmers have to the practices they applied in the last three years and to the practices, they are still applying. It was established that farmers practice the EA practices they know and that drop out is not common. On average, 34.2% of households have some knowledge in EA, 29.2% of households applied that knowledge in the last three years, while 27.5% still apply some EA practices. Nevertheless, the benefits of the practices in terms of production cost reduction or soil fertility improvement still need to be quantified as indicated in the Table 4.

Table 4: Knowledge and practice of EA

<i>Types of EA</i>	<i>EA practices knowledge</i>		<i>EA practices applied in last 3 years</i>		<i>EA practices still applying</i>	
	Freq.	%	Freq.	%	Freq.	%
Organic fertilizers/compost	200	98	200	98	200	98
Crop rotation	193	94.6	193	94.6	192	94.1
Cover crops/mulches	165	80.9	149	73	144	70.6
Intercropping	162	79.4	125	61.3	110	53.9
agroforestry (Fruits) trees	136	66.7	127	62.3	120	58.8
Conservation agriculture/minimum till	114	55.9	105	51.5	101	49.5
Terracing	109	53.4	43	21.1	35	17.2
Small scale irrigation	104	51	66	32.4	61	29.9
Contour planting	101	49.5	86	42.2	76	37.3
Cultural control	64	31.4	41	20.1	32	15.7
Green manure plants	54	26.5	51	25	48	23.5
Biological soil conservation practices	38	18.6	23	11.3	19	9.3
Use of weather and climate information	34	16.7	31	15.2	30	14.7
Eco friendly chemical pesticides	34	16.7	29	14.2	24	11.8
Natural pesticides and anti- weeds such as push and pull	34	16.7	25	12.3	26	12.7
Recycled harvested rain water	33	16.2	19	9.3	18	8.8
Valley tank/dam	30	14.7	13	6.4	14	6.9
Mixed crop (Beans or Soya beans)	24	11.8	22	10.8	19	9.3
Integrated soil fertility management	15	7.4	14	6.9	13	6.4
Farm ponds	11	5.4	1	0.5	1	0.5
Mechanical and physical control	8	3.9	3	1.5	4	2
Crop insurance	6	2.9	2	1	2	1
Climate smart post-harvest value addition	4	2			2	1
Use of SST Equipment's	1	0.5	1	0.5		
<i>Average</i>	70	34.2	60	29.2	56	27.5

Source: Primary data

Challenges and Stresses to Agriculture Production in the Study Area. The greatest challenges and stresses reported by farmers in Kirehe district which is located in the Eastern Savannah agro ecology and which is the driest agro ecology of the country were mainly insufficient rainfall and drought (combined they account for 50%). Karongi also follows in terms of stresses caused by insufficient rainfall and drought. For such case, solar powered drip irrigation are recommended. However, the districts in the Western Province (Karongi and Nyabihu) predominantly in the Congo-Nile Watershed divide agro ecology did not experience drought related stresses mainly due to the abundance of rainfall in that agroecology. Nevertheless, all districts ranked high the stress due to diseases and pests and the infertile soils. EA can potentially provide many solutions to these highlighted challenges and stresses as indicated in the Table 5.

Table 5: Challenges and stresses affecting agricultural production in the study area

Factors	Kamonyi		Karongi		Kirehe		Nyabihu		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Diseases and pests	33	23.4	40	22.5	23	23.0	11	27.5	107	23.3
Insufficient rainfall	35	24.8	24	13.5	30	30.0	2	5.0	91	19.8
Drought	22	15.6	29	16.3	20	20.0	3	7.5	74	16.1
Infertile soil	11	7.8	24	13.5	0	0.0	6	15.0	41	8.9
Inadequate fertilizer	21	14.9	14	7.9	0	0.0	2	5.0	37	8.1
Heavy rainfall	2	1.4	14	7.9	13	13.0	6	15.0	35	7.6
Crops destroyed by animals (grazed)	7	5.0	13	7.3	8	8.0	1	2.5	29	6.3
Flood	8	5.7	3	1.7	4	4.0	1	2.5	16	3.5
Landslide	1	0.7	10	5.6	0	0.0	0	0.0	11	2.4
Other reason	1	0.7	4	2.2	1	1.0	5	12.5	11	2.4
Inappropriate seeds		0.0	1	0.6	1	1.0	3	7.5	5	1.1
Late sowing	0	0.0	2	1.1	0	0.0	0	0.0	2	0.4

