

ORIGINAL ARTICLES



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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

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ABOUT NOARA

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, incomes 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

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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 organizations 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.

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NOARA KEY SERVICES

NOARA shall undertake functions appropriate to meeting the objectives cited in this constitution including 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.

The functions of the Network shall be conducted as much as possible by pooling and making use of members' own human, financial and technical resources. However, NOARA shall also make concerted effort to mobilize resources at various levels (local, national, regional, continental and international) to support research and networking activities, for a vibrant and successful Network.

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.

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Scope

Contributions may be on Agricultural Economics, Agricultural Engineering, Agricultural Extension, Agroforestry, Animal science, Crop/Environmental protection, Crop science, Environmental Sciences, Fishery/Aquaculture, Pharmacy, Soil science, Veterinary Medicine, Wildlife Management. Careful editing and scrutiny are required before sending manuscript to the editor as no room for alteration may exist once an article is accepted for publication based on reviewers' comments. Contributors are to send their manuscripts, not previously published or being considered for publication elsewhere to:

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Evaluation of Agroecological Transition Practices in Organic and Conventional Farming Systems in Uganda

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Abstract

Agricultural production is a set of practices that not only provide food but also conserve ecosystems and revitalize and preserve biodiversity and the environment. This agricultural production was confronted with a plethora of challenges as a result of the utilization of chemical substances from conventional farming. In response to environmental damage, some farmers started producing organically, which led to an agroecology transition in their practices, similar to conventional farmers. This research sought to evaluate agroecological transition practices in organic and conventional farming systems in Uganda. Data were collected through purposeful sampling in central and northwestern Uganda. In central Uganda, data were collected from 52 organic farmers in Kizigo and Naggalama villages. In northwestern Uganda, data were collected from 65 conventional farmers in the agroecology transition in Kisambo and Kijumba villages. The one-way ANOVA analysis was used to reveal the significant statistical difference between the agroecology practices implemented by organic and conventional farmers. The results revealed that the majority of respondents were women, accounting for 57.69% of those specializing in organic farming and 63.08% of those specializing in conventional agriculture within the context of agroecology transition. The conventional farmers, as organic farmers, use cover crops to control weed growth, the planting of legumes or cover crops to enhance soil fertility and reduce soil erosion, mixed cropping/intercropping to manage pests and diseases, and crop rotation to control pests and diseases on the farm for agroecology transition. There are significant differences ($p = 0.000$) between organic and conventional farmers about the use of crop residues and green manure as organic fertilizer, mulching to conserve soil moisture, bush fallowing to restore soil nutrients, and applying compost to improve soil fertility.

Keywords: organic farming, conventional farming, agroecology practices, agroecology transition, Uganda

Résumé

La production agricole est un ensemble de pratiques qui non seulement fournissent de la nourriture, mais aussi conservent les écosystèmes et revitalisent et préservent la biodiversité et l'environnement. Cette production agricole a été confrontée à de nombreux défis liés à l'utilisation de substances chimiques issues de l'agriculture conventionnelle. Face aux dommages environnementaux, certains agriculteurs ont adopté l'agriculture biologique, ce qui a conduit à une transition agroécologique de leurs pratiques, à l'instar des agriculteurs conventionnels. Cette recherche visait à évaluer les pratiques de transition agroécologique dans les systèmes agricoles biologiques et conventionnels en Ouganda. Les données ont été collectées par échantillonnage ciblé dans le centre et le nord-ouest de l'Ouganda. Dans le centre, les données ont été collectées auprès de 52 agriculteurs biologiques des villages de Kizigo et Naggalama. Dans le nord-ouest, les données ont été collectées auprès de 65 agriculteurs conventionnels en transition agroécologique dans les villages de Kisambo et Kijumba. L'analyse de variance à un facteur a permis de révéler la différence statistique significative entre les pratiques agroécologiques mises en œuvre par les agriculteurs biologiques et conventionnels. Les résultats ont révélé que la majorité des répondants étaient des femmes, représentant 57,69 % des agriculteurs biologiques et 63,08 % des agriculteurs conventionnels dans le cadre de la transition agroécologique. Les agriculteurs conventionnels, comme les agriculteurs biologiques, utilisent des cultures de couverture pour contrôler la croissance des mauvaises herbes, des légumineuses ou des cultures de couverture pour améliorer la fertilité et réduire l'érosion des sols, des cultures mixtes/intercalaires pour lutter contre les ravageurs et les maladies, et pratiquent la rotation des cultures pour lutter contre ces ravageurs et maladies dans l'exploitation, dans le cadre de la transition agroécologique. Il existe des différences significatives ($p = 0,000$) entre les agriculteurs biologiques et conventionnels concernant l'utilisation des résidus de culture et des engrais verts comme engrais organique, le paillage pour conserver l'humidité du sol, la jachère arbustive pour restaurer les nutriments du sol et l'application de compost pour améliorer la fertilité des sols.

Mots-clés : agriculture biologique, agriculture conventionnelle, pratiques agroécologiques, transition agroécologique, Ouganda

1. Introduction

Nowadays, agriculture has become a nest of problems such as biodiversity loss, soil degradation, contaminated groundwater, floods, droughts, storms, etc. These problems, most of which are due to climate change, lead to declining production, malnutrition, and poverty, and are generated by conventional agriculture that focuses on using chemicals to increase productivity. The conventional agriculture for Africa is characterized by hunger alleviation initiatives, food access (Moseley, 2016), increased demand for industrial goods and stimulation of the non-farm

economy, lower food prices, and the release of scarce foreign exchange for non-food imports (Byerlee et al., 2005; Bezemer and Headey, 2008; Haggblade et al., 2007). This convention failed because of the environmental damage, groundwater contamination, biodiversity loss, soil degradation, and fragmentation of the natural relationship for Africans with their environment. Conventional agriculture is promoted for cash crops and focuses on the use of chemicals that destroy biodiversity, damage ecosystems, contaminate food, and provide unhealthy food to the population. Recognized as a science, practice, and social movement (Wezel et al., 2020), agroecology

encompasses using scientific, experiential, and indigenous socio-ecological knowledge to agri-food systems to preserve or improve ecosystem processes, provide food, and bring value to ecosystem services (beyond food production) for humans (Ewert et al., 2023; Méndez et al., 2013; Wezel et al., 2020). Africa's natural agricultural resource base has been shown to have considerable potential for rapid productivity growth in staple crops (Moseley, 2016). The agroecological transition is now emerging as a holistic process for restoring ecosystems to their natural role in conserving biodiversity and resources. The agroecological practices focuses firstly on production-oriented agriculture, based on increasing the efficiency of resource use (e.g. fertilizer, pesticides and water), recycling waste or by-products from one subsystem to another (Kuisma et al. 2012) and applying sound agricultural practices (Ingram, 2008) or precision agriculture technologies (Rains et al. 2011), and secondly on enhancing the ecosystem services provided by biodiversity (Le Roux et al. 2008; Zhang et al. 2007). The scarce scientific literature on agroecology in the region suggests a rather critical stance towards the transformative potential of the farming approach (Dahlin and Rusinamhodzi, 2019; Mugwanya, 2019; Giller et al., 2009; Tiftonell et al., 2012). For agroecology to change the paradigm of conventional agriculture towards a participatory, transdisciplinary, and action-oriented design of sustainable agroecosystems and food systems, its successful transitions require a common understanding of the long-term implications of changes for food systems (Méndez et al., 2013; Migliorini et al., 2018). This research sought to evaluate agroecological transition practices in organic and conventional farming systems in Uganda. First, the research focuses on the various agroecology practices employed by organic and conventional farmers. Second, it analyzes the perceptions of organic and conventional farmers

regarding these practices in terms of crop production, biodiversity preservation, and the quality of the environment and food produced. Third, the research points out whether there are statistically significant differences between the agroecology practices implemented by organic and conventional farmers.

2- Methodology

2-1- Area of study

The evaluation of the impact of agroecological and conventional farming systems on biodiversity within farmlands was conducted in Central Uganda (Hoima District and Kiryandongo District) and Northwestern Uganda (Hoima District and Kiryandongo District)

Central Uganda is covered by the tropical climate 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).

The Northwestern receives a rainfall pattern with totals ranging from about 800mm in the Lake Albert flat, rising rapidly the further away East above the Escarpment to between 1250-1500mm per annum before tapering off to 1000mm in the Eastern border areas of the district (Headquarters, 2015). However, the rainfall pattern has become more erratic and less predictable. It is distributed between the two seasons from March to July and from September to November. The region has a small annual variation in air temperatures, and the climate may be described as generally hot and humid, with average monthly temperatures varying between 27°C and 31°C. The temperature maximums consistently above 30°C and sometimes reaches 38°C. Average minimum

Figure 1 shows the districts selected for this evaluation

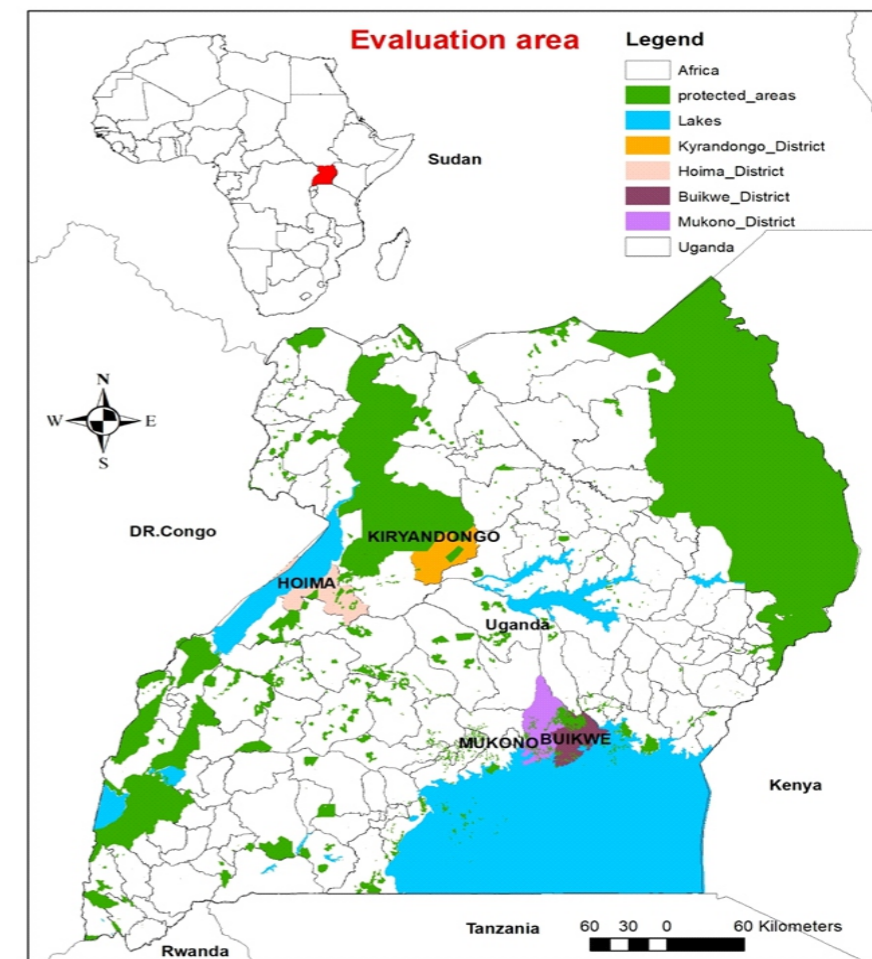


Figure 1: Evaluation area map

2-2- Sampling

The evaluation of the impact of agroecological and conventional farming systems on biodiversity within farmlands in Uganda was conducted in four districts: two in central Uganda (Buikwe District and Mukono District) and two in northwestern Uganda (Hoima District and Kiryandongo District). The central and northwestern regions were purposely selected according to the farmers' group benefits: organic training in the central region and agroecology transition practices in the northwestern region. Data collection was carried out in central Uganda with the Uganda Youth at Risk Development Network in Kizigo Village, as well as with the Naggalama Kiwebwa Youth Entrepreneurs in Naggalama Village. In northwestern Uganda, data collection was carried out with the East

African Crude Oil Pipeline Host Communities' Farmers Group in Kisambo, as well as with the Kijumba Farmers Group in Kijumba. The farmer's group in central Uganda was involved in agroecology with support from the Agency for Integrated Rural Development (AFIRD) and Participatory Ecological Land Use Management (PELUM) Uganda. The conventional farmer's group in northwestern Uganda is supported by the Centre for Environmental Research and Agriculture Innovations (CERAI) with the Inclusive Green Economy Network East Africa (IGEN-EA) project for agroecology transition. The photos depict the different farmer groups participating in this survey. The following table shows the groups of farmers interviewed districts, samples, and.

Table 1: Data collection district and sample

Region	District	Village	Number of respondents	Name of group
Central Uganda	Buikwe	Kizigo	32	Uganda Youth At Risk Development Network
	Mukono	Naggalama	20	Naggalama kiwebwa youth entrepreneurs
Northwestern Uganda	Hoima	Kisambo	37	East African Crude oil pipeline Host communities' farmers Group
	Kiryandongo	Kijumba	28	Kijumba farmers group



Photo 1: Organic farmers group Buikwe



Photo 2: Organic farmers group Mukono



Photo 1: Organic farmers group Kiryandongo



Photo 2: Organic farmers group Hoima

2-3- Presentation of the institutions

• Agency for Integrated Rural Development (AFIRD) is a non-government organization registered under number No: S-5914/2404 and certificate No: 2222 in 1998. They implemented some rural development projects in which their actions consisted of training the farmers in organic sustainable practices through farm planning, soil protection, and water harvesting, the integration of animals into the farming system, and vegetable growing using indigenous seeds. AFIRD website is <https://www.afirduganda.org/>

• Centre for Environmental Research and Agriculture Innovations (CERAI) is youth-led non-profit organization aimed at environmental and natural resource Governance. The organization is committed to conserve and protect Uganda's environment in its density through public policy research and advocacy to influence environmental, energy and agricultural policies in favor of the local person. Through research, advocacy, and community education, CERAI works with local-level leaders and community structures to promote sustainable management of natural resources

for economic development. Agroecology project will be implemented in Albertine region Uganda with communities that are being affected by oil and gas activities. The main objective of this project will be to scale up agroecology practices to combat food insecurity in oil affected districts of Hoima in Albertine Graben. The project will promote agroecological farming practices through raising awareness and enhancing capacities of oil affected farmers in sustainable environmental agriculture practices to improve their livelihoods. This will contribute to building sustainable national and local food systems by increasing awareness on agroecology, increasing the number of farmers who practice agroecology and trigger policy changes that elevate the position of agroecology in the national and local food systems at local government levels. The project will directly benefit over 500 participants including women and youth and will engage them in different activities to advance their leadership and reinforcing their capacity to engage and fully support the transition to environmentally sustainable agriculture practices. Over years, CERAI has been working in partnership with other sister organizations and for this project, CERAI will work with Inclusive Green Economy Network East Africa (IGEN-EA), Kikuube district Farmers Association and East Africa crude Oil Pipeline affected communities to implement this project. The project will build cooperation and collaboration with different stakeholders and mainstreaming of sustainable environmental agriculture practices into policies. The collaborative partners will include ministry of agriculture, local governments, media and policy makers. All these will be part of the project implementation and will help in community mobilization and sensitization. The project is expected to develop agroecology network, build youth alliances and develop linkages and synergies with policy makers and leaders and this will build a strong network of environmental agriculture

practitioner's that will scale up environmental agriculture practices across the country. The website is <https://ceraiug.org/>

2-4- Data collection and analysis

Data was collected through semi-structured interviews using questionnaires, observation, and visits to farms. Focus group discussions were also conducted with organic and conventional farmers regarding agroecology practices. The analysis focuses on thematic analysis and descriptive statistics, such as mean, percentage, and standard deviation. A one-way ANOVA analysis using SPSS 20 software revealed significant statistical differences in agroecology practices between organic and conventional farmers.

3- Results

3-1- Profile of respondents

The group of farmers from Central Uganda are organic farming group that implements agroecological practices on their farms. The group of farmers from Northwestern Uganda are conventional farming group that is involved in an agroecological transition. The results revealed that most respondents were women, accounting for 57.69% of those specializing in agroecology and 63.08% of those specializing in conventional agriculture (Figure 3). The average farm size of the agroecological farmers is 1.52 (±1.03) acres, while the average farm size of the conventional farmers is 2.37 (±3.23) acres. Organic farmers are considered agroecology farmers. The organic farmers have an average of 3.73 years (±1.72) of experience in agroecological practices, and the conventional farmers have an average of 15.31 years (±12.02) of experience, with 2 years in agroecology transition (Figure 4). Most organic farmers and conventional farmers involved in agroecological transition are between 18 and 35 years old (Figure 5). The conventional farmers were mostly educated at the primary level (56.92%), while the agroecological farmers were mostly educated at secondary and university level (73.08%) (Figure 6).

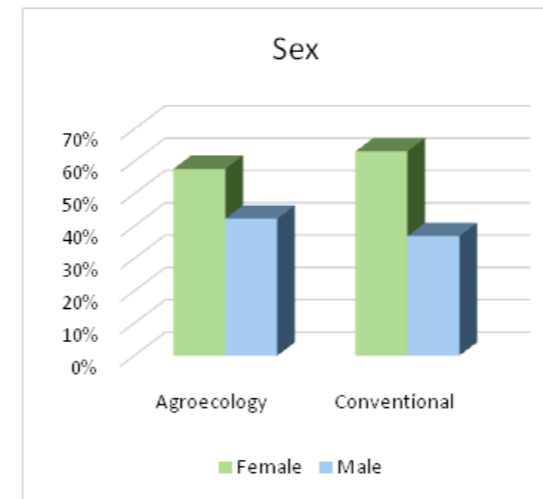


Figure 3: Sex of farmer's respondents

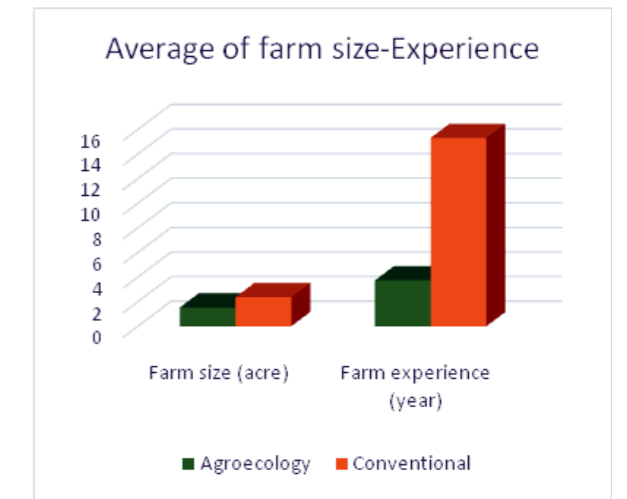


Figure 4: Farm size- Experience of farmers

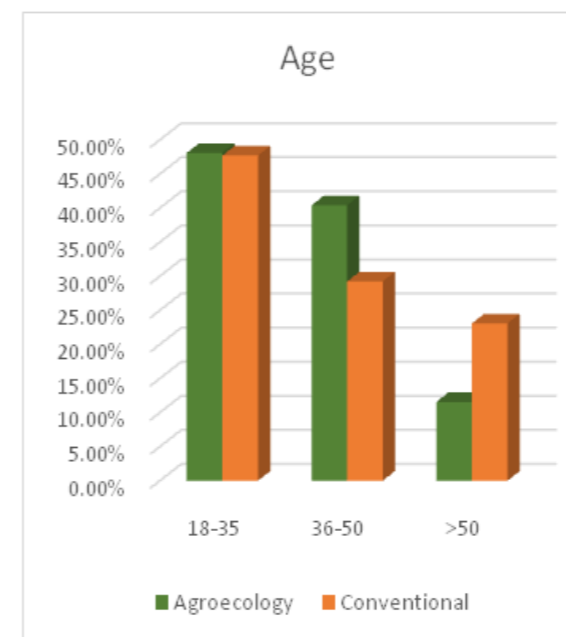


Figure 5: Age of the farmers

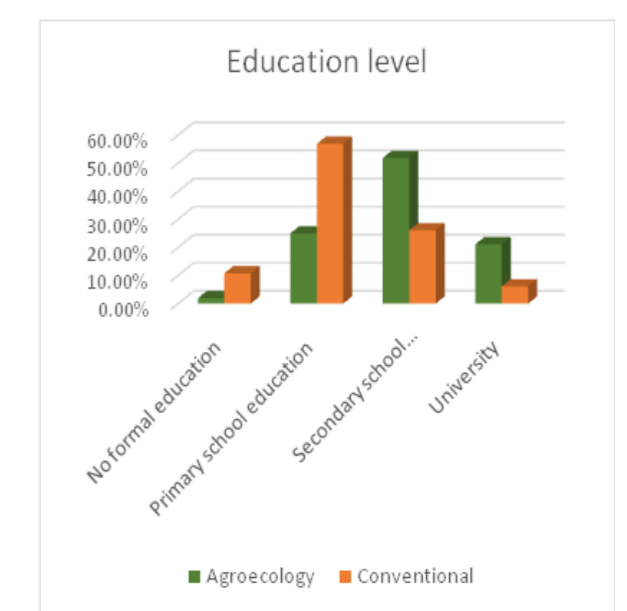


Figure 6: Education level of the farmers

3-2- Land tenure possessed by organic farmers and conventional farmers

Land tenure is a key factor in agricultural investment for food production and biodiversity conservation. The results of an evaluation of the impact of agroecological and conventional farming systems on biodiversity on farmland in Uganda showed that land tenure differed according to production systems. For

conventional agriculture, the land tenure is inheritance for the majority of farmers. Agroecology farm is exploited in land the tenure is split between inheritance and rent for the majority of farmers' respondents. Figure 7 shows the different land tenure held by agroecological and conventional farmers involved in transitioning to agroecology.