The root causes of food shortage in the study area were identified as poor rainfall, poor soil fertility, lack of farming inputs, and lack of financial resources/alternative means to acquire food. Some EA practices that help in soil moisture conservation (e.g. mulching, increased soil organic matter through composts and manure) could help in sustaining agricultural production in Kirehe, Karongi and Kamonyi. Potential solutions proposed by KIIs include Identification and mobilization of more farmers/ cooperatives to engage in local seed production using EA approach; improving post-harvest handling through use of drying grounds, threshers, reapers and storage facilities; Promote a stronger research collaboration for seed value chain, with links to EA practices in Rwanda. Other potential solutions include: Improving the capacities of farmers along the specific value chains (e.g. inputs, production, processing, storage and marketing, consumption); Improving awareness, knowledge and information on the benefits of EA for environment such as soil protection, reducing pollution and biodiversity and Training extension workers in IPM, pesticide sellers, collectors and wholesaler on pesticide or others chemicals on proper pesticide application techniques and safe use of pesticides.

Proposed new EA indicators for Ministry of Agriculture and Animal Resources (MINAGRI). Given that there are few indicators on EA in MINAGRI and NISR Seasonal Agriculture Survey (SAS), the study proposed the need to strength existing EA indicators that need improvement for efficiency as well as the proposed new EA practices, targeting achievement of food security, improved nutrition and promoting sustainable agriculture. The indicators are arranged per the respective EA practices thematic area. The indicators mainly cover (i) the conservation agriculture, (ii) soil-related fertility management, (iii) agroforestry, (iv) sustainable management of pests and diseases, and (v) nutrition sensitive agriculture indicators.

Youth and Women in Agriculture Sector in Rwanda. The National Agriculture Policy (NAP, 2018-2030) promotes skills development for farmers, youth and women as a strategy to increase economic opportunities and contribute to the goals of poverty reduction. The National Youth Policy (2021) reiterates Rwanda's commitment to undertake systematic youth programming through a multi-sectorial strategy involving partnerships between the GoR, development partners, the private sector, civil society organisations, and communities to join the efforts in terms of the creation of decent/productive jobs, entrepreneurship and innovation. Despite key policies and strategies that support women and youth in agriculture and other sectors in Rwanda, key inequality areas and implementation barriers including cultural norms, practices and attitudes reduce opportunities for equitable and inclusive growth and development in the agricultural sector.

Discussions

Rwanda, like many other countries, grapples with the complex challenge of achieving sustainable food systems and climate resilience amidst a backdrop of environmental degradation, limited resources, and climate change impacts. In response to these challenges, there is a growing recognition of the potential of Ecological Agriculture (EA) practices to address food security and climate resilience issues. This discussion explores the role of EA in Rwanda, focusing on its

contribution to sustainable food systems and climate resilience, as well as the challenges and opportunities for its implementation.

Recent research in Rwanda suggests that current policies under-represent social and political causes of poverty and food insecurity[9], and that the benefits of this transformation are not always equally shared by women and girls[10] and smallholder producers⁵⁰Moreover, household wealth, focus of agricultural production, and livelihood strategies are observed to constrain the ability of farmers to access support under current policies and programs and realize their benefits; smallholder farmers in particular are likely to experience adverse outcomes of current policies[11].

Ecological Agriculture encompasses a range of practices that prioritize ecological sustainability, biodiversity conservation, and environmental stewardship. In Rwanda, EA practices have shown significant potential in promoting sustainable food systems through various mechanisms. One of the key contributions of EA to sustainable food systems is its emphasis on biodiversity conservation. By promoting crop diversity, intercropping, and agroforestry, EA enhances ecosystem resilience and reduces vulnerability to pests, diseases, and climate variability. Initiatives such as the promotion of nutritious indigenous food crops and agroforestry in Rwanda have demonstrated promising results in improving food security and nutrition.