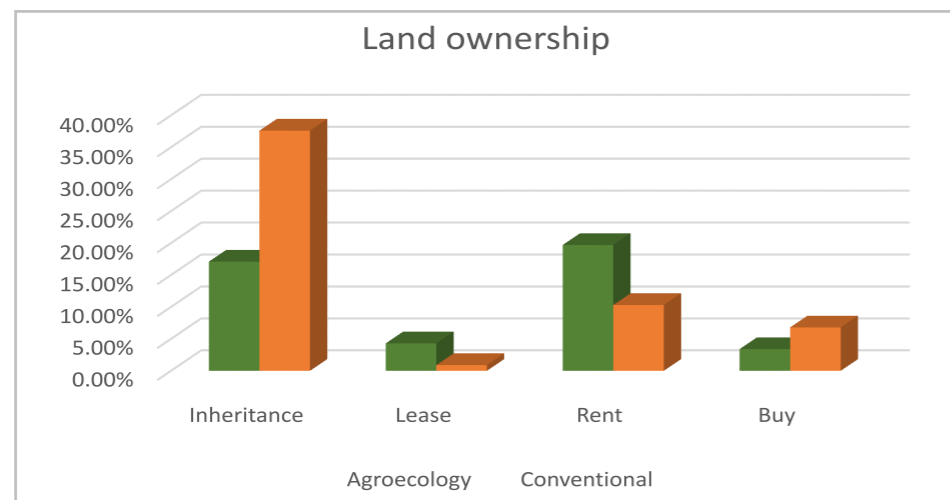


Figure 7: land tenure

3-3-Perception of agroecology practices on crop production and significance test

Agroecology is a set of practices used by organic and conventional farmers to transition to agroecology. The perception of the implementation of agroecology practices differs in organic and conventional farming. As regards crop production, organic and conventional farmers focus on increasing crop yield and resistance to pests and diseases and providing non-contaminated or toxic crops in the context of agroecological transition. The results revealed that, like conventional farmers, the majority of

organic farmers recognized that agroecological practices increased crop yields more than conventional farming did (88.46% and 61.54%, respectively). This justifies the difficulty that conventional farmers face in accessing chemical inputs due to a lack of financial resources, limited availability in the area, or the high price of these inputs. The majority have noticed that agroecology practices increase crop resistance to pests and diseases. However, agroecology practices do not contaminate crops on farms, as claimed by the majority of organic and conventional farmers. The figure shows the perception of agroecology practices on crops

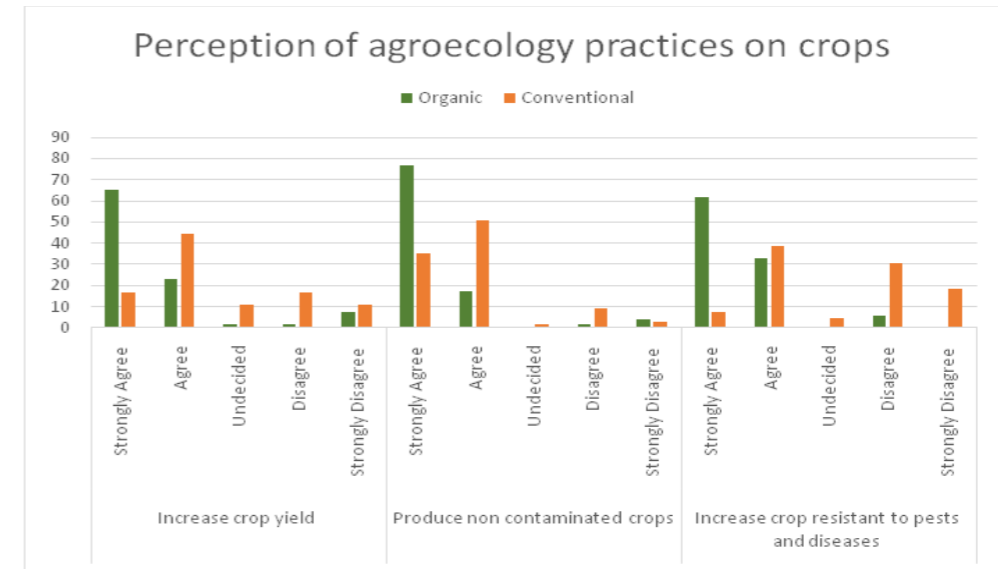


Figure 8: Perception of agroecology practices on crop production

The agroecology practices implemented on organic and conventional farms highlight differences in inputs and uses. To confirm these differences statistically, we used ANOVA analysis. The results of the one-way ANOVA analysis showed that the use of cover crops to control weed growth, the planting of legumes or cover crops to enhance soil fertility and reduce soil erosion, mixed

cropping/intercropping to manage pests and diseases, and crop rotation to control pests and diseases on the farm are significantly different (p = 0.000) across organic and conventional farming in the agroecology transition (see table).

Table 2: One-way ANOVA test for crop agroecological practices in organic and conventional farming

Variables		Sum of Squares	df	Mean Square	F	Sig.
Use cover crops to control weed Growth	Between Groups	12.350	1	12.350	26.415***	0.000
	Within Groups	53.769	115	0.468		
	Total	66.120	116			

Planting of legumes or cover crops to increase the fertility of the soil and to reduce soil erosion	Between Groups	11.077	1	11.077	27.622***	0.000
	Within Groups	46.119	115	0.401		
	Total	57.197	116			
Mixed farming (planting of crops and rearing of animals)	Between Groups	1.200	1	1.200	2.822	0.096
	Within Groups	48.919	115	0.425		
	Total	50.120	116			
Mixed cropping/intercropping to control pests and diseases	Between Groups	14.156	1	14.156	30.661***	0.000
	Within Groups	53.092	115	0.462		
	Total	67.248	116			
Crop rotation to control pests and diseases on the farm	Between Groups	4.985	1	4.985	15.950***	0.000
	Within Groups	35.938	115	0.313		
	Total	40.923	116			

*** significant at 1%

3-4- Perception of agroecology practices on environmental resources and biodiversity, and significance test

The protection of biodiversity and regeneration of environmental resources are pivotal to agroecology practices in both organic and conventional farming systems, which are key to shifting to an agroecology transition. The perception of agroecology practices on environmental resources and biodiversity encompasses the effects of agroecology practices on groundwater,

soil aeration, biodiversity, and land degradation. The results revealed that most conventional farmers disagreed that agroecological practices cause soil erosion, do not ensure a clean environment and safe food, and pollute groundwater. However, the conventional farmers agreed with organic farmers that agroecological practices improve soil aeration and biodiversity. (figure)

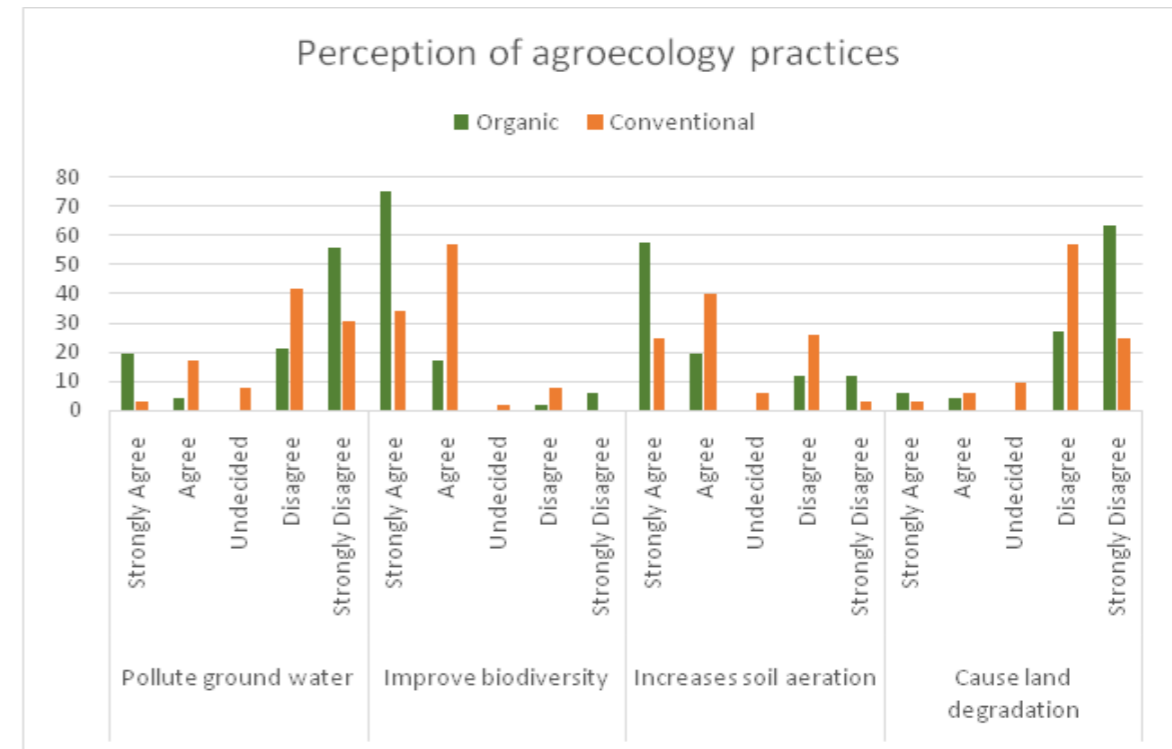


Figure 9: Perception of agroecology practices on environmental resources and biodiversity

The agroecology practices that this study takes into account for biodiversity protection are biological pest control (use of predators), the use of animal/green manure, and the use of plant extracts to control pests and diseases. Other practices include the use of natural, local inputs (plants, seeds, and animal genotypes) and biotechnologies to preserve earthworms in the soil and maintain the availability of insects, such as termites,

bugs, grasshoppers, and snails, on my farm. One-way ANOVA analysis revealed that these agroecology practices implemented by farmers for biodiversity protection are significantly different ($p = 0.000$) across organic and conventional farming in the agroecology transition (Table 3).

Table 3: One-way ANOVA test for biodiversity protection practices in organic and conventional farming

Variables		Sum of Squares	df	Mean Square	F	Sig.
Biological pest control (Use of predators)	Between Groups	22.804	1	22.804		
	Within Groups	47.504	115	0.413	55.205***	0.000
	Total	70.308	116			
Use of animal/green manure	Between Groups	27.788	1	27.788		
	Within Groups	45.904	115	0.399	69.617***	0.000
	Total	73.692	116			
Use of plant extracts to control pests and diseases	Between Groups	13.846	1	13.846		
	Within Groups	74.923	115	0.652	21.253***	0.000
	Total	88.769	116			
Use of natural local inputs (plants, seeds, animal genotypes)	Between Groups	18.312	1	18.312		
	Within Groups	51.381	115	0.447	40.985***	0.000
	Total	69.692	116			
Use biotechnologies to preserve earthworms in the soil	Between Groups	13.540	1	13.540		
	Within Groups	43.708	115	.380	35.626***	0.000
	Total	57.248	116			
Preserve availability of insects like termites, bugs, grasshoppers, snails, etc. on my farm	Between Groups	3.696	1	3.696		
	Within Groups	34.304	115	0.298	12.391***	0.001
	Total	38.000	116			

*** significant at 1%
 The sustainability and regeneration of environmental resources represent the core of agroecology practices. This research focuses on evaluating the implementation of agroecology practices in organic and conventional farming systems. These practices include using crop residues as organic fertilizer, mulching to conserve soil moisture, bush fallowing to restore soil nutrients, minimum tillage, and applying compost to improve soil fertility. The one-way ANOVA test revealed significant differences (p = 0.000)

between the use of crop residues as organic fertilizer, mulching to conserve soil moisture, bush fallowing to restore soil nutrients, and applying compost to improve soil fertility in organic and conventional farming during the agroecology transition. The following table presents the one-way ANOVA test for environmental resources used in organic and conventional farming systems.
 Table 4: One-way ANOVA test for environmental resources used in organic and conventional farming systems

Variables		Sum of Squares	df	Mean Square	F	Sig.
Use of crop residues on the farm as organic fertilizer	Between Groups	13.540	1	13.540		
	Within Groups	43.708	115	0.380	35.626***	0.000
	Total	57.248	116			
Use of mulching to conserve soil moisture	Between Groups	14.312	1	14.312		
	Within Groups	38.919	115	0.338	42.288***	0.000
	Total	53.231	116			
Bush fallowing to restore soil nutrients	Between Groups	24.004	1	24.004		
	Within Groups	49.688	115	0.432	55.555***	0.000
	Total	73.692	116			
Minimum tillage	Between Groups	3.617	1	3.617		
	Within Groups	61.169	115	0.532	6.800	0.010
	Total	64.786	116			

	Between Groups	30.694	1	30.694		
Compost application	Within Groups	44.554	115	0.387	79.226***	0.000
	Total	75.248	116			

*** significant at 1%

3-5- Perception of agroecology practices on food and well-being

The outputs of agroecology practices are to provide healthy and safe food and to build a sound environment for population well-being. However, the research tried to collect data about how organic and conventional farmers perceive agroecological practices related to nutritious crops, farmer health, food quality, and the

environment. The results revealed that, like conventional farmers, the majority of organic farmers strongly agree that agroecology practices provide crops with high nutritional value. They also strongly disagree that these practices do not ensure good health for farmers, guarantee safe food, or maintain a clean environment. The figure depicts the perception of agroecology practices on crop nutritious, farmers health, and quality of food and environment

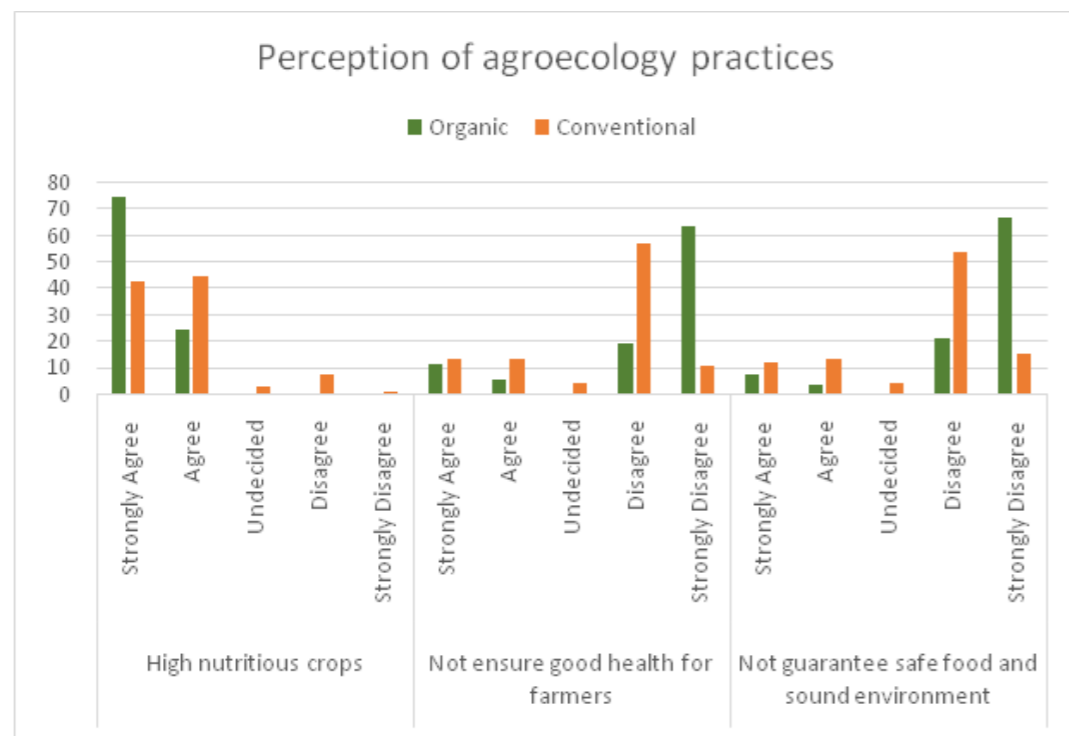


Figure 10: perception of agroecology practices on crop nutritious, farmers health, and quality of food and environment

3- Discussion

Conventional farming focused on using chemical inputs in agriculture, which led to environmental disasters (such as a drastic reduction in soil fertility and variations in rainfall over time and space), in response, farmers changed their farming systems by implementing agroecology practices for transition. Agroecology practices, which encompass mulching, longer and more diversified crop rotations, and intercropping (Silici 2014; HLPE 2019), are the result of conventional farmers in Northwestern Uganda. Conventional farmers, like organic farmers, use cover crops to control weed growth, plant legumes or cover crops to enhance soil fertility and reduce soil erosion, practice mixed cropping/intercropping to manage pests and diseases, and implement crop rotation to control pests and diseases on the farm for agroecology transition. Intercropping and cover cropping leverage plant functional traits through crop species and cultivar selection and management, yielding a range of ecosystem services, such as weed suppression and nitrogen fixation (Wood et al, 2015; Faucon, et al, 2017). Both organic and conventional farmers who engaged in agroecology transition practices perceived that these practices increased their crop yields and resistance to pests and diseases. Conventional farmers revealed that agroecology practices improve soil aeration, which positively affects biodiversity, which is recognized as a benefit of organic farming (Smith et al. 2020; Tuck et al. 2014). There is a significant difference (p = 0.000) between organic and conventional farmers regarding the use of crop residues and green manure as organic fertilizers, mulching to conserve soil moisture, bush fallowing to restore soil nutrients, and applying compost to improve soil fertility. It was also noted that organic farming increases the abundance of organisms

by 50% and species richness by 30% (Bengtsson et al, 2005; Tuck et al., 2014). Organic farming is particularly beneficial to soil microbes, plants, pollinators, and predators (Lichtenberg et 2017; Lori et al., 2017). By avoiding synthetic inputs, organic farmers used plant extracts to control pests and diseases, as well as biological pest control and natural local inputs (plants, seeds, and animal genotypes). This makes significant differences (p = 0.000) from conventional farming systems, which for agroecology transition started reducing synthetic inputs using or substituting them by using organic matter.

4- Conclusion

The evaluation of the impact of agroecological and conventional farming systems on biodiversity within farmlands in Uganda highlighted the different practices used by organic farmers and conventional farmers for agroecology transition. The organic farmers implement agroecological practices such as mulching to conserve soil moisture, planting of legumes, practicing minimum tillage, alley cropping and cover crops to increase the fertility of the soil and to reduce soil erosion, mixed cropping and intercropping to control pests and diseases, green manure and compost to fertilize the soil, use of ash to reduce pest infestation on the farm. The conventional farm which emphasize on utilization of synthetic inputs in agriculture production, the conventional farmers for transitioning to agroecology practice in majority planting leguminous crops, cover crops, and practice rotational crop systems, avoid the use of synthetic fertilizers to transition to the use of animal manure as fertilizer for soil, combine the practices of alley cropping and cleared weeds to decay on the farm. They recognize that agroecological practices don't cause soil erosion (land degradation), ensure safe food and a clean environment, don't pollute

groundwater and improve soil aeration and biodiversity. From the results, we recommend to:

- * Organic farmers focus more on the diversity of crops, animals and activities for the resilience of the production and their sustainability.
- * Conventional farmers need to increase agroecological practices in their farms to reduce

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Evaluating the Impact of Conventional and Agroecological Farming Systems on Biodiversity and Environmental Sustainability in Rwanda

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Abstract

This study evaluates the impacts of conventional and agroecological farming systems on biodiversity and environmental sustainability within maize and bean farming landscapes in Rwanda's Kamonyi and Musanze districts. By analysing soil chemical properties and microbial diversity, alongside farmer perceptions and socio-economic factors, the research reveals that agroecological practices, which utilize organic inputs like animal manure, compost, and crop residues, significantly enhance soil health by improving pH, available phosphorus, calcium, and magnesium levels compared to conventional farming reliant on chemical fertilizers and herbicides. Agroecological farms also demonstrate higher microbial populations and diversity, indicating healthier soil ecosystems critical for sustained productivity. Additionally, the study highlights the predominance of women farmers and the limited involvement of youth, underscoring the need for targeted policies to support equitable resource access and youth engagement. Farmer knowledge and positive attitudes toward agroecology, including the adoption of practices such as crop rotation, cover cropping, mulching, and biological pest control, further affirm its environmental benefits and contribution to biodiversity conservation. The findings advocate for scaling agroecological approaches through strengthened extension services, capacity building, and accessible organic inputs, complemented by multi-stakeholder collaboration to foster climate-resilient, sustainable agricultural landscapes that align with Rwanda's broader goals of food security, environmental stewardship, and inclusive rural development.

Keywords: agroecology, attitudes, climate resilience, food security, industrial farming, perceptions, Rwanda.

Résumé

Cette étude évalue l'impact des systèmes agricoles conventionnels et agroécologiques sur la biodiversité et la durabilité environnementale des paysages de culture du maïs et du haricot dans les districts de Kamonyi et Musanze au Rwanda. En analysant les propriétés chimiques des sols et la diversité microbienne, ainsi que les perceptions des agriculteurs et les facteurs socio-économiques, la recherche révèle que les pratiques agroécologiques, qui utilisent des intrants organiques comme le fumier animal, le compost et les résidus de culture, améliorent significativement la santé des sols en améliorant le pH et les niveaux de phosphore, de calcium et de magnésium disponibles, par rapport à l'agriculture conventionnelle qui repose sur les engrais et les herbicides chimiques. Les exploitations agroécologiques présentent également des populations et une diversité microbiennes plus élevées, signe d'écosystèmes pédologiques plus sains, essentiels à une productivité soutenue. De plus, l'étude met en évidence la prédominance des agricultrices et la faible implication des jeunes, soulignant la nécessité de politiques ciblées pour soutenir un accès équitable aux ressources et l'engagement des jeunes. Les connaissances des agriculteurs et leurs attitudes positives envers l'agroécologie, notamment l'adoption de pratiques telles que la rotation des cultures, les cultures de couverture, le paillage et la lutte biologique contre les ravageurs, confirment ses bienfaits environnementaux et sa contribution à la conservation de la biodiversité. Les résultats plaident en faveur d'une transposition à grande échelle des approches agroécologiques grâce à des services de vulgarisation renforcés, au renforcement des capacités et à l'accès aux intrants biologiques, complétés par une collaboration multipartite afin de favoriser des paysages agricoles durables et résilients au climat, conformes aux objectifs plus larges du Rwanda en matière de sécurité alimentaire, de gestion environnementale et de développement rural inclusif.

Mots-clés: agroécologie, attitudes, résilience climatique, sécurité alimentaire, agriculture industrielle, perceptions, Rwanda.

1.0. Introduction

1.1. Background and Rationale of the study

The intersection of food security, environmental degradation, and climate change is reshaping the future of agriculture globally. Modern industrial agricultural systems, particularly those characterized by intensive monocultures and heavy chemical inputs, have contributed significantly to environmental degradation, biodiversity loss, and climate vulnerability (Altieri, 2018; FAO, 2019). As a result, sustainable alternatives are increasingly being sought, among which agroecology has emerged as a promising solution. Agroecology integrates ecological principles with traditional knowledge to design farming systems

that are not only productive but also socially just and environmentally sustainable (Gliessman, 2015; Wezel et al., 2020).

Agroecological approaches emphasize biodiversity, soil fertility, natural pest control, and ecosystem services over synthetic inputs and monocultures. This systems-based perspective on agriculture aims to restore the ecological balance while maintaining or improving yields, ultimately enhancing resilience to climate variability (Altieri & Nicholls, 2017; Titttonell, 2014). As such, agroecology aligns with several United Nations Sustainable Development Goals (SDGs), including eradicating poverty and hunger (Goals 1 and 2), achieving climate resilience (Goal 13), and conserving biodiversity (Goal 15).

In Africa, agroecology holds promise. The continent faces growing climate risks, land degradation, and food insecurity. Smallholder farmers, who produce nearly 70% of the continent's food, are highly vulnerable to climate shocks and environmental degradation (IPCC, 2007; AU, 2015). In sub-Saharan Africa, climate projections suggest that agricultural productivity may decline by up to 21% by 2080 without major adaptations (IPCC, 2007). Within this context, agroecological practices—such as intercropping, use of organic compost, and agroforestry—can provide locally adapted solutions that enhance ecological integrity while improving food sovereignty and livelihoods (Lipper et al., 2014; NEPAD, 2012).

At the policy level, African institutions are beginning to recognize the value of agroecology. The African Union's Agenda 2063 and the Comprehensive Africa Agriculture Development Programme (CAADP) promote sustainable and climate-resilient agricultural systems (AU, 2015; NEPAD, 2012). Despite this, agroecological approaches are often underrepresented in implementation frameworks, overshadowed by conventional models that prioritize short-term productivity over long-term sustainability. Limited awareness, weak extension systems, and insufficient market and policy support remain major constraints to widespread adoption of agroecological practices (Shiferaw et al., 2019; van Rijn et al., 2018).

Rwanda, with its predominantly smallholder farming population and hilly terrain, illustrates many of these continental trends. Agriculture contributes significantly to the country's GDP and employs most of its rural population (NISR, 2022). However, Rwanda also faces severe challenges, including soil erosion, declining soil fertility, loss of agro-biodiversity, and increased exposure to climate extremes (MINAGRI, 2023). The government has responded with progressive frameworks such as the National Strategy for Transformation (NST2) and the Strategic Plan for

Agriculture Transformation (PSTA5), which emphasize climate-smart agriculture and sustainable intensification (MINAGRI, 2023). Yet, the incorporation of agroecological principles within these frameworks remains minimal, and conventional input-heavy systems continue to dominate.

In Rwanda's context, evaluating the impact of different farming systems—particularly conventional versus agroecological—on biodiversity and environmental sustainability is essential. Agroecological farming systems have been shown to foster greater species diversity, healthier soils, and enhanced pest resistance compared to conventional systems (Khan et al., 2015; Ghosh et al., 2020). However, the extent of their application and effectiveness in Rwanda remains insufficiently documented. Understanding how farmers perceive and interact with agroecological practices is crucial for tailoring interventions that resonate with local needs, capacities, and knowledge systems (Munyaneza et al., 2020; Désiré et al., 2018). Agroecology is not merely a set of techniques—it also represents a broader movement that challenges industrialized food systems and promotes equitable access to resources and sustainable livelihoods (Wezel et al., 2020). As a science, practice, and social movement, agroecology advocates for participatory innovation processes that place farmers' experiences and knowledge at the centre of transformation. Its multifaceted nature—encompassing ecological, economic, and socio-cultural dimensions—makes it well-suited for addressing the complex sustainability challenges facing Rwanda's agricultural sector (FAO, 2004).

This study, therefore, seeks to evaluate and compare the ecological outcomes of conventional and agroecological farming systems in Rwanda. By focusing on biodiversity and environmental sustainability, the research aims to generate context-specific evidence that informs agricultural policy,

extension strategies, and investment priorities. Such insights are timely, given the urgent need to reconcile agricultural productivity with ecological resilience and long-term food security in Rwanda and across sub-Saharan Africa.

1.2. Overview of agroecology and conventional farming

The potential benefits of conventional or industrial farming to address global food security challenges due to rapid population growth are widely acknowledged in contemporary literature. However, modern industrial agriculture has been criticised for favouring privatisation, harbouring accumulation, and, in effect, displacing farmers. Unlike conventional farming, which uses hybrids and artificial chemicals detrimental to health and the environment, agroecology is a process of transformation, not limited to a set of farming practices. It is an approach that integrates ecological science with other scientific disciplines and knowledge systems, including local and traditional knowledge, to guide the sustainable transformation of the current agrifood system (Mendez et al., 2013). Agroecological systems empower grassroots communities by granting them sovereignty over food production and by creating a more democratic regime of agriculture. Agroecology contributes to nutrition, health, and food security; high yields and increased productivity due to improved soil fertility and diversified crops for small-scale farmers (Giraldo, 2019). Timmermann and Félix (2015) also noted that agroecology enables farmers to give back to their communities and expand the natural, human care to a more concrete, utilitarian benefit for their surroundings.

An ecological farming system has the potential to adapt and mitigate the impacts of climate change by allowing people to live with stress and reducing emissions through carbon sequestration. The system allows

communities can build resilience by increasing their crop diversity through community-based seed production and seed sharing practices. It conserves biodiversity, enhances food security, and food sovereignty among vulnerable communities (Markiewicz-Keszycska, 2025). Some of the functions of agroecology include reducing reliance on external inputs, especially those obtained from fossil fuels. It also aims to enhance self-organized ecological functions that promote soil regeneration, natural pest predation, natural hydrological cycles, and diverse local communities.

1.3. Agriculture in Rwanda

In Rwanda, the agricultural sector is the backbone of rural livelihoods. However, it grapples with increasing challenges of productivity, ecological degradation, and adverse impacts of climate change. For decades, the government has been promoting intensification of conventional farming primarily through the Crop Intensification Program (CIP) which focused on consolidating land, increasing the use of chemical inputs, and scaling monoculture production for major crops like maize and beans (Nzabonimpa and Blake, 2016). The country's National Strategic Transformation (NST2) of 2024-2029 and Strategic Plan for Agricultural Transformation (PSTA5) prioritize climate-smart agriculture, resilience building, and sustainable intensification as ways of addressing challenges related to soil health, poor crop growth, and sustainable productivity (Minagri, 2023). While these policies resulted in improved crop yields and poverty reduction, they are criticized due to their negative impacts on biodiversity, soil health, and a lack of long-term resilience.

Agroecological and conventional agricultural practices are part of the agricultural practices of farmers in Africa. These practices have their impacts (positive and

negative) on the biodiversity of farmlands and implications thereof. Objective assessment of agricultural systems provides more empirical data for policymakers. Such data could help Africa substantiate its stand on appropriate farming systems. Despite policy interest, empirical assessments of Rwandan farmers' actual knowledge, attitudes, and practices regarding agroecology are limited. The study comprehensively assesses farmers' knowledge, opinions, and participation in agroecological practices within maize and bean farming landscapes in the country.

Nzabonimpa, F., & Blake, J. (2016). *The Impact of Rwanda's Crop Intensification Program on Agricultural Productivity and Food Security. Food Policy, 62, 149-158*



Figure 1: Location of the study areas (shown by black rectangles) in Rwanda

2. Materials and methods

2.1 Study sites

The study was conducted in Rwanda's districts of Kamonyi and Musanze (Fig. 1), from January to June 2025. Kamonyi district lies to the southern province in the Central Plateau zone at moderate altitude and rainfall suitable for maize cultivation. It has 450,849 people and covers a land area of 655.4 km². Musanze district has 476,522 people occupies a land area of 530.3 km² in Buberuka Highlands in the northern province. The district is situated at high altitude and experiences cool climate suitable for growing beans (GGGI, 2022; NISR,

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Source: https://en.wikipedia.org/wiki/Districts_of_Rwanda#/media/File:RwandaDists.png

Farmers in the two districts practise agroecological and conventional farming of beans and maize. Table 1 summarizes farming systems, main crops, districts, local locations, and farmers' groups involved in agroecological and conventional agriculture.

Table 1: Characteristics of sampled farm locations

Farming practices	Crops	District	Farmer Group	Lat. (°S)	Lon. (°E)	Alt. (m)	Landscap e position	Slope (%)
Agroecological	Maize	Kamonyi	CEFAPE K	2.0153 46	29.89813 9	1631	On terraces	25
	Beans	Musanze	Muko	1.5418 18	29.63415 8	1654	Valley	1-2
Conventional	Beans	Musanze	Gataraga	1.4153 5	29.53131 5	2354	Hilly	10-15
	Maize	Kamonyi	Kobiyaki	2.0097 02	29.89518 0	1617	On terraces	20

Source: Primary data, 2025.

2.2 Data collection

The questionnaire was designed in Kobo Toolbox to capture respondents' understanding and involvement in agroecological farming. It was divided into four sections. The first part of the questionnaire was designed to collect socio-economic details of farmers. It consisted of 19 statements, covering addressing topics such as personal contact information, age, gender, religion, level of education, farmer group name and location, land tenure, labour source, farming experience, size of farm, farming system (conventional/agroecology), crops cultivated, and animals reared:

The second part of the questionnaire solicited information about farmers' know-how on different aspects of agroecological practices. It consisted of 11 statements seeking Yes/No responses. Topics addressed include whether agroecological agriculture uses of synthetic fertilizer, animal manure, compost, off-farm and kitchen wastes, allowing cleared weeds to decay on the farm, crop rotation to control pests. In addition, respondents were asked whether agroecology involves planting of leguminous/covercrops to reduce soil erosion and increases oil nutrients, all eycropping to reduce erosion, prevents l and degradation. ensures sustain ability of ecosystems, involves bush fall owing to replenish lost nutrients and reduces environmental pollution.

The third part sought the opinions of farmers about agroecology. It consisted of 14 structured statements including whether agroecology (as opposed to conventional farming) pollutes ground water, increases crop yields than, produced crops are not toxicfree, produce highly nutritious crops, do not ensure good health for the farmers and their families, produce crops more resistant to pests and diseases than conventionally, increases oil erosion, does not pollute the environment, does not ensure safe food and clean environment, helps to improve biodiversity. produce crops does not command more valuethan those of conventional crops, increases soil aeration, and causes land degradation. Farmers were asked to respond to each statement by using a 5-point Likert scale, ranging from 1 = Strongly disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, and 5 = Strongly agree.

Lastly, the fourth section focused on how farmers are involved in agroecological practices based on 28 statements. The statements highlighted whether farmers always, occasionally or do not apply various aspects of agroecology stated in the questionnaire. The statements related to the improvement of using manure, ash, earthworms, legumes/covercrops, bush fallowing, shifting cultivation, and crop residues. Soil erosion control and moisture retention using mulching, legumes, Pests and disease control using crop rotations, ash, predators. plant extracts, and off farm organic

kitchen wastes. among others
The respondent's consent was secured before the data collection. A total of 125 farmers practising agroecological and conventional farming systems were surveyed. In Kamonyi district data were gathered from 61 farmers: 24 conventional and 37 agroecological. In Musanze district, there were 64 respondents consisting of 30 conventional and 34 agroecological farmers. Each participating farmer provided detailed responses, enabling statistical analyses.

2.3. Laboratory soil sampling and analysis

Soil sampling was among the key study aspect, which was performed in each site under each farming practice. Composite soil samples were collected from five points per farm at 0-20 cm depth to represent plot under conventional and agroecological practices. Each composite sample was split into batches, one for physical-chemical analysis and another one for microbial analysis. Beside the composite sample, separate samples were collected using the rings for determining the bulk density. Samples were labelled, packaged, and analysed at the Rwanda Agriculture and Animal Resources Board laboratories. Field inventories documented crops, flora, fauna, terrain features, and biodiversity indicators such as species richness and abundance through observations and counts, ensuring comprehensive ecological characterization of sampled farms. Table 2 presents the

Table 2: Characteristics of sampled farm locations

Farming practices	Crops	District	Sector/Cell/Village	Latitude (°S)	Longitude (°E)	Altitude (m)	Landscape position	Slope (%)
Agroecological	Maize	Kamonyi	Gacurabwenge/Nkingo / Kamonyi	2.015346	29.898139	1631	On terraces	25
	Beans	Musanze	Muko/Cyivugiza/ Nyagahango	1.541818	29.634158	1654	Valley	1-2

Conventional	Beans	Musanze	Gataraga/Mudakama/ Rubaka	1.541535	29.531315	2354	Hilly	10-15
	Maize	Kamonyi	Gacurabwenge/Nkingo / Kamonyi	2.009702	29.895180	1617	On terraces	20

Source: Primary data, 2025.

2.4. Data processing and analysis

The collected data were systematically processed using SPSS and Excel. Survey data were coded and analysed for descriptive statistics comparing agroecological and conventional farming systems. Soil samples underwent laboratory analysis to determine the physical and chemical properties, assess microbial population and diversity. Analysis of physical and chemical properties followed analytical methods provided by J. Robert Okalebo et al., 1993 for each parameter, while microbial population and diversity were assessed using standard techniques for colony estimate, Shannon and Simpson Diversity Indexes. Below is the description of these microbial techniques:

Microbial Enumeration

Standard dilution and plating techniques were used to estimate colony-forming units (CFU) per gram of dry soil for bacteria, fungi, and actinomycetes. After incubation, the petri dishes with 30-300 colonies for accuracy were chosen. Colonies were counted and the CFU/gr was calculated using the following formula:

$$CFU=NC*DF$$

Where: CFU is the colony forming units per gram, NC is the number of colonies and DF is the dilution factor per volume plated (ml)

$$H^1= 1 \sum_{I=1}^n pi * \ln (P^1)$$

Where: H[?] = Shannon diversity index, ? is the sum or total number of species, ln is the natural logarithm and pi is the proportion of the entire community made up of species I.

We calculated the proportion of each species in the community, multiply each proportion by its natural log, and sum all those values and multiply by -1. A higher H[?] means greater diversity (more species and/or more even distribution) whereas lower H[?] means less diversity (fewer species or dominance by one).

The Simpson Index (D) is a measure of diversity that accounts for both the number of species present (richness) and the relative abundance or evenness of each species in a community. It was calculated as:

$$D= 1- \sum_{I=1}^n (Pi)$$

Where: pi is the proportion of individuals belonging to species I, ? is the total number of species/ Lower values of D indicate higher diversity and vice versa. The Simpson's Diversity Index (1-D) is the most intuitive form with values range from 0 (no diversity) to nearly 1 (high diversity). The tables 8 and 9 present results of microbial population and diversity obtained from soil samples collected in conventional and agroecological farms of the investigated sites.

3.0. Results

3.1 Perception of farmers on agroecological practice farming

3.1.1. Demographic data of farmers

Most farmers were more than 50 years of age with the youths constituting the lowest proportion. Female farmers were more than their male counterparts. In

terms of marital status, most participants were married with only 3 being divorced. A lot of farmers had gone for primary education with only 2 reaching university level. Four farmers had no formal education (Table 3). Table 3: Socio-economic characteristics of the respondents

Variable	Gender			
	Male	Female	Total	
Age (years)	18-35	12	16	28
	36-50	14	31	45
	>50	16	36	52
Marital Status	Single	4	9	13
	Married	38	61	99
	Widowed	0	10	10
	Divorced	0	3	3
Level of Education	Primary	32	62	94
	Secondary	8	17	25
	University	2	0	2
	No formal	0	4	4
Total	42	83	125	
Percentage	33.6	66.4	100	

Among the 125 farmers who participated in the survey 54(43.2%) practised conventional or industrial agriculture and the majority, 71(56.8%) were adopting agroecological practises (Fig. 2). In both farming systems, females outnumbered males. Farmers

practising convectional farming consisted of 32(59.3%) females and 22(40.8%) males. Similarly, agroecological farmers comprised 51(71.8%) females and 20(28.2%) males.

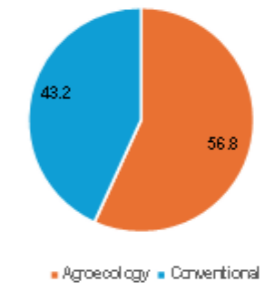


Figure 2: Percentage of farmers practising conventional and agroecological farming
Maize and beans are grown under conventional and agroecological farming practices in the study districts. Land under maize cultivation was 1,272.8 acres. The area cropped beans was 1,092.8 acres. Table 3 shows the number of farmers growing maize and beans under agroecological and conventional farming systems.

Table 4: Frequency of agroecological and conventional farmers growing beans and maize

Crop	Conventional	Agroecological	Total
Maize only	5	10	15
Beans only	11	4	15
Maize and beans	38	57	95
Total	54	71	125

During the survey, it was noted that none of the agroecological farmers use chemical fertilizer in crop production. Instead, they used animal manure and organic fertilizer to improve soil fertility. Farmers owned sheep, pigs, chickens, goats, cows and rabbits, which are important for manure among other uses. However, 51 out of the 54 conventional farmers were using urea, DAP, Amidas and Winner. The remaining 3

conventional farmers indicated that they were not applying chemical fertilizers but were using herbicides including Touchdown forte, Roundup and Rocket Jackmax to control crop pests and diseases in their farms. Table 4 shows the gendered differentiated use of chemical fertilizers among conventional farmers.

Table 5: Use of chemical fertilizers by male and female famers

Gender	Frequency	Percentage
Male	21	41
Female	30	51
Total	51	100

3.1.2. Farmers' knowledge on agroecological practices Fig. 3 highlights the understanding of farmers on what agroecological is all about. A large number (>80%) of the respondents agreed with all attributes of agroecological given during the questionnaire survey. Only 1.2% of the farmers disagreed that agroecological agriculture involves the use of animal manure. Whereas, up to 25.6 % of the participants disagreed

that agroecological involves the practice of bush fallowing to replenish lost nutrients. With regards to environmental protection, most participants agreed that planting leguminous or cover crops, bush fallowing and alley cropping reduce soil erosion and increase soil nutrients.

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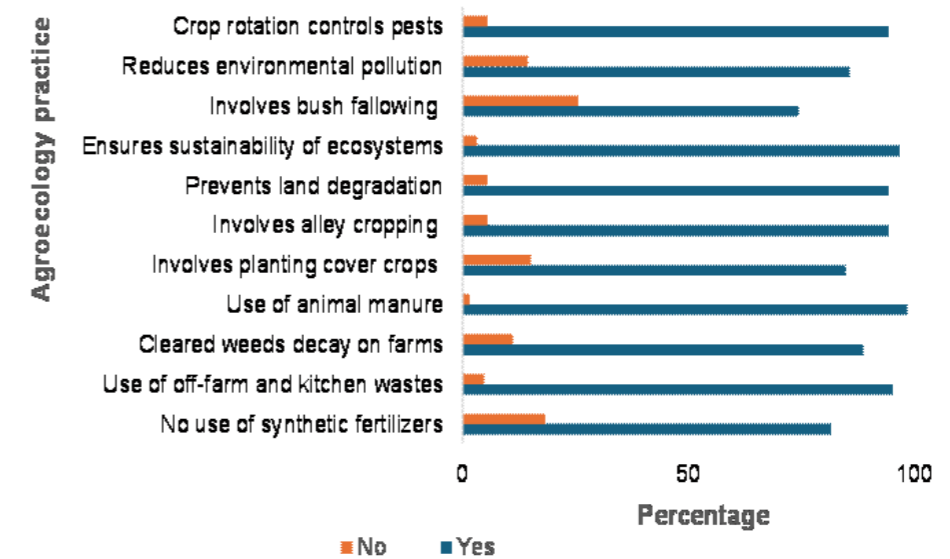


Figure 3: Perceptions of farmers on agroecological practices

3.1.3. Opinions of farmers about agroecological practices

Most farmers agreed that agroecological is beneficial to livelihoods, biodiversity, health and the environment. A large percentage (83%) strongly agreed that agroecological produce are highly nutritious. Few farmers concurred with the assertion that agroecology farming systems are harmful to the environment and quality of life. Very few farmers (less than 30%) were undecided on each aspect asked. A large proportion (17%) could not decide on whether agroecological

farming increases soil aeration or not. On the groundwater pollution and land degradation, 31% and 30% of the farmers asserted that agroecological farming contributes to these problems respectively. Surprisingly, 47.2% of the farmers highlighted the crops grown under agroecological farming do not ensure good health to farmers and their families (Fig. 4).

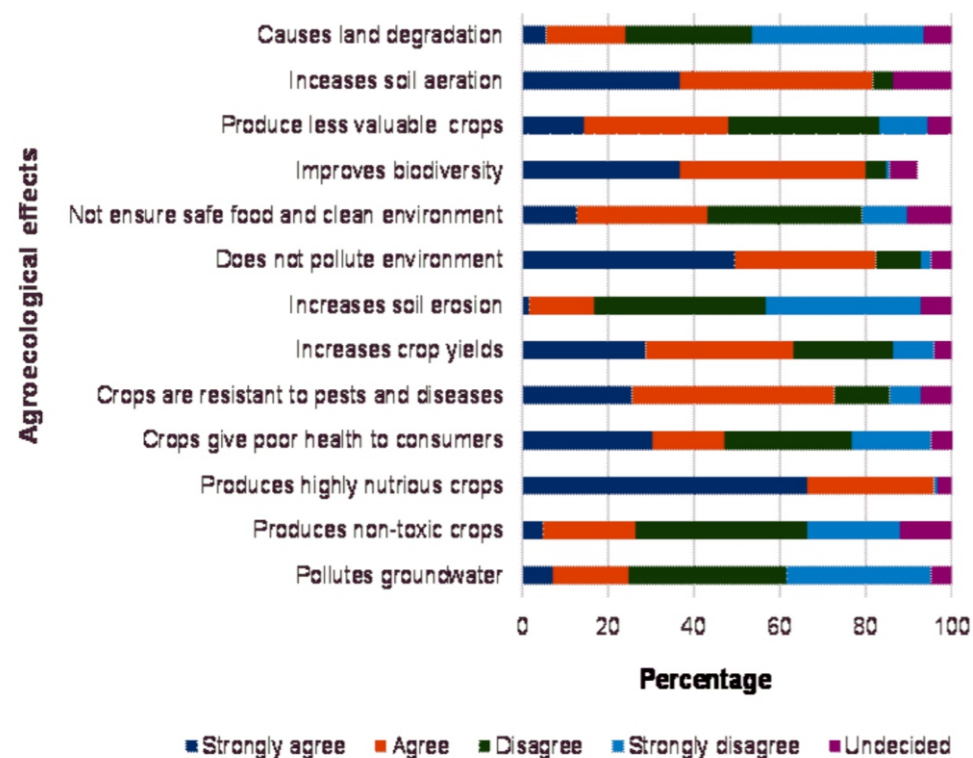


Figure 4: Benefits of agroecological farming to environmental and human health.

3.1.4. Involvement of farmers in agroecological practices using flora and fauna

Farmers' consistency in applying agroecological practices strongly vary with the activities undertaken (Fig. 5). Generally, in all their activities, farmers always adopt agroecological principles. Notably, out of the 125 farmers, 107 had never used hormones for plant

tissue improvement. Only 9 farmers always used hormones, and a similar number had occasionally use hormones to enhance tissue development.