Furthermore, EA practices contribute to soil health and fertility, crucial for sustainable agriculture. Practices such as crop rotation, organic soil amendments, and minimal tillage improve soil structure, water retention, and nutrient cycling, thereby enhancing long-term productivity and sustainability. Given the significant challenge of soil degradation in Rwanda, the adoption of EA practices can play a critical role in restoring soil health and fertility. Moreover, EA promotes climate-resilient crop production by building adaptive capacity and reducing vulnerability to climate change impacts. Practices such as rainwater harvesting, conservation agriculture, and integrated pest management contribute to enhancing resilience to droughts, floods, and extreme weather events. Overall, the contribution of EA to sustainable food systems in Rwanda lies in its ability to enhance biodiversity, soil health, and climate resilience, thereby improving agricultural productivity, food security, and nutrition outcomes.

Despite the promise of EA, several challenges hinder its widespread adoption in Rwanda. Limited financial resources, infrastructure constraints, and lack of access to credit and inputs pose significant barriers to smallholder farmers. Many farmers continue to rely on conventional farming methods due to a lack of technical skills, knowledge, and training. Addressing these barriers requires targeted education, extension services, and capacity-building programs to promote the adoption of EA practices among farmers. Additionally, environmental factors such as landslides, deforestation, and soil erosion undermine the sustainability of agricultural systems. Unsustainable land use practices exacerbate soil degradation, necessitating a multi-sectoral approach involving land use planning and conservation measures. Smallholder farmers, already vulnerable due to historical power imbalances, are now grappling with the impacts of climate change. Farm-level climate resilience is critical for food security and livelihood protection⁴³. Adoption of ecological agriculture and increased landscape forest cover have been shown to enhance the abundance and diversity of pollinators in key commodity crops, while supporting natural pest control services by providing habitats for beneficial insects and birds, and reducing the reliance on pesticides.

However, there are also opportunities for promoting EA in Rwanda. The integration of EA into national policies and strategies provides a policy framework for promoting sustainable agriculture. Mainstreaming EA principles into policy formulation and implementation can create an enabling environment for the adoption of sustainable farming practices. Moreover, there is increasing recognition of the importance of sustainable agriculture for achieving food security and climate resilience goals. With growing awareness of the environmental and social benefits of EA, there is an opportunity to mobilize political support and investment for its promotion.

Conclusions and Recommendations

In conclusion, this study highlights the significant contribution of Ecological Agriculture (EA) to sustainable food systems and climate resilience in Rwanda. EA practices have shown positive impacts on biodiversity, soil health, climate-resilient crop production, livelihoods, and environmental sustainability, demonstrating their transformative potential. Promoting nutrition-sensitive EA, including practices like intercropping, crop rotation, mixed cropping, rainwater harvesting and irrigation, agroforestry, sustainable pest and disease management, aflatoxin control measures, and biofortification, can further enhance these benefits.

However, despite a considerable portion of households in Rwanda having knowledge of EA practices, the actual application of this knowledge remains moderate. Key challenges in integrating EA into policies for sustainable food systems and climate change include limited financial resources, infrastructure constraints, and low adoption of modern technologies.

To address these challenges and capitalize on the potential of EA, several recommendations are proposed. Enhance coordination among stakeholders to ensure effective implementation of agricultural policies and programs, fostering collaboration and knowledge sharing among government agencies, NGOs, research institutions, and other stakeholders. Increase awareness and build capacity among farmers regarding agroecological practices through education, training, and extension services, empowering them to adopt sustainable farming methods. Foster stronger research collaboration for the seed value chain with links to EA practices, promoting context-specific agroecological solutions tailored to Rwanda's agricultural landscape. Strengthen policy implementation by monitoring and evaluating progress, establishing mechanisms to track the impact of interventions aimed at promoting agricultural sustainability and food security. Improve resource access for smallholder farmers by facilitating their access to quality seeds, land, and markets through targeted interventions and support mechanisms. Foster partnerships with international organizations and donor agencies to access technical expertise, financial resources, and best practices in sustainable agriculture. Ensure alignment and coherence between agricultural policies, environmental conservation efforts, and broader development goals to maximize synergies and minimize trade-offs. Prioritize investments in resilience-building measures, including EA practices such as soil conservation and water management, to enhance Rwanda's adaptive capacity to climate change impacts.

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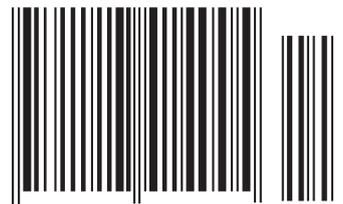
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Access online at:
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ISBN: 978-978-60736-5-1 (Prints)



978-978-60736-0-6 (Online)