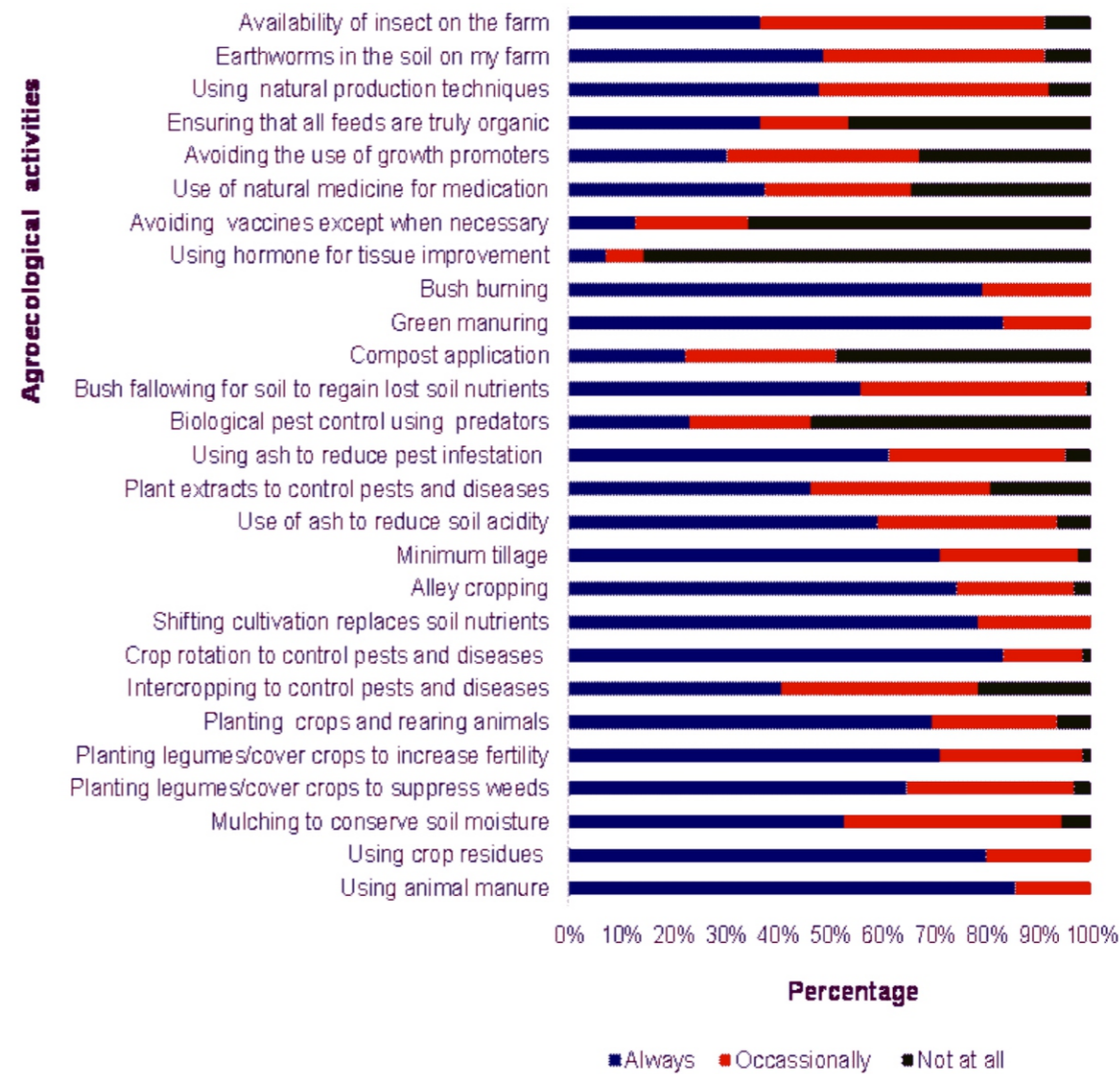


Figure 5: Farmers' adoption of agroecological practices

3.2. Impact of conventional and agroecological practices on soil properties

3.2.1. Effect of conventional and agroecological practices on soil properties in Kamonyi and Musanze sites

The table 6 presents show the impact of the conventional and agroecological practices on key soil parameters including physical, chemical and micronutrients in the selected sites.

Table 6: Effect of conventional and agroecological practices on soil properties in Kamonyi and Musanze sites

Soil parameters	Kamonyi		Musanze			
	Conventional	Agroecological	Difference	Conventional	Agroecological	Difference
pH water	4.4	4.7	0.3	5.2	6.1	0.9
Al ³⁺ (cmol/kg)	1.2	0.2	1.0	-	-	-
H ⁺ (cmol/kg)	0.8	0.5	0.2	0.3	0.1	0.2
Tot.N (g/kg)	0.9	0.1	0.0	6.3	3.4	0.3
Org.C (g/kg)	0.9	0.9	0.0	3.7	3.1	0.6
Av.P (mg/kg)	6	24	18	5	37	32
Ca (cmol/kg)	1.6	2.0	0.3	9.9	14.1	4.1
Mg (cmol/kg)	0.4	0.6	0.2	1.0	1.4	0.4
K (cmol/kg)	0.2	0.1	0.1	0.4	1.3	0.9
Na (cmol/kg)	-	-	-	0.1	0.7	0.1
CEC (cmol/kg)	10	10	0.1	22	21	1.3
Fe (mg/kg)	2,067	1,643	424.0	2,301	2,187	114
Zn (mg/kg)	25	16	9.0	98	109	10
Mn (mg/kg)	131	167	35.9	237	230	6
Cu (mg/kg)	9	6	2.6	10	17	7
Sand (g/kg)	670	730	6.0	490	530	4.0
Silt (g/kg)	130	110	2.0	390	390	-
Clay (g/kg)	200	160	4.0	120	80	4.0
Texture	Sandy Clay Loam	Sandy Loam		Loam	Sandy Loam	
Bulk Density (g/cm ³)	1.4	1.3	0.1	0.8	0.8	0.0

Results indicate an improvement of soil properties under agroecological practices compared to the conventional practice in both sites. The effect is higher in Musanze than in Kamonyi, the two sites being in contrasting agroecological zones and soil types. Musanze being in high altitude with higher moisture, under volcanic soils, can explain its high effect compared to Kamonyi, located in the middle altitude with less moisture, where also soils are inceptisols. The agroecological practice increased the soil pH by 0.3 to 0.9 units and the available phosphorus by 18.3 and 32.3 mg/kg in Kamonyi and Musanze respectively. These practices which often include the use of organic manures and lime, have the potential to enhance soil organic matter and microbial activity, which may lead to gradual increase of soil pH or maintenance of its levels. Contrary, the conventional practice, mostly relying on the use of synthetic fertilizers, intensive tillage and application of monoculture, can lead to disruption of soil structure, reduction of biodiversity and consequently result in soil acidification overtime. These results are aligned with other research which show that agroecologically managed soils generally have higher pH levels compared to conventionally managed soils (Pimentel D. et al., 2005; Khan M. A., et al., 2015; Teague W. R. and Bakker M., 2017; Gattinger A. et al., 2012).

In accordance with Tiftonell P. and Giller K. E., 2013; Roldán A., et al., 2018, and Potts J. et al., 2016), the substantial higher values of available phosphorus under the agroecological practices, can be attributed to their effects on soil structure improvement and microbial activity, solubilization of phosphorus through enhance of soil microbial communities, and reduction of phosphorus runoff. Conversely, conventional practices can lead to a decrease in soil organic matter and a decline in microbial diversity, ultimately hindering the natural processes that facilitate the availability of phosphorus in the soil (Scialabba N. E.H. and Hattam C., 2002).

While the trace elements such as iron and zinc seem to be higher and above the acceptable limits in both farms, they tend to be reduced under agroecological practices, especially in Kamonyi district. The level of iron above 2,000mg/kg are generally considered as excessive for most of crops. In Musanze, the levels of zinc seem to be elevated but remain below 200 mg/kg, considered as indicative of excessive level, especially in agricultural lands. These findings align with existing literature, which indicates that agroecological practices play a significant role in improving soil health and promoting natural nutrient recycling, leading to soils with adequate and balanced levels of micronutrients (Giller K. E., et al, 2009).

It is well known that copper is an essential micronutrient for plants and microorganisms, but excessive amounts can lead to toxicity and environmental concerns. Results from this study indicated that the concentration levels of this nutrient are in the acceptable range for the plant growth both in Kamonyi and Musanze, ranging between 6.6 and 17.8 mg/kg. Generally, copper concentrations over in the soil is 100 mg/kg is considered as excessive in many contexts, with potential phytotoxic effects becoming more pronounced as levels increase (Reilly C., et al., 2016).

3.2.2. Impact of conventional and agroecological practices on soil microbial

Soil microorganisms are fundamental to nutrient cycling, plant growth, and soil health. Agricultural practices, especially cropping systems and input management, can profoundly influence microbial abundance and diversity. Results from this study on microbial population and diversity under the two compared agricultural systems are presented in tables 7 and 8

Table 7: Microbial population under conventional and agroecological farming in the selected sites

District/Site	Practice	Crop	Bacteria (10 ⁴ CFU/g)	Fungi (10 ⁴ CFU/g)	Actinomycetes (10 ⁵ CFU/g)
Musanze/Muko	Agroecological	Beans	4.2	2.8	1.6
Musanze/Busogo	Conventional		2.9	1.7	0.9
Kamonyi/Gacurabwenge	Agroecological	Maize	3.6	2.1	1.3
Kamonyi/Gacurabwenge	Conventional		2.4	1.2	0.7

Table 8: Microbial diversity under conventional and agroecological farming in the selected sites

District/Site	Practice	Crop	Shannon Index (H')	Simpson Index (1 - D)	Dominant Microbial Groups
Musanze/Muko	Agroecological	Beans	1.68	0.81	Rhizobium, Trichoderma, Bacillus
Musanze/Busogo	Conventional		1.42	0.74	Aspergillus, Pseudomonas
Kamonyi/Gacurabwenge	Agroecological	Maize	1.6	0.78	Azotobacter, Penicillium
Kamonyi/Gacurabwenge	Conventional		1.35	0.7	Fusarium, Bacillus

The results indicate that microbial populations and diversity were consistently higher under farms using agroecological practices (improved cultivation systems) in both districts than in the conventional farming. The group of microbial identified are bacteria, Fungi and Actinomycetes whose dominance ranges from 44.8 to 50%, 64.7 to 75%, and 77.8 to 85% across the two sites respectively. The dominance is likely higher in Kamonyi under maize than in Musanze under beans. These results align with numerous studies which indicate that agroecological practices often promote healthier and more diverse microbial communities

compared to conventional methods. They contribute to increase microbial biomass and activity, improve soil health indicators, including increased soil organic carbon (SOC), which supports abundant microbial life (Ghosh S. et al., 2020; Altieri M.A., 2018).

Higher microbial diversity is observed under the agroecological practice as well as compared to the conventional. Improved soil structure, and organic matter content provide habitats and energy sources to soil microorganisms which support a more diverse microbial community. Bean cultivation in Muko

exhibited the highest diversity indices, likely due to the symbiotic relationship with Rhizobium and other N-fixing bacteria. Conventional systems, particularly in Kamonyi, showed the lowest diversity, suggesting lack of adequate conditions for microbial communities. In alignment with other studies (Vogel A. et al., 2021; Zhang X. et al., 2020); Geng Y. et al., 2019), it is well demonstrated that agroecological systems contribute significantly to higher microbial abundance and diversity compared to conventional systems.

The dominant microbial groups in the agroecological practice are Rhizobium, Trichoderma, Bacillus, Azotobacter, and Penicillium, which play an important role in soil health as they contribute to nitrogen fixation through symbiotic relationships with leguminous plants (Liu J. and Xu G., (2007), formation of soil aggregates, decay of organic matter and enhancing nutrient mineralization, making them more available to plants (Jansson J.K. and Hofmockel, K.S., 2018; Goodfellow M. and Fiedler H.P., 2010), facilitate nutrient uptake through symbiotic associations with plant roots to enhance plant growth and reliance to stress (Smith S. E. and Read D. J., 2008).

4. Discussion

The study provides compelling evidence that agroecological farming systems markedly enhance biodiversity and environmental sustainability compared to conventional practices in Rwanda's maize and bean farming landscapes. Agroecological practices, which emphasize organic inputs such as animal manure, crop residues, and compost, foster improved soil health by increasing pH, available phosphorus, and essential micronutrients like calcium and magnesium. This contrasts with conventional systems, largely driven by Rwanda's Crop Intensification Program (CIP), which promote chemical fertilizers and herbicides, resulting in

degraded soil chemical properties and reduced microbial diversity. The microbial populations of bacteria, fungi, and actinomycetes, along with diversity indices such as Shannon and Simpson, are significantly elevated under agroecological management, confirming the positive impact of organic amendments on soil microbial ecosystems (Altieri, 2018; Vogel et al., 2021; Ghosh et al., 2020).

From a socio-economic perspective, the study identifies gender and youth dynamics that influence farming practices, noting a predominance of women farmers across both systems and a low level of youth involvement. This demographic pattern underscores the need for targeted policy frameworks and capacity-building initiatives to empower female farmers and engage younger generations to ensure agricultural sustainability (Batas et al., 2025; National Gender Policy, 2021; National Youth Policy, 2015). Farmer perceptions align closely with agroecological principles, with high recognition of benefits including healthier, non-toxic food production, improved soil fertility, reduced environmental pollution, and enhanced ecosystem services (Munyaneza et al., 2020; Méndez et al., 2013).

The reduction of excessive micronutrients, particularly iron and zinc, in agroecological soils further indicates healthier, less toxic environments for plant growth. These findings support global literature advocating agroecology as a pathway to reconcile food security with ecological resilience amid climate change challenges (Altieri & Nicholls, 2017; Lipper et al., 2014). The study recommends policy reinforcement to scale agroecological practices through farmer training, accessible organic inputs, and innovative engagement strategies targeting youth and gender equity to foster biodiversity-friendly and climate-resilient farming systems in Rwanda (MINAGRI, 2023; FAO, 2019; NEPAD, 2012).

5. Conclusion and recommendations

The study conclusively demonstrates that agroecological farming systems provide significant benefits over conventional farming practices in promoting biodiversity and enhancing environmental sustainability within Rwanda's agricultural landscapes. Agroecological practices, characterized using organic inputs such as animal manure and compost, improve soil chemical properties including pH and available phosphorus, while fostering richer and more diverse microbial communities essential for soil health and ecosystem function. Farmers' positive perceptions of agroecology, recognizing its role in producing healthy, non-toxic food and supporting ecosystem services, further reinforce the practical viability and social acceptability of these practices.

Socio-economic patterns observed reveal a predominance of women in both farming systems, with notably low involvement of youth, which presents challenges for the long-term sustainability and scaling of agroecological agriculture. Addressing these gender and generational dimensions through targeted capacity building and empowerment initiatives should be a priority. Policies and programs must be designed to create equitable access to resources, training, and decision-making for women, while simultaneously developing strategies to engage the youth by making farming more attractive and viable as a livelihood option.

From a policy perspective, the evidence encourages a strategic transition in Rwanda's agricultural agenda away from dependence on chemical-intensive conventional farming towards agroecological

Acknowledgements:

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approaches. This requires strengthening institutional support mechanisms, including extension services, availability of organic inputs, and incentives that motivate farmers to adopt and sustain agroecological practices. Integrating agroecology into national frameworks, such as the Strategic Plan for Agricultural Transformation, can help promote ecological resilience, biodiversity conservation, and sustainable food production in the face of ongoing climate challenges.

Lastly, the study highlights the need for collaborative, multi-stakeholder partnerships involving government agencies, research institutions, farmer organizations, and development partners to design context-appropriate interventions. Facilitating participatory farmer training, developing agroecology-friendly value chains, and launching youth-oriented agripreneurship initiatives can accelerate the adoption of sustainable farming systems that reconcile environmental health with food security goals. Such integrated approaches will be instrumental in ensuring a resilient and inclusive agricultural future for Rwanda.

Conflict of interest: The authors declare no financial interests or personal relationships which may be considered as potential competing interests.

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Impact Des Systèmes Agricoles Agroécologiques et Conventionnels Sur la Biodiversité des Terres Agricoles dans les Parcelles Maraicheres de la localite de Yamoussoukro en Cote D'Ivoire

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Abstract

African biodiversity, and more specifically that of West Africa, is of crucial global importance. In Côte d'Ivoire, this ecological wealth is currently under threat. In this context, the project aims to comparatively assess the impact of agroecological and conventional practices on the biodiversity of agricultural lands in Yamoussoukro, Côte d'Ivoire, particularly in market gardening. The study, conducted in six plots (three agroecological and three conventional), uses a multidisciplinary approach combining socioeconomic surveys, floristic, edaphic, and microbiological analyses. The results demonstrate that agroecological systems exhibit significantly higher plant and microbial biodiversity (Shannon index = 2.9 versus 1.2 in conventional systems) and a better species distribution (equitability = 0.92). Agroecological soils exhibit higher organic carbon content (2.4%), a near-neutral pH (6.5), and a higher cation exchange capacity, indicating improved fertility. Soil fauna is also more diverse, with an abundance of earthworms, beetles, and millipedes, indicating a more balanced ecosystem. In contrast, conventional plots exhibit degraded soil structure, marked acidification (pH 5.3), and a dominance of gastropods, a sign of trophic imbalance. However, the study reveals greater pathogen pressure in agroecological systems due to the absence of chemical pesticides and still incomplete biological regulation. In conclusion, agroecology represents a sustainable path to reconcile productivity, resilience, and biodiversity conservation, provided strong institutional support is provided: technical training, secure land tenure, support for participatory research, and the promotion of appropriate marketing channels.

Keywords: Agroecological, Conventional, Biodiversity, Market gardening, Ivory Coast



Résumé

La biodiversité africaine, et plus particulièrement celle de l'Afrique de l'Ouest, est d'une importance cruciale au niveau mondial. En Côte d'Ivoire, cette richesse écologique est aujourd'hui menacée. Dans ce contexte, le projet vise à évaluer comparativement l'impact des pratiques agroécologiques et conventionnelles sur la biodiversité des terres agricoles de Yamoussoukro en Côte d'Ivoire, notamment en culture de maraichères. L'étude, menée dans six parcelles (trois agroécologiques et trois conventionnelles), mobilise une approche pluridisciplinaire combinant enquêtes socio-économiques, analyses floristiques, édaphiques et microbiologiques. Les résultats démontrent que les systèmes agroécologiques présentent une biodiversité végétale et microbienne nettement plus élevée (indice de Shannon = 2,9 contre 1,2 en conventionnel) et une meilleure répartition des espèces (équitabilité = 0,92). Les sols agroécologiques affichent une teneur accrue en carbone organique (2,4 %), un pH proche de la neutralité (6,5) et une capacité d'échange cationique plus élevée, indiquant une fertilité améliorée. La faune du sol y est également plus diversifiée, avec une abondance de lombrics, coléoptères et mille-pattes, témoignant d'un écosystème plus équilibré. En revanche, les parcelles conventionnelles montrent une structure du sol dégradée, une acidification marquée (pH 5,3) et une dominance de gastéropodes, signe de déséquilibre trophique. L'étude révèle cependant une plus forte pression pathogène dans les systèmes agroécologiques, en raison de l'absence de pesticides chimiques et d'une régulation biologique encore incomplète. En conclusion, l'agroécologie constitue une voie durable pour concilier productivité, résilience et conservation de la biodiversité, à condition d'un appui institutionnel fort : formation technique, sécurisation foncière, soutien à la recherche participative et promotion de circuits de commercialisation adaptés.

Mots clés: Agroécologiques, Conventionnels, Biodiversité, Maraichères, Côte d'Ivoire

Introduction

La biodiversité de l'Afrique revêt une importance capitale à l'échelle mondiale, tant par sa richesse que par son rôle dans le maintien des équilibres écologiques et socio-économiques. Le continent africain couvre environ 20,2 % de la surface terrestre et abrite près d'un quart des espèces de mammifères connues, environ un cinquième des espèces d'oiseaux et un sixième des espèces végétales (Myers et al., 2000; UNEP, 2014). En outre, l'Afrique compte huit des 36 points chauds mondiaux de la biodiversité, des zones qui combinent une richesse exceptionnelle d'espèces endémiques avec un niveau élevé de menaces (Mittermeier et al., 2011). Ces régions, essentielles à la conservation mondiale, jouent un rôle fondamental dans le maintien des services écosystémiques, notamment la pollinisation,

la régulation climatique, la fertilité des sols et la disponibilité des ressources en eau (MEA, 2005). Cette richesse biologique, conjuguée aux savoirs autochtones et locaux, constitue un pilier stratégique pour le développement durable en Afrique (Pretty et al., 2009). En effet, la biodiversité soutient directement la sécurité alimentaire et la souveraineté alimentaire du continent en améliorant la résilience des systèmes agricoles face aux aléas climatiques et aux pressions anthropiques (FAO, 2020). La diversité des cultures, des espèces animales et des microorganismes dans les agroécosystèmes africains génère des biens et services essentiels, tels que la nutrition, la santé et la stabilité des moyens de subsistance (Tschamntke et al., 2012). Malgré cette importance, l'Afrique souffre d'un déficit d'informations fiables sur l'état et la dynamique de sa biodiversité, ce qui limite la capacité à concevoir des

politiques de conservation efficaces (FAO, 2002). Par ailleurs, la conversion des terres pour l'agriculture conventionnelle, souvent intensive, est une source majeure de perte de biodiversité, tandis que les pratiques agroécologiques, respectueuses de l'environnement, offrent une alternative prometteuse pour préserver et restaurer les écosystèmes (Altieri, 1999 ; Kremen & Miles, 2012). Ces pratiques contribuent non seulement à renforcer la résilience des exploitations agricoles au changement climatique, mais aussi à réduire la vulnérabilité des communautés rurales (IPBES, 2019). Sur le plan international, la Conférence des Nations Unies sur la biodiversité tenue en 2022 a marqué un tournant en rassemblant près de 200 pays autour d'un accord ambitieux visant à protéger la nature d'ici 2050 (CBD, 2022). Cependant, plusieurs pays africains ont souligné que l'accord omettait certains éléments cruciaux pour garantir la protection effective de la biodiversité continentale, en particulier face à des menaces croissantes telles que le déclin des insectes pollinisateurs, la pollution plastique des océans et la surexploitation des ressources naturelles (Potapov et al., 2021). La mise en œuvre de cet accord pourrait transformer profondément les systèmes agricoles, les chaînes d'approvisionnement et renforcer le rôle des communautés autochtones dans la conservation. Dans ce contexte, il est essentiel de mieux comprendre les impacts comparés des pratiques agricoles agroécologiques et conventionnelles sur la biodiversité des terres cultivées en Afrique, afin de fournir des données empiriques solides aux décideurs politiques et aux acteurs locaux. Cette démarche est particulièrement cruciale en Afrique de l'Ouest, et plus spécifiquement en Côte d'Ivoire, où l'agriculture constitue un secteur clé pour l'économie et la sécurité alimentaire (World Bank, 2020). L'objectif principal de cette étude est d'évaluer comparativement l'impact des pratiques agroécologiques et conventionnelles sur la biodiversité des terres agricoles en Côte d'Ivoire. De manière spécifique, il s'agit de comparer l'influence

de l'agriculture agroécologique et conventionnelle sur la flore et la biodiversité microbienne et d'évaluer le potentiel de contribution des pratiques agroécologiques à la conservation de la biodiversité et leurs effets possibles sur les systèmes alimentaires et les moyens de subsistance de groupes d'agriculteurs spécifiques.

1) MATERIELETTMETHODE**1.1) Matériel**

Pour la réalisation de cette étude, divers matériels techniques ont été utilisés sur le terrain et en laboratoire. Sur le terrain, un mètre ruban de 3 mètres a permis de mesurer les circonférences des cacaoyers et des arbres associés. Un décamètre de 60 mètres a servi à délimiter les parcelles, tandis qu'un GPS a été utilisé pour enregistrer les coordonnées géographiques. Trois plateaux ont été mobilisés pour le tri des vers de terre, conservés ensuite dans des petits pots en verre. Un appareil photo numérique a permis de documenter visuellement les observations. Au laboratoire, les échantillons de vers de terre ont été conservés dans du formol. L'eau distillée et le chlorure de potassium ont été utilisés pour déterminer respectivement le pH eau et le pH KCl des sols. Une étuve a permis la déshydratation des échantillons, qui ont ensuite été pesés à l'aide d'une balance électronique. Un pH-mètre a complété les analyses de sol.

1.2) METHODOLOGIE**1.2.1) Sites d'étude**

Le projet NOARA a été mis en œuvre à Yamoussoukro (6°49' N, 5°17' O), capitale politique de la Côte d'Ivoire, située en zone de savane arborée au climat subéquatorial, avec une pluviométrie annuelle de 1 200 à 1 500 mm et une température moyenne de 27 °C (SODEXAM, 2020). L'agriculture y associe cultures

vivrières (maïs, igname), maraîchères (tomate, aubergine) et de rente (cacao, café). Trois parcelles agroécologiques et trois conventionnelles ont été sélectionnées selon les types de pratiques, la diversité culturale, l'accessibilité et l'engagement des producteurs, permettant une comparaison rigoureuse des systèmes agricoles.

1.2.2) Outils et techniques de collecte des données

Une approche méthodologique pluridisciplinaire a été adoptée, combinant des outils qualitatifs et quantitatifs pour évaluer l'impact des systèmes agricoles sur la biodiversité.

1.2.3) Enquêtes socio-économiques auprès des producteurs

Une enquête semi-structurée a été menée auprès de 120 producteurs agricoles répartis sur les quatre localités. L'objectif était de recueillir des données sur le niveau de connaissance des pratiques agroécologiques des paysans. Ces enquêtes ont été élaborées pour enrichir la compréhension du contexte local et permettre de mieux cerner les pratiques à l'origine des impacts observés sur la biodiversité.

1.2.4) Étude comparative de l'influence de l'agriculture agroécologique et de l'agriculture conventionnelle sur la flore, la faune microbienne et la structure édaphique

1.2.4.1) Dispositif expérimental et évaluation de la diversité végétale

La composition floristique a été faite selon un dispositif mis en place dans les deux systèmes agricoles. Dans chaque champ visité, trois unités d'échantillonnage (UE) de 50 m × 50 m ont été créées. Ensuite, trois placettes carrées (PIC) de 10 m × 10 m (100 m²) ont été délimitées avec un décimètre à l'intérieur de chaque unité d'échantillonnage. Dans chaque placette carrée, trois placeaux carrés (PC) de dimensions 5 m × 5 m ont

été mises en place. Puis, à l'intérieur de chaque PC, trois sous-placeaux carrés (SPC) de superficie 6,25 m² (2,5 m × 2,5 m) ont été délimités selon le dispositif d'inventaire floristique cité par N'Gbala et al. (2017) (figure 1).

Les paramètres évalués ici ont concerné la richesse spécifique qui est le nombre total d'espèces différentes dans un écosystème, l'indice de Shannon qui permet de mesurer aussi la diversité d'un écosystème, il prend en compte le nombre d'espèces, mais aussi la répartition végétale. Ainsi, plus sa valeur est élevée plus la diversité est considérée comme importante, cela montre qu'il y a beaucoup d'espèces différentes et qu'aucune espèce ne domine véritablement. L'équitabilité a été aussi évaluée, elle indique l'uniformité dans un écosystème et cela aide à comprendre si un écosystème est équilibré ou pas.

L'équitabilité (E) peut être calculée à l'aide de l'indice de Shannon (H') et de la richesse spécifique (S) comme suit (Pielou, E.C. (1966), Shannon, C.E. (1948):

$$E = \frac{H'}{\ln(S)}$$

Calcul de l'indice de Shannon (H') (Pielou, E.C. (1966), Shannon, C.E. (1948):

- Pour chaque espèce, calculez la proportion (p) d'individus de cette espèce par rapport au total :

$$Pi = \frac{ni}{NO}$$

Où ni est le nombre d'individus de l'espèce i et N est le nombre total d'individus.

Calculez H' avec la formule :

$$H' = -\sum (pi \cdot \ln(pi))$$

où la somme est effectuée sur toutes les espèces.

Richesse spécifique (S)

La richesse spécifique est simplement le nombre total d'espèces dans l'échantillon :

$$S = \text{nombre total d'espèces}$$

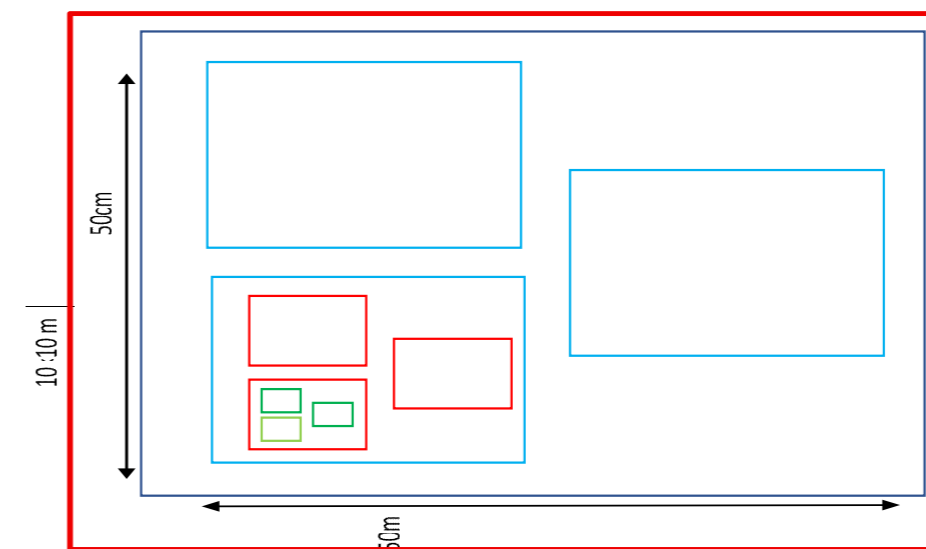


Figure 1: Plan d'échantillonnage dans une parcelle

Figure 1 : Dispositif expérimental pour l'évaluation de la diversité végétale

1.2.4.2) Analyses physico-chimiques et microbiologiques des sols

Afin d'évaluer les paramètres édaphiques et biologiques un dispositif sera mis en place. Le sol sera prélevé dans chaque SPC un quadrat de 0,25m × 0,25m sera délimité, creusé avec tarière dans les différents systèmes à deux niveaux soit 0-10 cm et 10-20 cm de profondeur du sol. Plusieurs paramètres ont été évalués, il s'agit de : Carbone organique, pH(H₂O), Macro-éléments, oligo-éléments et propriétés chimiques, Diversité des macro-invertébrés du sol et la Santé des plantes et pression pathogène

• Carbone organique et pH(H₂O)

Les sols ont été prélevés dans les plantations de type conventionnel et agroécologique. Ils ont été transportés au laboratoire pour l'étude des paramètres édaphiques. Une masse de 500 g du sol des deux niveaux et 1 kg du composite a été pesé à l'aide d'une balance à chaque type de sol. Les échantillons ont été séchés pendant 7 jours à la température ambiante, puis tamisés avec un tamis de maille 2 mm. Ensuite, trois fois 10 g de chaque échantillon destiné à la mesure du pH de l'eau ont été mis dans des bocaux. La mesure du pH de l'eau a été effectuée avec 25 ml d'eau distillée. Le mélange a été homogénéisé et laissé pendant 30 min. Avant la lecture, le pH-mètre

sera étalonné avec une solution tampon de pH 7 et calibrer par la solution tampon pH 4. Les pH des solutions seront lus en plongeant l'électrode d'un pH-mètre pendant 2min dans chaque tube Conyers MK and Davey BG (1988), Pansu M and Gautheyrou J (2006), Qiu X-C and Zhu Y-Q (1986) et Schofield RK and Taylor AW (1955).

La matière organique des échantillons de chaque échantillon en suivant la méthodologie suivante (FAO,2017). Trois fois 5 g pour chaque type de plantation et par niveau de profondeur et mis dans des creusets. Ensuite, mettre l'échantillon de sol prélevé dans les différents récipients et peser l'ensemble. Les creusets seront placés dans un four à moufle pendant 5h à 600° C. Après ce passage au four, les échantillons seront pesés. La teneur en matière (MO) sera déterminée en suivant la relation ci dessous.

$$MO (\%) = \frac{MI - MS}{MI - MC} \times 100$$

MI : masse du récipient MI, MS masse de l'échantillon mis au four (5 g), MC est la masse du contenu. Le taux de carbone sera déterminé après le taux de matière organique: C % = MO / 1,724

• Macro-éléments, oligo-éléments et propriétés chimiques du sol

L'évaluation des Macro-éléments, oligo-éléments et propriétés chimiques du sol ont été fait selon les recommandations de George E Rayment et David J Lyons(2012)

• Analyse physique du sol

La densité apparente du sol sera déterminée au laboratoire. Des cylindres de 20 cm et de rayon 2 cm

seront remplis avec les sols. Les cylindres ayant deux ouvertures l'une sera fermée par des tissus, déposés dans des portoirs. Ces différents portoirs contenant les cylindres seront mis dans un récipient contenant de l'eau. L'eau va s'infiltrer jusqu'à la surface des cylindres pour compacté le sable pendant 24 h. Après les 24 h retiré les cylindres de l'eau laissé reposer pendant 24h, puis retiré le sable imbibé d'eau des chaque site mètres les dans les papiers aluminium. Le différent papier allure contenant du sable seront misent à l'étuve à 105°C, vérifié la masse des échantillons après 24h pendant 3jours et enfin déterminé la densité apparente par la formule suivante :

$$DA = \text{Poids sec des échantillons} / \text{volume du cylindre (g/cm}^3\text{)}$$

La mesure de la texture c'est fait selon la methode de Beretta et al., 2014

• Diversité des macro-invertébrés du sol

À l'aide d'une pelle, un échantillon de sol d'environ 20 cm de profondeur a été prélevé. Ensuite, le sol a été placé dans un. L'échantillon a été Tamisé par la suite à travers la maille pour séparer les macro-invertébrés du sol. Le matériel tamisé a permis de compter les macro-invertébrés en fonction du nombre d'individus de chaque espèce.

- Santé des plantes et pression pathogène
- Chaque parcelle a fait l'objet d'un suivi phytosanitaire pour évaluer l'état de santé des cultures. L'évaluation a porté sur :
 - La présence de maladies fongiques (mildiou, oïdium, fusariose, etc.);
 - Les maladies bactériennes (flétrissement bactérien, taches bactériennes);
 - L'infestation par des ravageurs (pucerons, aleurodes, chenilles, thrips, etc.).

Des observations visuelles ont été complétées par des analyses de laboratoire (isolement et identification des

pathogènes) à partir d'échantillons de feuilles, racines et fruits prélevés sur des plants malades.

1.2.4.3) Analyse statistique

Dans le cadre de cette étude, différentes méthodes d'analyses ont été mis en outre. Ces analyses seront réalisées avec trois logiciels de traitements de données. Les indices de shannon, de piélou, les densités des espèces et les aires des plantations dans chaque zone d'étude ont été soumis à une variance à un facteur (Anova 1) lorsque la normalité, l'indépendance des échantillons et l'égalité des variances seront respectées. En absence de normalité des distributions ou de non homogénéité des variances, le test non paramétrique de Kruskal-Wallis a été utilisé. Tous ces analyses seront réalisées à l'aide du logiciel Statistica et Past, Les

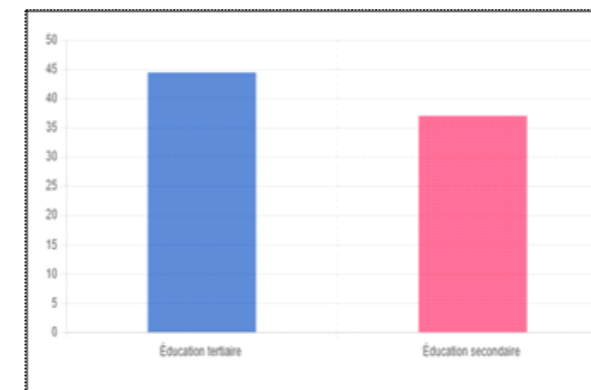


Figure 2 : Niveau d'éducation des personnes Figure 3. Type de système agricole

données de l'enquête seront analysées à l'aide du logiciel Sphinx.

1.3) RESULTATS

1.3.1) Enquête auprès des producteurs

Données démographiques

L'enquête révèle que les agriculteurs ont principalement un niveau d'éducation élevé, ce qui favorise l'adoption de techniques agricoles modernes (figure 2). Les exploitations des paysans sont majoritairement de petite à moyenne taille (souvent < 5 ha), localisées en grande partie en zones rurales (figure 3). Les systèmes de production sont partagés entre conventionnel (48 %) et agroécologique (44 %), traduisant une transition en cours (Tableau I).

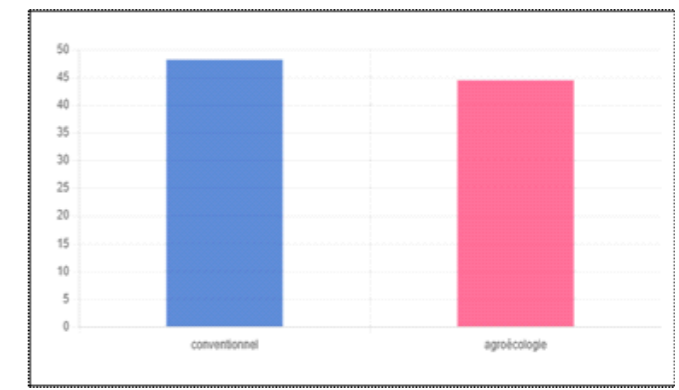


Tableau I : Classification des exploitations

Catégories	Taille (en ha)	Pourcentage
Petites exploitations	≤ 1 ha	20 %
Moyennes exploitations	> 1 ha à ≤ 5 ha	40 %
Grandes exploitations	> 5 ha	20 %
Données ambiguës	Non précisé	20 %

Connaissances des agriculteurs en matière de pratiques agroécologiques

L'enquête montre que les agriculteurs ont une bonne connaissance des principes fondamentaux de l'agroécologie, notamment le fait qu'elle exclut l'utilisation d'engrais de synthèse et favorise la réduction de la pollution ainsi que la durabilité des écosystèmes. Ils sont également conscients de l'importance de recycler les déchets agricoles et de laisser les mauvaises herbes se décomposer naturellement pour enrichir le sol. Cependant, certaines pratiques plus spécifiques, comme l'usage du fumier animal ou la rotation des cultures pour contrôler les

ravageurs, sont moins bien maîtrisées, révélant un besoin de formation complémentaire. La majorité reconnaît également le rôle des légumineuses et cultures de couverture dans la protection contre l'érosion et l'amélioration de la fertilité des sols. Enfin, les techniques visant à prévenir la dégradation des sols et à reconstituer la fertilité, telles que la jachère, sont bien comprises et acceptées. Ces résultats indiquent un fort potentiel pour le développement de l'agroécologie, avec toutefois un besoin d'accompagnement pour renforcer les compétences techniques des agriculteurs et favoriser une adoption plus complète des pratiques durables (Tableau II).

Tableau II : Récapitulatif des perceptions et pratiques agroécologiques

FORMULATION DE LA QUESTION	OUI(%)	NON (%)
L'agriculture agroécologique consiste à pratiquer l'agriculture sans engrais de synthèse.	81,48	14,81
Elle implique l'utilisation de déchets agricoles et de cuisine.	74,07	4,81

Elle consiste à laisser les mauvaises herbes se décomposer sur la ferme.	70,37	25,93
Elle implique l'utilisation de fumier animal et la rotation des cultures pour contrôler les ravageurs	55,56	25,93
Elle implique la plantation de légumineuses/cultures de couverture pour réduire l'érosion.	77,78	7,41
Elle prévient la dégradation des sols.	74,07	11,11
Elle réduit la pollution de l'environnement.	81,48	11,11
Elle garantit la durabilité de l'écosystème (jachère incluse).	85,19	7,41

1.3.2) Diversité végétale

Les résultats montrent clairement une différence marquée entre les systèmes agroécologique et conventionnel en termes de diversité des cultures. Dans les parcelles agroécologiques, la richesse spécifique est élevée, avec 12 espèces différentes recensées. L'indice de Shannon, qui mesure la diversité en tenant compte à la fois du nombre d'espèces et de leur abondance relative, est également élevé (environ 2,9), indiquant une diversité riche et bien répartie. L'équitabilité proche de 0,92 suggère que les espèces sont presque également représentées, ce qui favorise un équilibre écologique et une bonne répartition des ressources. À l'inverse, les parcelles conventionnelles présentent une richesse spécifique beaucoup plus faible, avec seulement 5 espèces. L'indice de Shannon, autour de 1,2 traduit une diversité réduite, avec une dominance

plus forte de quelques espèces. L'équitabilité plus basse (environ 0,75) indique une répartition inégale des cultures, avec probablement une ou deux espèces largement majoritaires. Ces données confirment que le système agroécologique favorise une diversité culturelle élevée et équilibrée, ce qui peut améliorer la résilience des agroécosystèmes, la fertilité du sol et la lutte contre les ravageurs. En revanche, le système conventionnel est plus spécialisé et moins diversifié, ce qui peut limiter ces avantages écologiques (Tableau III).

Tableau III: recherche spécifique en fonction des systèmes

Système	Richesse spécifique	Indice de Shannon (H')	Équitabilité (E)
Agroécologique	12	2.9	0.92
Conventionnel	5	1.2	0.75

1.3.3) Analyses physico-chimiques et microbiologiques des sols*Carbone organique et pH*

Les résultats montrent une nette différence entre les systèmes agroécologique et conventionnel en termes de qualité du sol. Dans les parcelles agroécologiques, le taux de carbone organique est élevé, avec une valeur moyenne de 2,40 %. Ce niveau indique une bonne teneur en matière organique, essentielle pour la fertilité du sol, la rétention d'eau, et l'activité biologique. Par ailleurs, le pH du sol est proche de la neutralité soit 6,5, un environnement favorable à la plupart des cultures, permettant une meilleure disponibilité des nutriments. À l'inverse, les parcelles conventionnelles présentent

un carbone organique beaucoup plus faible avec une moyenne de 0,85 %, traduisant un sol moins fertile et plus appauvri en matière organique. Le pH est également plus acide soit 5,3 ce qui peut limiter la disponibilité de certains nutriments et affecter la croissance des plantes. Ces différences suggèrent que les pratiques agroécologiques contribuent à améliorer la qualité du sol maintenant ou en augmentant la matière organique et en stabilisant un pH favorable. En revanche, le système conventionnel semble associé à une dégradation progressive des propriétés du sol, probablement liée à des pratiques plus intensives et moins respectueuses de l'écosystème du sol (Tableau IV).

Tableau IV: Taux de matière organique en fonction des systèmes

Système	Carbone organique (%)	pH (H ₂ O)
Agroécologique	2.40	6.5
Conventionnel	0.85	5.3

Macro-éléments, oligo-éléments et propriétés chimiques

Les analyses chimiques des sols montrent une nette supériorité des sols sous système agroécologique par rapport au système conventionnel. Les sols des parcelles agroécologiques présentent des teneurs plus élevées en éléments nutritifs essentiels tels que l'azote (N), le phosphore (P), le potassium (K), le calcium (Ca) et le magnésium (Mg). Par exemple, le phosphore est plus du double dans les parcelles agroécologiques (16,4 mg/kg) comparé au conventionnel (7,2 mg/kg). Cette richesse nutritionnelle favorise une meilleure croissance des plantes et une productivité potentielle plus élevée. De plus, la capacité d'échange cationique (CEC), indicateur clé de la fertilité du sol, est également plus importante dans le système

agroécologique (13,5) que dans le système conventionnel (8,1), traduisant une meilleure capacité du sol à retenir et échanger les nutriments. Concernant les micronutriments (Fer, Manganèse, Zinc, Cuivre), les valeurs sont également plus élevées sous agroécologie, témoignant d'une plus grande diversité et disponibilité des éléments nécessaires au bon développement des cultures. Enfin, les teneurs en Sodium (Na) sont faibles dans les deux systèmes, indiquant une faible salinité du sol. En résumé, ces résultats confirment que le système agroécologique favorise un sol plus riche, fertile et équilibré, ce qui est bénéfique pour la durabilité des cultures, alors que le système conventionnel présente des sols appauvris et moins propices à une production agricole soutenable (Tableau V).

Tableau V : teneurs en minéraux en fonction des systèmes

Systèmes	N (g/kg)	P (mg/kg)	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	AE	CEC
Agroécologique	2	16.4	0.5	5.5	1.9	0.14	85	26	3.5	1.2	0.6	13.5
Conventionnel	0.8	7.2	0.2	3.1	1.1	0.06	60	19	1.4	0.5	1.2	8.1

Légende : AE = Acidité échangeable (cmol/kg) ; CEC = Capacité d'échange cationique (cmol/kg)

Analyse physique du sol

Les sols des parcelles agroécologiques présentent une texture plus équilibrée, avec une teneur en argile en moyenne de 31 % et de 24% en limon contre 22% d'argile et 18% de limon dans les parcelles conventionnelles. En revanche, les sols conventionnels ont une proportion plus élevée de sable 60 % contre 45 % dans l'agroécologie. La densité apparente du sol est

également plus faible dans les parcelles agroécologiques (1,22 g/cm³) que dans les conventionnelles (1,38g/cm³). Une densité apparente élevée indique un sol plus compact, moins aéré, ce qui limite la croissance racinaire et l'activité microbienne essentielle à la fertilité du sol. En conclusion, les sols des systèmes agroécologiques ont des propriétés physiques plus favorables à la vie du sol et à la

croissance des plantes, ce qui contribue à une meilleure durabilité des systèmes de production comparé aux sols des systèmes conventionnels, plus sableux et compactés (Tableau VI).

Tableau VI : Type de sol en fonction des systèmes de cultures

Système	Argile (%)	Limon (%)	Sable (%)	Densité apparente (g/cm ³)
Agroécologique	31	24	45	1.22
Conventionnel	22	18	60	1.38

Diversité des macro-invertébrés du sol

L'analyse des résultats met en évidence une nette différence entre la parcelle agroécologique et la parcelle conventionnelle en termes d'abondance et de diversité de la faune du sol. La densité totale d'organismes est plus élevée en agroécologie (61 individus/m²) qu'en agriculture conventionnelle (40 individus/m²), traduisant une plus grande activité biologique et un meilleur équilibre du sol. Les lombrics, indicateurs clés de la fertilité, sont nettement plus nombreux en système agroécologique, confirmant l'effet bénéfique des pratiques respectueuses du sol telles que l'apport de matière organique et la réduction du travail mécanique. De même, les coléoptères, termites, mille-pattes et arachnides présentent des densités supérieures dans la parcelle agroécologique, ce qui témoigne d'une diversité fonctionnelle plus riche et d'une meilleure stabilité écologique. À l'inverse, la

forte présence de gastéropodes dans la parcelle conventionnelle suggère un déséquilibre trophique lié à la diminution des prédateurs naturels et à la dégradation de la structure du sol. L'indice de Shannon (2,9 contre 1,2) et l'uniformité (0,92 contre 0,75) confirment la supériorité de la diversité et de la répartition des espèces dans le système agroécologique. Ces observations démontrent que les pratiques agroécologiques favorisent la restauration de la biodiversité du sol, améliorent sa structure et renforcent les services écosystémiques essentiels (Tableau VII).

Tableau VII : espèces en fonction du type d'agriculture

Critère	Espèces	Parcelle agroécologique	Agriculture conventionnelle
Organismes observés	Lombrics	20 individus/m²)	3 individus/m²)
	Coléoptères	4/m²	1/m²
	Termites	5/m²	1/m²
	Mille-pattes	5/m²	1/m²
	Arachnides	5/m²	2/m²
	Gastéropodes	10/m²	15/m²
Taxonomie	Mollusques	8/m²	12/m²
	Arthropodes	2/m²	0/m²
	Annélides	10/m²	5/m²
Abondance totale		61 individus/m²	40 individus/m²
Richesse taxonomique (familles)		8	6
Indice de diversité de Shannon (H')		1,87	1,39
Uniformité		0,9	0,78

1.3.4) Santé des plantes et pression pathogène

Ravageurs dans les parcelles agroécologiques Les relevés sanitaires ont révélé une forte pression pathogène dans les systèmes agroécologiques, surtout dans les cultures maraichères. Parmi les principaux ravageurs identifiés dans les parcelles

agroécologiques, on note la présence significative de pucerons, qui s'attaquent aux jeunes pousses et provoquent l'enroulement et la déformation des feuilles, tout en favorisant le développement de la fumagine à cause de leur miellat. Des infestations de cochenilles farineuses ont également été observées, ces

dernières se nourrissant des tissus foliaires et affaiblissant les plants. Les thrips, quant à eux, causant des dégâts en piquant les tissus végétaux, se manifestent en entraînant des décolorations argentées sur les feuilles et la déformation des jeunes fruits.

Enfin, la présence de mouches mineuses a été relevée, avec leurs galeries caractéristiques creusées à l'intérieur des feuilles, ce qui diminue l'efficacité de la photosynthèse et affaiblit les plantes (Figure 4, 5 et 6).



Figure 4 : impact des pucerons sur un plant d'aubergine



Figure 5 : effets néfastes des thrips sur un plant de piment



Figure 6 : dommages occasionnés par les cochenilles farineuses sur un plant d'aubergine

Maladies fongiques

Au cours des observations menées sur les différentes parcelles, plusieurs maladies fongiques ont été diagnostiquées sur les cultures maraîchères, avec des symptômes typiques bien reconnaissables. Le mildiou, causé par *Phytophthora* spp., s'est particulièrement manifesté sur le gombo et le concombre. Les feuilles infectées présentaient des taches huileuses jaunâtres en surface, accompagnées d'une moisissure blanche ou noire au revers. Dans les cas avancés, les plants montraient des signes de pourriture rapide, compromettant la récolte. La fusariose, observée principalement sur la tomate et l'aubergine, se traduisait par un flétrissement asymétrique des feuilles. Une coupe longitudinale des tiges révélait un brunissement des vaisseaux conducteurs, symptôme

caractéristique de cette pathologie fongique systémique. La sclérotinia (ou pourriture blanche) affectait principalement la courgette. Les parties atteintes, notamment les tiges et les collets, étaient envahies d'un mycélium blanc cotonneux, associé à une pourriture molle. On notait aussi la présence de scléroties noirs incrustés dans les tissus nécrosés. L'alternariose, fréquente sur la tomate et parfois sur les laitues, se reconnaissait à l'apparition de taches brunes en cercles concentriques sur les feuilles, causant une défoliation prématurée et une baisse de vigueur des plants. Enfin, l'oïdium était très répandu sur le concombre et la courgette, en particulier dans les zones à forte humidité. Cette maladie se caractérise par un dépôt poudreux blanc recouvrant les deux faces des feuilles, provoquant leur dessèchement progressif et un ralentissement de la croissance (figure 7, 8 et 9).



Figure 7 : Alternariose sur feuille de laitue



Figure 8 : Oïdium sur feuille de concombre



Figure 9 : Mildiou sur feuille de gombo

Maladies bactériennes

Les cultures maraîchères, notamment en système agroécologique, ont montré une vulnérabilité accrue aux maladies bactériennes, accentuée par l'absence de traitements phytosanitaires chimiques. Deux pathologies majeures ont été recensées (Figure 10 et 11):

Le flétrissement bactérien, causé par *Ralstonia solanacearum*, a été fréquemment observé sur l'aubergine et la tomate. Il se manifeste par un

flétrissement brutal et irréversible des plantes, souvent en plein jour, sans signes précurseurs évidents. À la coupe, les tiges apparaissent brunies et laissent échapper un suintement blanchâtre, signe typique de l'infection bactérienne des vaisseaux conducteurs.

La tache bactérienne, principalement repérée sur l'aubergine et le piment, se caractérise par de petites lésions sombres sur les feuilles, bordées d'un halo jaune. Ces lésions évoluent rapidement, provoquant une dégradation du feuillage, une réduction de la photosynthèse et une perte de vigueur des plants.



Figure 10 : Tache bactérienne observée sur un plant d'aubergine



Figure 11 : Flétrissement bactérien observé sur un plant d'aubergine

Discussion

Les résultats de notre étude permettent de dresser un tableau contrasté mais instructif des systèmes agroécologiques comparés aux systèmes agricoles conventionnels dans les zones d'étude. Ils révèlent une perception globalement favorable de l'agroécologie par les producteurs, ainsi que des bénéfices écologiques significatifs, bien que certaines limites persistent, notamment en matière de rendements et de gestion des ravageurs. Cette discussion s'articule autour des principaux axes évalués dans l'étude : perceptions paysannes, diversité biologique, propriétés du sol, santé des plantes, et les défis d'adoption. La majorité des agriculteurs interrogés démontrent une bonne connaissance des principes généraux de l'agroécologie, et manifestent un intérêt pour son application. Toutefois, certaines pratiques spécifiques, telles que l'usage de fumier animal ou la rotation des cultures

comme moyen de gestion des ravageurs, restent encore insuffisamment maîtrisées ou appliquées. Ce constat rejoint celui de (Adetonah et al. (2011).), qui ont montré au Bénin que l'adoption des pratiques agroécologiques est freinée par un manque de formation technique, des ressources limitées, et l'insécurité foncière. En Côte d'Ivoire, une étude similaire réalisée dans la filière cacao par Sangne (2015) note que si les producteurs perçoivent bien les bénéfices des systèmes durables, ils peinent néanmoins à intégrer certaines techniques par manque de vulgarisation et de soutien technique. Le profil des agriculteurs ayant adopté l'agroécologie dans notre enquête est caractérisé par un niveau d'éducation relativement élevé et une certaine jeunesse, deux facteurs souvent associés à une plus grande ouverture à l'innovation Sangne (2015). Ce résultat souligne l'importance de cibler ces groupes dans les programmes de promotion de l'agroécologie. L'un des

résultats les plus marquants de l'étude concerne la richesse spécifique et la diversité végétale dans les systèmes agroécologiques. Les indices de diversité de Shannon y sont nettement plus élevés que dans les systèmes conventionnels, traduisant non seulement une plus grande variété d'espèces cultivées, mais aussi une meilleure répartition des individus entre ces espèces. Ce constat s'inscrit dans les observations de Kpangui (2015), selon lesquels les systèmes agricoles diversifiés favorisent la biodiversité tout en renforçant les services écosystémiques essentiels comme la régulation naturelle des ravageurs et la résilience au stress climatique. La macrofaune du sol, également analysée, montre une abondance et une diversité taxonomique bien plus importantes dans les parcelles agroécologiques. La présence d'organismes tels que les vers de terre, les collemboles et les myriapodes, indicateurs biologiques de la qualité du sol, confirme l'effet positif des pratiques agroécologiques sur la vie édaphique. Ces résultats font écho aux travaux de Potapov et al. (2021), qui ont démontré que l'absence d'herbicides et l'apport de matières organiques favorisent le développement de la faune du sol, essentielle au bon fonctionnement des cycles biogéochimiques. Les analyses pédologiques confirment que les systèmes agroécologiques présentent des sols mieux structurés, avec une densité apparente plus faible, une texture équilibrée et une capacité de rétention en eau plus élevée. Les teneurs en carbone organique, en azote total et en nutriments essentiels (calcium, magnésium, potassium, etc.) y sont également supérieures. Ces résultats traduisent l'effet bénéfique des apports organiques (compost, fumier, résidus de culture) sur la fertilité des sols, et confirment les conclusions de Traoré, K, Toé AM. (2008) qui recommandent des apports réguliers de matière organique pour améliorer la productivité dans les zones maraichères. Par ailleurs, le pH des sols agroécologiques est plus proche de la neutralité, ce qui favorise la disponibilité des éléments nutritifs et limite

la toxicité de certains ions. Dans les systèmes conventionnels, l'acidification du sol, résultant souvent de l'usage intensif d'engrais minéraux, peut au contraire nuire à la croissance des plantes et à la vie du sol. Malgré ces atouts, les systèmes agroécologiques présentent certaines vulnérabilités, notamment en ce qui concerne la gestion des ravageurs et des maladies. Plusieurs producteurs ont rapporté des attaques importantes sur leurs cultures, en particulier sur les légumes à cycle court. Cette situation, fréquente dans les systèmes agroécologiques en phase de transition, est souvent liée à l'absence d'une régulation biologique pleinement fonctionnelle et au manque de stratégies alternatives de lutte intégrée. Toutefois, la littérature souligne que la diversification végétale, les rotations culturales et le maintien de haies ou d'habitats pour les auxiliaires peuvent progressivement réduire la pression parasitaire à moyen terme. Kpangui (2015), ont ainsi montré que la régulation naturelle des ravageurs devient plus efficace dans les systèmes agricoles diversifiés, où les prédateurs naturels peuvent se maintenir durablement. L'une des critiques fréquemment formulées à l'égard de l'agroécologie concerne la baisse de rendement à court terme. Cette perception est partagée par une partie des producteurs interrogés. Néanmoins, plusieurs études, rappellent que cette baisse est souvent transitoire et que les systèmes agroécologiques deviennent plus productifs et rentables à long terme, notamment grâce à la réduction des coûts d'intrants, à la meilleure résilience aux chocs climatiques, et à la valorisation des produits sur des marchés différenciés. Dans le contexte ivoirien, plusieurs contraintes freinent l'adoption à grande échelle de ces pratiques : manque de formation, accès limité au fumier ou au compost, insécurité foncière, et pression du marché pour des rendements rapides. L'étude de Kremen, C., Iles, A., & Bacon, C. (2012) sur les systèmes maraichers souligne que l'absence de droit foncier stable dissuade les investissements de long terme, en particulier pour des pratiques comme

l'agroforesterie ou l'amendement organique régulier. Conclusion de la discussion
Les résultats de cette étude confirment les apports positifs des systèmes agroécologiques sur les dimensions écologiques de la production agricole : biodiversité végétale et animale, amélioration de la structure et de la fertilité des sols, atténuation des effets de l'agriculture intensive. Toutefois, des efforts importants restent à fournir pour surmonter les contraintes socio-économiques et techniques qui entravent leur adoption durable. À cet effet, des actions

prioritaires devraient inclure le renforcement des capacités des producteurs, la mise en place de politiques de sécurisation foncière, la promotion de circuits de commercialisation adaptés aux produits issus de l'agroécologie, ainsi qu'un appui à la recherche participative pour l'adaptation locale des pratiques. Dans cette optique, l'agroécologie ne doit pas être perçue comme une alternative marginale, mais comme une voie crédible pour répondre aux défis de durabilité, de sécurité alimentaire et de résilience climatique en Côte d'Ivoire.

Reconnaissance:

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EVALUATION OF THE IMPACT OF AGROECOLOGICAL AND CONVENTIONAL FARMING SYSTEMS ON BIODIVERSITY IN FARMLANDS IN NIGERIA

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Abstract

Agroecological and conventional farming systems are major approaches to agricultural production in Southwest Nigeria. However, the two farming practices differ in practice. Although conventional farming may enhance soil biodiversity loss and disruption of soil biological processes because of agrochemicals on non-target organisms. Presently, these effects have been ameliorated with the production of highly biodegradable agrochemicals. Therefore, the sustainability and conservation of the biodiversity of soils by the two practices are difficult to measure. Comparison of biodiversity levels in agroecological and conventional farming systems across selected farmlands in Nigeria needs to be investigated. This study aims to investigate the impact of agroecological and conventional farming systems on biodiversity within farmlands in Southwest Nigeria, exploring the implications for sustainable agriculture and conservation.

Two parallel line transects at least 50 m apart and ranging from 120 m to 160 m long were demarcated in each farm site. Two or three (30 x 30 m²) plots were established on each line transect at an equal interval of 20 m. All the vascular plants on each sample plot were enumerated and identified to species level. The soil samples were randomly collected at six (6) points, at 0-15 cm depth, within each plot established in each farm site, using a soil auger. A composite sample (150g) was taken aseptically from 6 soil samples randomly collected within each plot, after mixing the soil samples thoroughly. A portion of each composite soil sample (100g) was air dried and physico-chemical properties determined (Electrical conductivity; ds/cm, Organic carbon; g/kg, total nitrogen; g/kg, phosphorus; mg/kg, potassium; cmol/kg). A small portion (50g) of each composite sample was taken aseptically and stored at 4°C using a cold chest, and microbiological properties were determined (total bacteria, total coliform, total fungi, and some specialized bacteria groups).

Most tree species identified on Agroecological and Conventional farms are nitrogen-fixing tree species such as *Delonix regia*, *Gliricida sepium*, *Vitalleria paradoxa*. The mean value of soil electrical conductivity in Agroecological farms (342.00 ds/cm) was higher than in the Conventional farms (284.5 ds/cm). The mean value of soil organic carbon content in Agroecological farms (1.55 g/kg) was higher than the Conventional farms (1.47 g/kg). The mean value of total nitrogen of the Agroecological farm (0.17 g/kg) was higher than Conventional farms (0.15 g/kg). The mean soil pH of Agroecological

farms was 6.14 while Conventional farms was 5.0. The mean value of ECEC of Agroecological farms (16.62 cmol/kg) was higher than Conventional farms (9.04 cmol/kg). The soils of Agroecological farms contained high populations of total heterotrophic bacteria (3.9x10⁸ CFUs/g), followed by fungi (2.0x10⁸ CFUs/g) and coliform (1.9x10³ CFUs/g), and other specialized bacteria. The soil samples of Conventional farms contained a high population of fungi (3.4 x 10⁸ CFUs/g), followed by heterotrophic bacteria (2.7 x 10⁸ CFUs/g) and coliform (1.1 x 10⁴ CFUs/g), and other specialized bacteria. Agroecological practice improves the nutrient supplying power and proliferation of heterotrophic bacteria. The soil condition of agroecological farms is more biologically active and ecologically balanced compared to the conventional systems.

Keywords: Soil microbial population, Conventional farming, Agroecological farming, Plant diversity

Résumé

Les systèmes agricoles agroécologiques et conventionnels constituent des approches majeures de la production agricole dans le sud-ouest du Nigeria. Cependant, ces deux pratiques diffèrent. Bien que l'agriculture conventionnelle puisse accentuer la perte de biodiversité des sols et perturber leurs processus biologiques en raison des produits agrochimiques sur les organismes non ciblés, ces effets ont été atténués grâce à la production de produits agrochimiques hautement biodégradables. Par conséquent, la durabilité et la conservation de la biodiversité des sols par les deux pratiques sont difficiles à mesurer. Il est nécessaire d'étudier la comparaison des niveaux de biodiversité des systèmes agroécologiques et conventionnels sur des terres agricoles sélectionnées au Nigeria. Cette étude vise à analyser l'impact des systèmes agroécologiques et conventionnels sur la biodiversité des terres agricoles du sud-ouest du Nigeria, en explorant leurs implications pour l'agriculture durable et la conservation.

Deux transects linéaires parallèles, distants d'au moins 50 m et d'une longueur comprise entre 120 m et 160 m, ont été délimités dans chaque site agricole. Deux ou trois parcelles (30 x 30 m²) ont été établies sur chaque transect linéaire, à un intervalle régulier de 20 m. Toutes les plantes vasculaires de chaque parcelle d'échantillonnage ont été dénombrées et identifiées au niveau de l'espèce. Des échantillons de sol ont été prélevés aléatoirement en six (6) points, à une profondeur de 0 à 15 cm, dans chaque parcelle établie sur chaque site agricole, à l'aide d'une tarière. Un échantillon composite (150 g) a été prélevé aseptiquement à partir de 6 échantillons de sol prélevés aléatoirement dans chaque parcelle, après avoir soigneusement mélangé les échantillons. Une portion de chaque échantillon composite (100 g) a été séchée à l'air libre et ses propriétés physico-chimiques ont été déterminées (conductivité électrique ; ds/g, carbone organique ; g/kg, azote total ; g/kg, phosphore, potassium). Une petite portion (50 g) de chaque échantillon composite a été prélevée aseptiquement et conservée à 4 °C dans une chambre froide, et ses propriétés microbiologiques ont été déterminées (bactéries totales, coliformes totaux, champignons totaux et certains groupes de bactéries spécialisées).

La plupart des espèces d'arbres identifiées dans les exploitations agroécologiques et conventionnelles sont des espèces fixatrices d'azote telles que *Delonix regia*, *Gliricida sepium*, *Vitalleria paradoxa*. Français La valeur moyenne de la conductivité électrique du sol dans les fermes agroécologiques (342,00 ds/cm) était plus élevée que dans les fermes conventionnelles (284,5 ds/cm). La valeur moyenne de la teneur en carbone organique du sol dans les fermes agroécologiques (1,55 g/kg) était plus élevée que dans les fermes conventionnelles (1,47 g/kg). La valeur moyenne de l'azote total de la ferme agroécologique (0,17 g/kg) était plus élevée que dans les fermes conventionnelles (0,15 g/kg). Le

pH moyen du sol des fermes agroécologiques était de 6,14 tandis que celui des fermes conventionnelles était de 5,0. La valeur moyenne de l'ECEC des fermes agroécologiques (16,62 cmol/kg) était supérieure à celle des fermes conventionnelles (9,04 cmol/kg). Les sols des exploitations agroécologiques contenaient de fortes populations de bactéries hétérotrophes totales ($3,9 \times 10$ UFC/g), suivies de champignons ($2,0 \times 10$ UFC/g), de coliformes ($1,9 \times 10$ UFC/g) et d'autres bactéries spécialisées. Les échantillons de sol des exploitations conventionnelles contenaient une forte population de champignons ($3,4 \times 10$ UFC/g), suivis de bactéries hétérotrophes ($2,7 \times 10$ UFC/g), de coliformes ($1,1 \times 10$ UFC/g) et d'autres bactéries spécialisées.

Les pratiques agroécologiques améliorent l'apport en nutriments et la prolifération des bactéries hétérotrophes. Les sols des exploitations agroécologiques sont plus actifs biologiquement et plus équilibrés écologiquement que ceux des systèmes conventionnels.

Mots-clés : Population microbienne du sol, Agriculture conventionnelle, Agriculture agroécologique, Diversité végétale

Introduction

The agriculture sector contributes to the food security and livelihoods of millions of people (Ogundari & Akinbode, 2013) in Nigeria. The Southwest region of Nigeria is a major agricultural hub of Nigeria due to its favourable climate and vast land of fertile soils (Adeoye & Afolami, 2015). However, farming practices significantly determine the sustainable production of goods and services through the conservation of biodiversity on the farmlands. Based on synthetic and agrochemical usage, Agroecological and conventional farming systems are major approaches to agricultural production in Southwest Nigeria. However, the two farming practices differ in practice (Adesina et al., 2017).

Agroecological farming systems are characterized by a reduction in synthetic inputs, which enhance the conservation of natural habitats for organisms and the maintenance of ecological processes (Gliessman, 2015; FAO, 2018). Conversely, Conventional farming systems are characterized by monoculture and intensive use of agrochemicals. Although conventional farming may enhance soil biodiversity loss and disruption of soil biological processes (Tilman et al., 2002; IPES-Food, 2016) due to the effect of

agrochemicals on non-target organisms. Currently, these effects have been mitigated through the production of highly biodegradable agrochemicals. Therefore, the sustainability and conservation of biodiversity, soil quality, and health are difficult to measure. Comparison of biodiversity levels in agroecological and conventional farming systems across selected farmlands in Nigeria, focusing on plant diversity, soil organisms, and wildlife presence, needs to be investigated. This study aims to investigate the impact of agroecological and conventional farming systems on biodiversity within farmlands in Southwest Nigeria, exploring the implications for sustainable agriculture and conservation.

MATERIALS AND METHODS

Study area

This study was conducted in Ibadan and Epe in Oyo and Lagos States, Nigeria, respectively. Ibadan and Epe are located between latitude $6^{\circ} 52'$ and $9^{\circ} 55'$ N and Longitude $3^{\circ} 53'$ to $5^{\circ} 9'$ E and $6^{\circ} 27'$ and $6^{\circ} 45'$ N and Longitude $3^{\circ} 23' 03''$ to $3^{\circ} 38' 40''$ E, respectively. Oyo State is within the derived savanna and lowland rainforest of Nigeria and covers a total of 28,454 square kilometers of land mass. Lagos State has a tropical wet and dry season with an average temperature range from

28 to 32°C during the day and 22 to 24°C at night (<https://www.lagosstate.gov.ng> accessed 23 January 2025)

Climatic and weather conditions of Oyo and Lagos States

Oyo State has an equatorial climate with dry and wet seasons and relatively high humidity. The dry season lasts from November to March, while the wet season starts in April and ends in October. Average daily temperature ranges between 25°C (77.0°F) and 35°C (95.0°F) almost throughout the year (<https://www.oldOyostate.gov.ng> access 23 January 2025).

Sample plot demarcation and sampling procedure for vascular plant and soil

Two parallel line transects at least 50 m apart and ranging from 120 m to 160 m long were demarcated in each farm site. Two or three (30×30 m²) plots were established on each line transect at an equal interval of 20 m. All the vascular plants on each sample plot were enumerated and identified with the assistance of a plant taxonomist. The soil samples were collected at 6 randomly chosen points, at 0-15 cm depth, within each plot established in each farm site, using soil auger. A composite sample was taken aseptically from 6 soil samples randomly collected within each plot, after mixing the soil samples thoroughly. A portion of each composite soil sample was kept inside plastic bags, labelled and immediately transported to the laboratory for air drying before the commencement of chemical analysis. The physico-chemical analysis carried out on the composite soil samples includes Electrical conductivity, Organic carbon content, total nitrogen, phosphorus, and potassium. A small portion (50g) of each composite sample was taken aseptically and stored at 4°C using a cold chest and subsequently transported to the laboratory for microbiological analysis. The population count of microbes carried out on a composite soil sample

included total bacteria, total coliform, total fungi, and some specialized bacterial groups. Furthermore, core samples of soil were taken at 0-12 cm depth, at the Centre of each plot, using an 8 cm diameter core. The cores were stored in a box before being taken to the laboratory for further analysis.

Soil chemical analysis

The soils were air-dried and sieved to 2.00 and 0.50mm before acid extraction in the laboratory. The soil pH was determined both in water and 0.01M CaCl₂ solution using a soil solution ratio of 1:1 water. The organic carbon content of the soil was determined by the Wet Oxidation method of Walkley and Black (1934). The soil total nitrogen (TN) was determined using the micro-Kjeldahl digestion technique. Available phosphorus was extracted using Melich 2 and determined calorimetrically by Molybdeophosphoric acid. Cation exchange capacity of the soil was determined with 1M NH₄OAC buffered at pH 7.0. Effective cation exchange capacity (ECEC) was calculated from the summation of exchangeable bases and exchangeable acidity. Extractable Zn, Cu, Fe, and Mn were extracted with 0.01M HCl solution and determined calorimetrically using an Atomic Absorption Spectrophotometer (AAS). Another portion of the soil samples was taken from the composite samples for particle size distribution (Sand, Silt, and Clay), using Bouyoucos hydrometer method.

Soil microbiological analysis

The population of heterotrophic bacteria in the soil samples was determined following Okpokwasili & Okorie (1988). Briefly, bacterial colonies were purified through repeated sub-culturing on suitable agar media. Pure isolates were maintained on nutrient agar slants and stored under refrigerated conditions ($4^{\circ}\pm 2^{\circ}\text{C}$) and at ambient laboratory temperature ($28^{\circ}\pm 2^{\circ}\text{C}$) for subsequent characterization and identification. Fungal Load was determined by following the serial dilution method of Pepper & Gerba (2004). Briefly, one

milliliter of appropriately diluted samples (ten-fold serial dilutions) was inoculated onto Potato Dextrose Agar (PDA) supplemented with chloramphenicol (0.1?g/L) to suppress bacterial growth. Inoculations were performed in triplicate using the pour plate technique. Plates were incubated at ambient temperature (28?±?4°C) for 2-4 days. After incubation, visible fungal colonies were counted and expressed as colony-forming units per milliliter (CFU/mL) using a digital colony counter. The Nitrifying Bacteria population was determined by using the Nwaugo et al. (2008) method. Briefly, a diluted soil sample (0.1?mL of the 10²³) was inoculated onto mineral salt agar medium containing: 0.06?g CaCl₂, 0.06?g FeCl₂, 0.06?g MgSO₄?7H₂O, 0.106?g KH₂PO₄, 0.06?g Ca(NO₃)₂, and 0.488?g (NH₄)₂SO₄. The medium was solidified with 1% Difco Noble Agar. Inoculation was done using the spread plate technique, and plates were incubated at room temperature (28?±?2°C) for 48-72 hours and the colonies were counted. Lipolytic bacterial populations were enumerated using the method of Mohan et al. (2008). Briefly, diluted samples were plated onto tributyrin agar and incubated for 24 hours. The appearance of clear halo zones around colonies indicated positive lipolytic activity. Phosphate-

solubilizing bacteria were spread by spreading 0.1?mL of the 10²³ dilution on NBRI-BPB medium solidified with 1% Difco Noble Agar and incubated at 30°C for three days. Colonies that produced distinct yellow halo zones were considered positive for phosphate solubilization (US Patent, 2003).

Data analysis

Soil samples were prepared and analyzed in a laboratory, and the data generated were subjected to descriptive analysis such as percentage (%), Coefficient of Variation (CV), and t-test at ?0.05.

3.0 RESULTS

3.1. Vascular plant on Agroecological and Conventional farms in Lagos and Oyo State, Nigeria

A few tree species were found on both Agroecological and Conventional farms, as shown in Table 1. Conventional farms harbor more tree species than Agroecological farms. Most tree species identified on Agroecological and Conventional farms are nitrogen-fixing tree species such as *Delonix regia*, *Gliricida sepium*, *Vitalleria paradoxa*

Table 1. Scientific names of the tree species identified on Agroecological and Conventional farms in Oyo and Lagos State, Nigeria

	Farms	Tree species
Agroecological Farms	Ajibode Farms	<i>Delonix regia</i> ,
	FunAde Farms	<i>Cola millenii</i> , <i>Bitter leaf</i>
Conventional Farms	SAA Farms	<i>Morinda lucida</i>
	R and J Farms	<i>Gliricida sepium</i> , <i>Vitalleria paradoxa</i> , <i>Persea americana</i>

3.2 Soil physico-chemical properties of Agroecological and Conventional farms in Lagos and Oyo State, Nigeria

Soil nutrient concentrations were calibrated from soil samples collected from topsoil (0-15cm) in Agroecological and Conventional farms in Nigeria. The Electrical conductivity of the soil ranged from 154.00 to 530.00 ds/cm in Agroecological farms, while it ranged from 151.00 to 416.00 ds/cm in Conventional farms. The mean value of soil electrical conductivity in Agroecological farms (342.00 ds/cm) was higher than that of Conventional farms (284.5 ds/cm).

The organic carbon content of the soil ranged from 0.92 to 2.17 g/kg in Agroecological farms, while it ranged from 1.15 to 1.79 g/kg in Conventional farms. The mean value of organic carbon soil content in Agroecological farms (1.55 g/kg) was higher than the

Conventional farms (1.47 g/kg). The nitrogen content of the soil varied from 0.10 to 0.23 g/kg in Agroecological farms, while it varied from 0.13 to 0.17 g/kg in Conventional farms. The mean value of total nitrogen of the Agroecological farm (0.17 g/kg) was higher than Conventional farms (0.15 g/kg). The least and highest soil total nitrogen was obtained in the Agroecological farms. The wide variation in soil total nitrogen of agroecological farms may be due to different drainage conditions. The available phosphorus content of the soil ranged from 7.65 to 46.78 g/kg in Agroecological farms, while it ranged from 50.02 to 98.25 g/kg in Conventional farms. The mean value of available phosphorus of Conventional farms (74.14 g/kg) was higher than that of Agroecological farms (27.22 g/kg). There was a wide variation in the available phosphorus content between Conventional farms.

Table 2. Soil chemical-physical properties of composite samples taken from the 0-15cm surface layer of Agroecological and Conventional Farms

Parameters	Ajibode Farm	FUNADE Farm	SAA Farm	R and J Farm
pH (1:1) H ₂ O	6.14	4.96	5.48	5.19
Nitrogen g/kg	0.2	0.1	0.1	0.2
Phosphorus mg/kg	46	7	50	98
Organic Carbon g/kg	2.2	1.0	1.2	1.8
Exchangeable Cations cmol/kg				
Potassium	0.2	*	*	*
Calcium	24	3	5	8
Magnesium	1.7	0.4	0.6	1.0

* Not traceable

Sodium	0.4	0.2	0.2	0.3
Electrical conductivity ds/cm	530.0	154.0	151.0	416.0
Exchangeable Acidity cmol/kg	0.2	1.4	0.2	0.2
ECEC cmol/kg	27.4	5.9	7.2	10.9
Aluminium cmol/kg	0.3	0.7	0.3	0.3
Manganese mg/kg	103	13	63	88
Iron mg/kg	443	230	475	116
Copper mg/kg	5	2	1	3
Zinc mg/kg	92	7	6	13
Clay g/kg	194.4	132.0	91.4	132.6
Silt g/kg	307.4	170.4	151.6	91.0
Sand g/kg	498.2	697.6	757.0	776.4
Textural Class	Loam	Sandy Loam	Sandy Loam	Sandy Loam

The soil pH varied from 4.96 to 6.14 in Agroecological farms and 5.19 to 5.48 in Conventional farms. The mean soil pH of Agroecological farms was 6.14, while Conventional farms was 5.0. Therefore, the soil pH of Agroecological farms was higher than Conventional farms. However, there was wide variation in the soil pH between Agroecological farms. The variation may be due to differences in the water drainage and cropping system of the two farms.

The ECEC ranged from 5.86 to 27.37 cmol/kg in Agroecological farms, while it ranged from 7.16 to 10.92 cmol/kg in Conventional farms. The mean value of ECEC of Agroecological farms (16.62 cmol/kg) was higher than Conventional farms (9.04 cmol/kg).

Therefore, there was a wide difference in the value of ECEC between Agroecological farms compared to conventional farms. The soil Aluminium content ranged from 0.25 to 0.65 cmol/kg in Agroecological farms, while farms operating the Conventional system had the same value of Aluminium (0.30 cmol/kg).

The soil clay content of Agroecological farms ranged from 13.20 to 19.43 g/kg, while the soil clay content of Conventional farms ranged from 9.14 to 13.26 g/kg. The soil texture classes of two Agroecological farms were loam and sandy loam, while those of Conventional farms were sandy loam and sandy loam at 0-15cm.

3.3 Soil Microbiological Analysis on Agroecological and Conventional Farms in Lagos and Oyo State, Nigeria

3.3.1 Microbial Population in soils of Agroecological Farms (Ajibode and FUNADE farms)

The microbial population of soil samples of Ajibode and FUNADE farms in Oyo and Lagos States, respectively, is presented in Table 4. The soils of Agroecological farms contained high populations of total heterotrophic bacteria (3.9×10^8 CFUs/g), followed by fungi (2.0×10^8 CFUs/g) and coliform (1.9×10^3 CFUs/g), and other specialized bacteria (Table 4). Coliform bacteria population was the least microbial group with a load of 2.9×10^3 CFUs/g and 9.7×10^2 CFUs/g in Ajibode and FUNADE farms, respectively (Table 4).

For specialized bacteria groups, the soils of Agroecological farms contained high population of total nitrifying bacteria (1.7×10^5 CFUs/g), followed by total lipolytic bacteria (4.2×10^4 CFUs/g) and phosphorus-solubilizing bacteria (2.7×10^3 CFUs/g). Therefore, the specialized bacteria group with the least population count was phosphorus-solubilizing bacteria with a mean load of 2.7×10^3 CFUs/g in both Ajibode and FUNADE farms, respectively (Table 4).

3.3.2 Bacteria, fungi, and coliform species in Agroecological farms (Ajibode and FUNADE farms)
 Bacillus sp, Pseudomonas sp, Flavobacterium sp, and Corynebacterium sp were the most common and abundant heterotrophic bacteria group, with an occurrence of 100% in Ajibode and FUNADE farms (Table 4). Conversely, Staphylococcus sp and Micrococcus sp were common to Ajibode and FUNADE farms, respectively. Among the coliform bacteria group, Salmonella sp, Aeromonas sp, Proteus sp, and Klebsiella sp were common and abundant, with an occurrence of 100%, in Ajibode and FUNADE farms (Table 4). Aspergillus spp, Rhizopus sp, Candida sp, and Penicillium sp were common and

abundant fungi groups, with an occurrence of 100%. Mucor sp and Geotrichum sp were identified in Ajibode farm, with an occurrence of 50% while Saccharomyces spp was identified only in FUNADE farm (50%).

3.3.3 Specialized bacteria populations in Agroecological Farms (Ajibode and FUNADE farms)

Among the specialized bacteria groups, Bacillus spp, Pseudomonas sp, and Flavobacterium sp were the most common and abundant Phosphate Solubilizing Bacteria (PSB), with an occurrence of 100% in Ajibode and FUNADE farms (Table 4). Staphylococcus sp and Micrococcus sp were identified with an occurrence of 50% at the Ajibode farm and FUNADE farm, respectively. Bacillus spp, Salmonella sp, and Pseudomonas sp were the most common and abundant Lipolytic Bacteria (LB) group, with an occurrence of 100% in Ajibode and FUNADE farms. Flavobacterium sp and Micrococcus sp were identified with an occurrence of 50% in Ajibode and FUNADE farms, respectively. Bacillus spp, Pseudomonas spp, Micrococcus sp, Flavobacterium sp, and Staphylococcus spp were the most common and abundant nitrifying bacteria, with an occurrence of 100% in Ajibode and FUNADE farms (Table 4).

3.4 Microbial population in soils of Conventional farms (R&J and SAA farms)

The microbial population of soil samples of R&J and SAA farms in Oyo and Lagos States is presented, respectively, in Table 5. The soil samples of Conventional farms contained high population of fungi (3.4×10^8 CFUs/g), followed by heterotrophic bacteria (2.7×10^8 CFUs/g) and coliform (1.1×10^4 CFUs/g), and other specialized bacteria. Also, coliform bacteria population was the least microbial group with a load of 1.7×10^4 and 5.6×10^3 CFUs/g in R&J and SAA farms, respectively (Table 5). For specialized bacteria groups, the soils of Conventional farms contained a high population of total nitrifying bacteria (2.8×10^5

CFUs/g), followed by total lipolytic bacteria (4.8 x 10⁴ CFUs/g) and phosphorus-solubilizing bacteria (1.5 x 10³ CFUs/g) and. Therefore, the specialized bacteria group with the least population count was phosphorus-solubilizing bacteria with a mean load of 2.3 x10³ and 8.9 x 10² CFUs/g in both R & J farm and FUNADE farm, respectively (Table 5).

3.4.1 Bacteria, fungi, and coliform species in Conventional Farms (R & J and SAA farms)

Bacillus sp, Pseudomonas sp, Flavobacterium sp, Micrococcus sp, and Corynebacterium sp were the most common and abundant heterotrophic bacteria group, with an occurrence of 100% in R & J and SAA farms (Table 5). Among the coliform bacteria group, Salmonella sp; Aeromonas sp; Proteus sp, and Klebsiella sp were common and abundant, with an occurrence of 100%, in R & J and SAA farms (Table 5). Aspergillus sp, Rhizopus sp, Saccharomyces sp, Mucor sp, Geotricum sp, and Penicillium sp were common and abundant fungi groups, with an occurrence of 100% in

R & J and SAA farms. Candida sp was identified only in the SAA farm at 50%.

3.4.2 Specialized Bacteria populations in Conventional Farms (R & J and SAA farms)

Among the specialized bacteria groups, Bacillus spp, Pseudomonas sp, Flavobacterium sp, Micrococcus sp, and Corynebacterium sp were the most common and abundant Phosphate Solubilizing Bacteria (PSB), with an occurrence of 100% in R & J and SAA farms (Table 5). Bacillus spp; Salmonella sp and Pseudomonas sp, and Micrococcus sp were the most common and abundant Lipolytic Bacteria (LB) group, with an occurrence of 100%, in R & J and SAA farms. Flavobacterium sp was identified with an occurrence 50% in SAA farms. Bacillus sp; Pseudomonas sp; Flavobacterium sp, and Staphylococcus sp were the most common and abundant nitrifying bacteria with an occurrence of 100% in R & J and SAA farms (Table 5).

Table 3: Microbial Population and Dynamics in Soils of Conventional Farms

PARAMETERS	R&J Farm	SAA Farm	Mean Value
Total Bacteria Count (CFUs/g)	4.1 X 10 ⁸	1.4 X 10 ⁸	2.7x10 ⁸
Organisms Identified	<i>Bacillus spp; Pseudomonas sp; Flavobacterium spp; Micrococcus sp; Corynebacterium sp</i>	<i>Bacillus spp; Pseudomonas sp; Flavobacterium spp; Micrococcus sp; Corynebacterium sp</i>	
Total Coliform (CFUs/g)	1.7 X 10 ⁴	5.6 X 10 ³	1.1x10 ⁴
Organisms Identified	<i>Salmonella sp; Aeromonas sp; Klebsiella sp; Proteus sp;</i>	<i>Salmonella sp; Aeromonas sp; Proteus sp; Klebsiella sp; E coli;</i>	
Total Fungal Count (CFUs/g)	5.1 X 10 ⁸	1.9 X 10 ⁸	3.5x10 ⁸

Organisms Identified	<i>Aspergillus spp; Rhizopus sp; Saccharomyces spp; Mucor sp; Geotricum sp; Penicillium spp</i>	<i>Aspergillus spp; Rhizopus sp; Saccharomyces spp; Candida sp; Geotricum sp; Penicillium sp</i>	
Specialized Bacteria groups:			
Total Phosphate Solubilising Bacteria (CFUs/g)	2.3 x 10 ³	8.9 x 10 ²	1.5x10 ³
Organisms Identified	<i>Bacillus spp; Pseudomonas sp; Micrococcus sp; Staphylococcus sp</i>	<i>Bacillus sp; Pseudomonas spp; Flavobacterium sp; Staphylococcus sp</i>	
Total Lipolytic Bacteria (CFUs/g)	7.5 x 10 ³	9.0 x 10 ⁴	4.8x10 ⁴
Organisms Identified	<i>Bacillus sp; Salmonella sp; Pseudomonas sp; Micrococcus sp</i>	<i>Bacillus sp; Salmonella sp; Pseudomonas sp; Flavobacterium sp; Micrococcus sp</i>	
Total Nitrifying Bacteria (CFUs/g)	4.8 x 10 ⁴	5.3 x 10 ⁵	2.8x10 ⁵
Organisms Identified	<i>Bacillus spp; Pseudomonas spp; Flavobacterium sp; Staphylococcus spp</i>	<i>Bacillus spp; Pseudomonas sp; Micrococcus sp; Flavobacterium sp; Staphylococcus spp</i>	

4.0 DISCUSSION

4.1 Soil physico-chemical properties of Agroecological and Conventional farms in Oyo and Lagos States, Nigeria

The agroecological system of cropping does not involve the use of synthetic chemicals and inorganic fertilizers, while the Conventional farming system is mostly dependent on synthetic agro-chemicals and inorganic fertilizers. A few tree species were identified on both Agroecological and Conventional farms, and those trees are nitrogen-fixing species such as Delonix regia, Gliricidia septum, Vitellaria paradoxa. This

indicated that farms operating an Agroecological system do not incorporate the use of leaf litters of trees to rejuvenate their soils. Probably most of the Agroecological farms prefer to use poultry droppings for rejuvenating of their soils.

High Electrical Conductivity has been associated with high levels of nitrate and other selected soil nutrients such as P, K, Ca, Mg, Mn, Zn, and Cu (Vourlitis et al., 2012). The soils of Farms operating an Agroecological system contained more organic matter than those operating a Conventional system. There was a wide

variation in the organic carbon content between Agroecological farms. Moreover, there was a wide variation in the organic carbon content between Agroecological farms. The variation may be due to differences in the moisture content of the soils of Agroecological farms. Soil organic carbon of Ajibode farm was higher than other Agroecological farms, probably because one of the Agroecological farms (Ajibode farm) is located at the bank of the river Ajibode in the city of Ibadan. Manns et al (2016) revealed that soil that remains moistened for most times of the year has potential for carbon accumulation. The soil of Ajibode farm was consistently higher in ECEC than other Agroecological farms and other Conventional farms, probably due to its high organic matter accumulation. According to Asadu et al (1997), the organic matter of soils of sub-Saharan Africa alone could account for about 60% of the mean ECEC of soils. Oorts et al. (2000) reiterated that soil organic matter may account for 25 to 90% of the CEC in many tropical soils. However, the impact of soil organic matter on CEC is dependent on pH. Furthermore, most of the variation in soil chemistry could be associated with soil organic matter content. This shows the essential role of soil organic matter in nutrient storage and cycling. However, the source of soil organic matter in Agroecological farms may not be from decomposition and mineralization of leaf litter due to scanty number of trees identified on Agroecological farms. However, the sand fraction dominates the soil particle size distribution of the four (4) farms. Soils of Agroecological farms contained more clay and silt than those of Conventional farms. There is evidence that clay particles promote the accumulation of organic materials (Bohn et al., 1985, and Stevenson, 1994).

4.2 Soil micro-biological properties of Agroecological and Conventional farms in Oyo and Lagos States, Nigeria

The variety of vegetation observed in the agroecological farms consists mainly of shrubs and

large fruit trees like mangoes. The Farming systems were mainly intercropping of staple arable crops like maize with groundnut, cassava, vegetables, and cucumber, with total dependence on organic inputs and soil amendments like compost to boost soil fertility. The conventional farms consisted of monocropping on a large expanse of land of crops like maize, cassava, and vegetables with heavy dependence on synthetic fertilizer application.

The soil microbial analysis revealed the presence of inherent microbial communities, including bacteria, fungi, coliform bacteria, and specialized functional groups such as phosphate-solubilizing, lipolytic, and nitrifying bacteria. The diverse microbial populations confirm the biological presence of the soil and reinforce the fundamental role of microorganisms in nutrient cycling, organic matter decomposition, and plant nutrient uptake (Van der Heijden et al., 2008). In the agroecological farming systems (Ajibode UI and FUNADE farms), bacterial populations were predominant. Dominant genera included *Bacillus* spp., *Pseudomonas* sp., *Flavobacterium* spp., and *Corynebacterium* sp. These genera are well documented for their multifunctional roles in agroecosystems. For instance, *Bacillus* and *Pseudomonas* spp. are recognized for their phosphate-solubilizing and nitrifying capabilities, as well as their contribution to the degradation of organic matter and the mineralization of nutrients (Rodríguez and Fraga, 1999; Sharma et al., 2013). The higher bacterial load in agroecological farms suggests that these systems support soil conditions such as favorable pH, organic matter content, and minimal chemical disturbance that enhance bacterial proliferation and activity (Zhou et al., 2017). This is critical, as bacterial communities are central to nutrient transformation processes and contribute significantly to soil fertility and plant health (Berg and Smalla, 2009).

Conversely, conventional farms were characterized by a higher prevalence of fungi, notably *Aspergillus* spp., *Rhizopus* sp., *Saccharomyces* spp., *Geotrichum* sp., and *Penicillium* spp. Fungi tend to thrive in acidic soil environments, which may have resulted from the sustained application of synthetic fertilizers, known to reduce soil pH and negative impact bacterial activity (Geisseler & Scow, 2014). The dominance of fungi in these soils may also be indicative of a shift in microbial balance due to decreased organic matter input and chemical disturbance, leading to a reduction in beneficial bacterial populations.

The differences in microbial communities between Agroecological and Conventional systems highlight the impact of farming practices on soil biological health. The slightly acidic to neutral pH in agroecological farms likely supported the proliferation of beneficial bacteria, while the lower microbial diversity and lower levels of specialized bacterial groups in conventional soils can be attributed to reduced organic matter and the inhibitory effects of chemical inputs (Lori et al., 2017). These findings align with the established understanding that microbial diversity and function are closely linked to sustainable soil management practices that maintain organic inputs and minimize chemical disruptions.

The higher population of specialized bacterial groups, such as phosphate-solubilizing and nitrifying bacteria in agroecological soils, is particularly significant, as these organisms enhance nutrient bioavailability and contribute to long-term soil fertility. Their absence or reduced presence in conventional systems suggests potential nutrient cycling deficiencies and a less resilient soil ecosystem (Fierer, 2017).

5.0 CONCLUSION

5.1 Conclusion on soil physico-chemical properties on Agroecological and Conventional Farms in Oyo and Lagos State, Nigeria

There are a few trees identified on Agroecological farms; therefore, the practice mostly depends on other forms of organic input such as animal droppings and compost manure. However, planting more nitrogen-fixing trees on the farm sites should be encouraged. Low soil nutrients in one of the Agroecological farms show that the Agroecological system should be carefully handled because it may not guarantee an increase in mineral nutrients in the soils. Agroecological practices could be a way to prevent non-biodegradable components of many agrochemicals from entering the food chain. Farmers practicing an Agroecological system require more awareness of different ways through which organic matter of their farms could be improved because it is the basis for soil nutrient supply and retention.

In summary, this study highlights the critical role of microbial communities in maintaining soil health and the beneficial impact of agroecological practices in fostering microbial biodiversity and functionality. The dominance of bacteria, especially functional groups in agroecological systems, indicates a more biologically active and ecologically balanced soil environment compared to the conventional systems.

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MODERATION EFFECT OF KNOWLEDGE ON ORGANIC FOOD ACCEPTABILITY AMONG PERSONNEL OF IBADAN-BASED AGRO RESEARCH INSTITUTIONS

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Abstract

The use of agrochemicals in conventional farming has come with its benefits and also its baggage in the form of consequences for human health and serious environmental hazards. Organic food, which serves as an alternative remedy to this problem, is not quite popular in Nigeria's food market. This study examined the role knowledge of organic food plays in the determination of its acceptability. A multistage sampling procedure was used to select 203 academics and researchers from 12 out of 22 agricultural research and educational institutions within the Ibadan metropolis. A structured questionnaire was used to elicit responses on information about knowledge of organic food and the determinants of acceptability, and the data was analyzed using the partial least squares structural equation model (PLS-SEM). Result revealed Knowledge of organic food significantly moderated the relationship between the availability ($\beta = -0.443$), (T value = 2.949), indicating knowledge increases, affecting the acceptability of organic food to decrease, The acceptance constraints ($\beta = 0.25$), (T value = 2.784) indicated that as knowledge increases, the effect of organic food acceptance constraints on organic food acceptability increases. The perceived benefit ($\beta = 0.34$), and (T value = 1.961) indicates that as knowledge increases, the effect of perceived nutritional and health benefits on organic food acceptability increases. The study recommended that organic food consumers should strive to increase their knowledge about organic food, such as the nutritional and health benefits of organic food and should not base their acceptance solely on the availability of organic food products.

Keywords: Acceptability, Knowledge, Organic food, Agro-research Institutions, Ibadan

EFFET DE MODÉRATION DE LA CONNAISSANCE SUR L'ACCEPTABILITÉ DES ALIMENTS BIOLOGIQUES PARMIL LE PERSONNEL DES INSTITUTIONS DE RECHERCHE AGRICOLE BASÉES À IBADAN

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Résumé

L'utilisation d'agrochimiques dans l'agriculture conventionnelle présente des avantages, mais elle s'accompagne également de conséquences pour la santé humaine et de graves risques environnementaux. Les aliments biologiques, qui constituent une solution alternative à ce problème, ne sont pas très populaires sur le marché alimentaire nigérian. Cette étude a examiné le rôle que joue la connaissance des aliments biologiques dans la détermination de leur acceptabilité. Une procédure d'échantillonnage en plusieurs étapes a été utilisée pour sélectionner 203 universitaires et chercheurs parmi 12 des 22 institutions de recherche et d'enseignement agricoles situées dans la métropole d'Ibadan. Un questionnaire structuré a été utilisé pour recueillir des réponses sur la connaissance des aliments biologiques et les facteurs déterminants de leur acceptabilité, et les données ont été analysées à l'aide du modèle d'équations structurelles par moindres carrés partiels (PLS-SEM). Les résultats ont révélé que la connaissance des aliments biologiques modère de manière significative la relation entre la disponibilité ($\beta = -0,443$), (valeur T = 2,949), indiquant que l'augmentation des connaissances entraîne une diminution de l'acceptabilité des aliments biologiques. Les contraintes d'acceptation ($\beta = 0,25$), (valeur T = 2,784) ont indiqué que lorsque les connaissances augmentent, l'effet des contraintes d'acceptation des aliments biologiques sur l'acceptabilité des aliments biologiques augmente. Le bénéfice perçu ($\beta = 0,34$), et (valeur T = 1,961) indique que lorsque les connaissances augmentent, l'effet des bénéfices nutritionnels et sanitaires perçus sur l'acceptabilité des aliments biologiques augmente. L'étude recommande que les consommateurs d'aliments biologiques s'efforcent d'accroître leurs connaissances sur les aliments biologiques, tels que les avantages nutritionnels et sanitaires des aliments biologiques, et ne devraient pas baser leur acceptation uniquement sur la disponibilité des produits alimentaires biologiques.

Mots-clés: Acceptabilité, Connaissance, Aliments biologiques, Institutions de recherche agricole, Ibadan**Introduction**

The global quest for food yield increases, in the face of booming world population (Worldometer, 2022) which has led to the evolution of many technologies. Synthetic and inorganic agricultural inputs, such as agrochemicals and fertilizers, are good examples (FAO, 2017). These innovations have had an impact by improving not just the productivity but also the yield of crops (Halweil, 2007). The impact of these innovations, on the other hand, is not all positive. They mostly function at the expense of man, plant, the environment, or all at the same time (Hashimi et al.,

2020) with their active content exerting an irreparable impact on all non-targeted substances. The innovations exploit conventional farming mostly with some vices, thereby providing an unarguable benefit at a cost too heavy to bear. They have therefore become a major source of pollution for the environment and a complication for public health (Biswas, et al., 2014). The continuous loss in quality of most food products from conventional farming is not only felt in the form of taste, appearance, and depth of nutritional value loss (Richter, et al., 2015), it has also been traced to other forms of consequences, such as the occurrence of chronic terminal diseases of late, with virulence,

which, to a degree of fact, are unprecedented and not hereditary (Wimalawansa., 2015). The prevalence of these diseases has been traced to the recent increase in the uptake of synthetic agrochemicals (Sharma et al., 2017). Diseases such as cancer, neural disorders, birth defects, and reproductive and developmental anomalies have been traced to heavy use of some of these chemicals (Baranski et al., 2014). Other diseases such as mutagenicity and other health-related problems have either been directly or indirectly linked to the recent scaling up in the usage of agrochemicals and other yield-inducing technologies (Erhunmwunse, 2012) and (Dabady et al., 2015).

Most consumers naturally grow the urge to crave a sustainable solution, closest indication of these cravings is the unconscious display of acceptance behaviors before acceptance decisions. These are attitudes such as the usual opting for foods with features that indicate they are not products of contaminated farming systems. These consumers are on the lookout for food features such as freshness, tenderness, turgidity, desirable taste, and healthy and attractive coloration. The preference for foods with a history of eco-friendly processes also form part of some of the common behaviors of consumers. Ordinarily, acceptance of any product among consumers is determined by their perception of its benefits (Soroka et al., 2019) and their vulnerability to the threat that the product neutralizes (Morris et al., 2012). It is determined by the financial capability of the consumers. This can be in the form of value attached to the product, as expressed in the amount the consumer is willing to pay relative to a close substitute (Kulikovski et al., 2010). An average low-income earner is likely to judge a product, if it attracts premiums like organic food, as expensive regardless of its benefit to his health or the environment. The value attached to the product here is borne out more by the cost implications of its price on their income than by the perceived benefit of the product. There is then a need to assess the attached

value of a product in a population sample with above-average financial leverage for a premium-attracted product like organic food (Orji et al., 2012). A consumer with sound knowledge, and a positive perception of benefit but with very low purchasing power, will most likely value any expensive product and hence not accept it. Even the few who intended to buy, may not be willing to pay for it.

The extent of knowledge and practices of organic agriculture determines the perception people have of its potential and the advantages of its products. This is because unlike, other food products, organic food carries a premium, which sometimes can go as high as 100% of the price of the same product from conventional farming (Van Loo et al., 2011).

The place of knowledge of the benefits of a product that is either novel or unpopular, like organic food, in food markets is crucial to its acceptance in the face of this premium. Having been confirmed unpopular in the Nigerian market (Mgbenka et al., 2015), it is against the backdrop of the above that this study opines about the need to appraise the pivoting effect of knowledge in the relationship between all the above factors and the acceptance of organic food among consumers. Most important among these is the assessment of the role of this knowledge as to whether it moderates any of these established factors. This assessment is, however, mostly required among segments of the population with a tendency for superior knowledge. Firstly, the effect of the knowledge will possibly diverge among the general population, as most with little or no knowledge will attach a below-threshold value that may not justify the benefit of the product at the decision moment to accept or reject it. Also, the pioneer market for every unpopular product is always among people with an understanding of its advantages. The study therefore opined on the need to investigate the nexus of all the above factors as best among population segments with attributes that capacitate them with

some leverages needed most for the target market. Advantages of not just the ability to pay but also better access to information and superior knowledge about the product. In the context of this study, this is assumed to be a higher educational attainment for researchers and academics in the field of agriculture.

Hypothesis of the study

(Ho) Knowledge of organic food negatively moderates each of the relationships between perceived benefits, attached values, availability, acceptance constraints, and acceptance of organic food, such that an increase in knowledge weakens the above relationship.

The Health Belief Model (HBM), used to explain the acceptance of disease prevention strategies (Jones et al., 2015) (Abraham & Sheeran., 2015) was adopted as a guide. Using the six modular constructs of perceived benefits, perceived barriers, perceived susceptibility, perceived severity, self-efficacy, and cue to action to explain the drivers of health-related behaviors (Becker & Becker, 1974). It is informed by the human desire to avoid a life-threatening situation and the eagerness to quickly escape it if it has already caught up. Then there is the general assertion that certain actions can prevent the occurrence of the situation or cure it (Taylor et al., 2007). It predicts the behavioral acceptance of a health-related product to be a reaction to a series of driving forces. The study filled a theoretical gap by using additional constructs of attached value and availability to complement the fundamental constructs of the HBM, while testing the moderating influence of knowledge of the product under study.

Methodology

The study population is the senior staff of agriculture related education and research institutions in Ibadan metropolis. The list of all the senior academic, scientific and research officers, from grade seven and above, obtained from their staff directory was used as

the sample frame for the study. The first stage of the sampling procedure involved the stratification of the institutions into two (2) categories: the research only institutions and research/educational institutions. The second stage involved the adoption of fifty percent (50%) from each of the two stratified groups of institutions above. This then resulted in the selection of seven (7) research only institutions and four (4) research/education institutions. The selected research only institutions are the National Horticultural Research Institutes, Idi-Ishin, Ibadan (NIHORT), Forestry Research Institutes of Nigeria Jericho Hill, Ibadan (FRIN), National Cereal Research Institutes, Moor Plantation, Ibadan (NCRI), Institute of Agriculture Research and Training Apata, Abeokuta Road, Ibadan (IAR&T), Cocoa Research Institutes of Nigeria, Idi-Ayunre, Ibadan (CRIN), National Center for Genetic Resources and Biotechnology, Moor Plantation, Ibadan (NACGRAB), National Agricultural Extension and Research Liaison Services, Moor Plantation Ibadan (NAERLS). The selected four (4) research/education institutions Federal College of Animal Health and Production Technology, Apata, Ibadan, Federal College of Agriculture, Apata, Ibadan; Faculty of Agriculture, University of Ibadan; Federal College of Forestry, Ibadan; and the Faculty of Natural and Renewable Resources, University of Ibadan. The final stage involved the adoption of the proportional fraction obtained between the population and the calculated sample size (between 7% and 10%) of the senior staff from each of the selected institutions. The study employed the use of structured questionnaires to elicit information on respondents' socioeconomic characteristics, level of awareness and past experiences about organic products, level of knowledge and the perceived benefit of organic products, their availability, and willingness to pay for organic foods. The individual payout level to the premium price for each organic product will be verified. In addition, the questions will be designed to obtain respondents'

comments and suggestions to improve the organic product in the form of constraints they perceive are against its acceptance.

Moderation effect result

The analysis was carried out using Smart PLS software, version 3.0. All path coefficients were estimated using the PLS algorithm and their significance was assessed using bootstrapping with 600 replications at a significance level of 0.05. The interaction effect technique of testing moderation was adopted, as explained by Wu (2020). And as also used by Memon et al. (2019). The type of meditational effect was tested using a two-way interaction graph as used by (Razi et al., 2013)

As indicated in the table below, with knowledge as a moderator on the tested moderation model, a significant moderation effect occurs between organic food availability and organic food acceptance, with a significant direct interaction with acceptance (p-value=0.003, T stat=2.949). The negative value of the unstandardized estimate (-0.443) of the interaction term indicates an inverse influence existing in the relationship when moderated by knowledge. The simple effect of availability on acceptance indicates a value of 0.134. This value indicates that at the average level of respondent knowledge of organics, every unit increase in availability attracts an increase in acceptance of the food by 0.134. Whereas, at a higher level of knowledge a standard deviation unit increase), every unit increase in availability leads to changes in acceptance at the magnitude of the interaction (-0.443), which is calculated as; $0.134 + (-0.443) = -0.309$. This reveals a decrease in acceptance. On the contrary, for a lower level of knowledge, every unit increase in availability changes acceptance of the food by the magnitude of the interaction term, calculated as; $0.134 - (-0.443) = 0.577$, which reveals an increase in acceptance by 0.577. The interpretation of this is that, as the level of knowledge increases, the effect of

availability on organic food acceptability decreases. This suggests that consumers who are more knowledgeable about organic food may not base their acceptance solely on the availability of organic food products. It can also be interpreted to mean that an increase in knowledge level among respondents, inversely moderates the relationship between availability and organic food acceptance. This was observed in a trend of a decrease of -0.309. This can be explained by the loss of trust in the quality of organic food by consumers with good knowledge of its process. This is especially true whenever organic food becomes unexpectedly available. This can be corroborated by the affirmation that knowledge of organics negatively correlates with trust units goodness (Erasmus et al., 2020).

Knowledge also moderated significantly, the relationship between organic food acceptance constraints and organic food acceptance, with a direct interaction with acceptance significant at (P-value=0.001, T stat=2.949). The positive value of the unstandardized estimate (0.25) indicates a direct influence existing in the relationship when moderated by knowledge. The positive coefficient value indicates that as knowledge increases, the effect of organic food acceptance constraints on organic food acceptability increases. This suggests that consumers who are more knowledgeable about organic food may have a better understanding of the constraints associated with organic food, and therefore be more likely to accept organic food despite these constraints.

The simple effect of acceptance constraints on acceptance indicates a value of 0.164. This value indicates that at the average level of respondents' knowledge of organic, every unit increase in acceptance constraints attracts an increase in acceptance of the food by 0.164. Whereas, at a higher level of knowledge (a standard deviation unit increase), every unit increase in acceptance constraints leads to

changes in acceptance at the magnitude of the interaction (0.25), which is calculated as $0.164+0.25 = 0.414$. This is a positive increase in acceptance of 0.414. On the other hand, at a lower level of knowledge, a unit increase in acceptance constraints produces a change in acceptance to the weight of the interaction term, calculated as $0.164-0.25 = -0.086$ to reveal a decrease in acceptance by 0.086. The interpretation to this is that, knowledge directly moderates organic food acceptance among consumers at varying levels of constraint. The moderation, however, is such that, at a high level of knowledge, even when acceptance constraints increase, acceptance still increases by 0.414. On the other hand, at low knowledge levels an increase in acceptance constraints reduces acceptance by 0.086. The implication of this is that, as knowledge of organic increases among the respondents, the effect of acceptance constraints on acceptance becomes weaker. This can be corroborated by the presumed inverse correlation between consumption constraints and knowledge of organic food (Bardhan et al., 2019).

Knowledge also moderated the relationship between perceived nutritional and health benefits on organic food acceptance. The direct interaction with acceptance is significant (P-value=0.05, T stat=1.961). The positive value of the unstandardized estimate (0.34) of the interaction indicates a direct influence existing in the relationship when moderated by knowledge. The positive coefficient value indicates that as knowledge increases, the effect of perceived nutritional and health benefits on organic food acceptability increases. This suggests that consumers who are more knowledgeable about organic food may have a better understanding of the nutritional and health benefits of organic food, and therefore be more likely to accept and appreciate these benefits.

The simple effect of perceived nutrition and health benefits on acceptance on the other hand, indicates a negative value of -0.061. This value indicates that at the

average level of respondent knowledge of organic foods, every unit increase in perceived nutrition and health benefits attracts a decrease in acceptance of the food by 0.061. Whereas, at a higher level of knowledge, every unit increase in perceived nutrition and health benefit leads to changes in acceptance at the magnitude of the interaction (0.34), which is calculated as; $-0.061+0.34 = 0.279$. This reveals an increase in acceptance of 0.279. On the contrary, at a lower level of knowledge, every unit increase in perceived nutrition and health benefit changes acceptance of the food by the magnitude of the interaction term, calculated as; $-0.061-0.34 = -0.401$. This reveals a decrease in acceptance by 0.401. The interpretation of this is that knowledge moderates the relationship between perceived nutrition and health benefits and organic food acceptance among consumers. It does this at a trend of increase of 0.279 in the unit of acceptance for every unit increase in their perception of the food as being nutritional and of health benefit when there is a high level of knowledge. On the other hand, when there is a low level of knowledge organic acceptance decreases by 0.401 for every unit increase in perceived nutrition and health benefits. In another way, this can be explained as follows: with low knowledge of organics, consumers do not perceive the food as being beneficial to them nutritionally and health-wise, such that this perception is rather making them buy less organic when their knowledge is lower. When their knowledge improves, their perception of the nutrition and health benefits of organic food makes them buy it more. This can be corroborated by the positive correlation confirmed to exist between perceived nutrition, health benefits and acceptance of organic food (Magnusson et al., 2003).

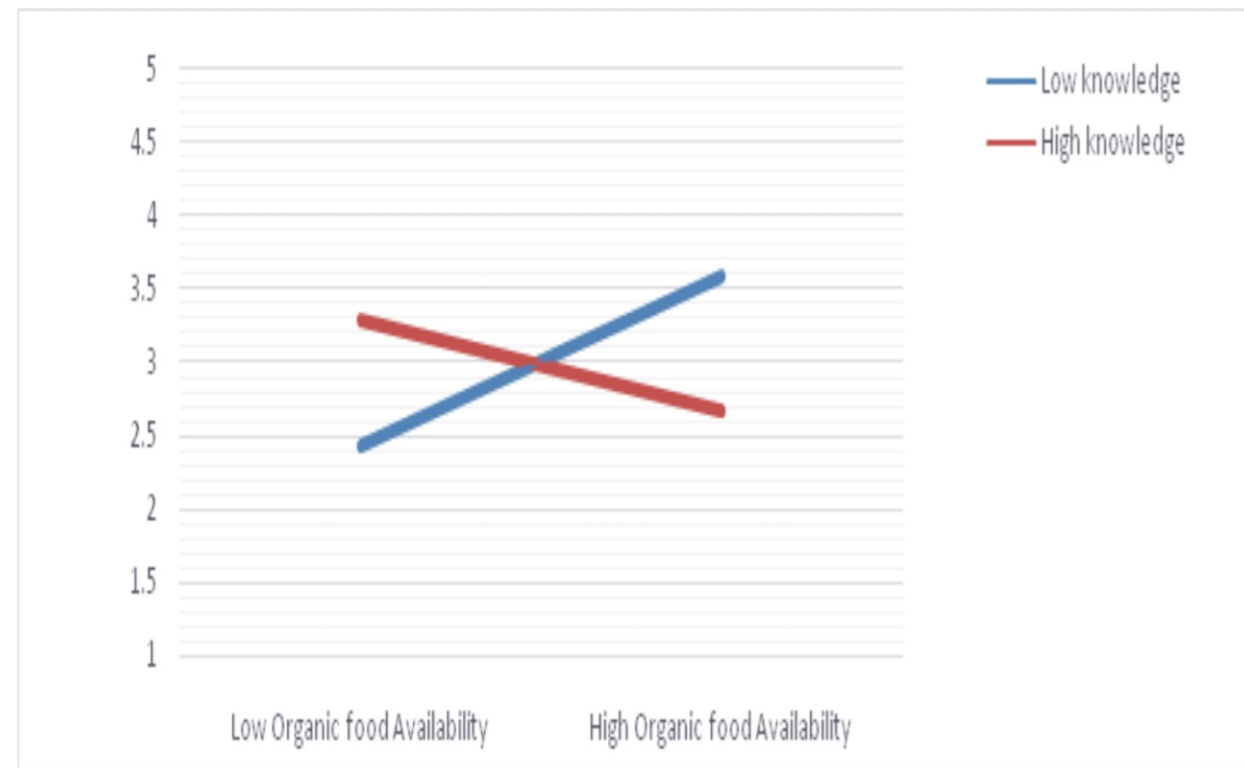
Table 4.5.6.a. The table of the moderation effect of knowledge on the relationships in the research model

Knowledge As A Moderator	Unstandardized Beta coefficient	T Statistics (O/STDEV)	P Values
Attached Value -> Acceptance	0.212	5.227	0.001
Availability -> Acceptance	0.134	3.875	0.001
Constraints -> Acceptance	0.164	4.758	0.001
Environmental benefit -> Acceptance	-0.188	4.194	0.001
Knowledge -> Acceptance	-0.013	0.332	0.74
Mod_Knowledge *Availability -> Acceptance	-0.443	2.949	0.003
Mod_Knowledge*Constraint -> Acceptance	0.25	2.784	0.006
Mod_Knowledge*Nutrition & health benefit -> Acceptance	0.34	1.961	0.05
Nutrition &Health benefit -> Acceptance	-0.061	1.344	0.18

Moderation interaction graphs of knowledge as a moderator for different relationships in the model

To confirm the types of moderation effects identified above to be statistically significant, there is a need to check for the interaction on a two-way moderation interaction graph; as informed by Memon et al., (2019). The Microsoft Excel worksheet used in conducting these slope difference tests was downloaded online at www.jeremydawson.co.uk/slopes.htm 2. Following the procedure used by Dawson et al., (2006), all the possible moderation effects that had earlier been confirmed to be statistically significant for each variable in the research model were tested against each other, and the plotted graphs are shown below.

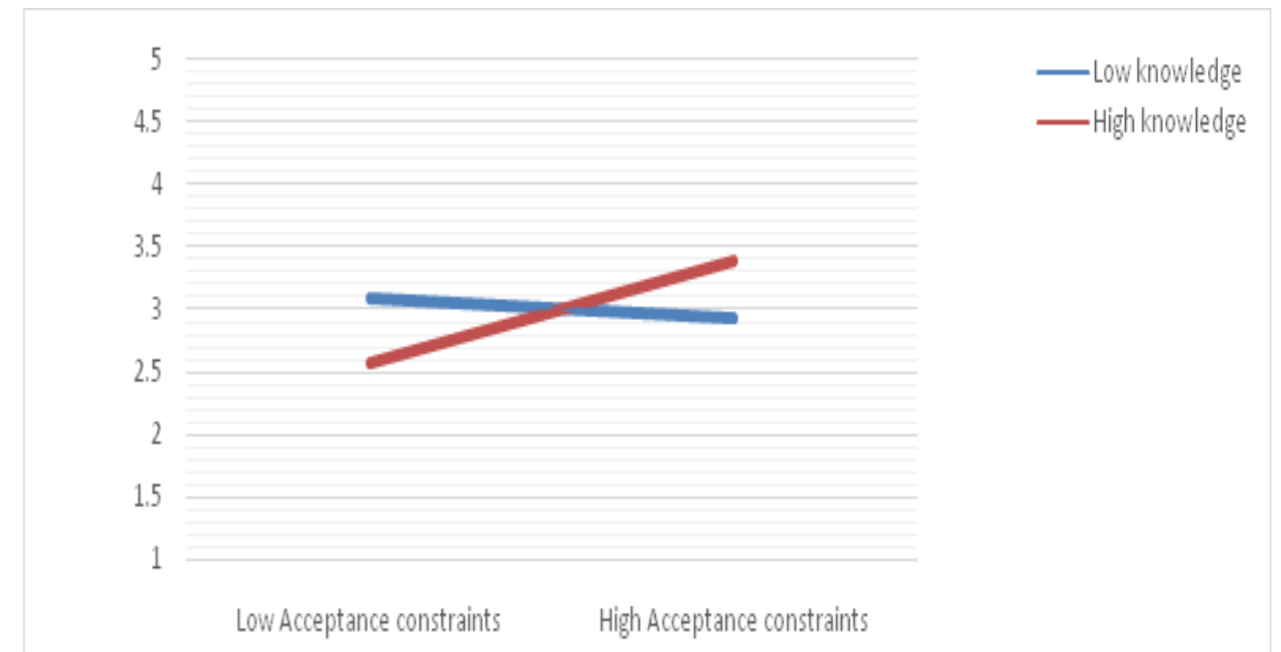
Graph 4.21.: The graph shows the dispersion of the relationship between availability and organic food acceptance, moderated by knowledge of organics



From Graph 4.21 above, it can be observed that the effect of knowledge on the relationship between organic food availability and its acceptance is mixed. Consumers with a low level of knowledge tend to accept organic food more as it becomes more available, while those with high level of knowledge accept it less with higher availability. The possible explanation can be that these consumers with a high knowledge of organic food may have less confidence in the process of organic food production when it floods the market, they

have less trust in new organic farmers turning in more organic product to the market, hence they buy less of the market quantity. This type of moderation effect can be said to be antagonistic moderation (Corraini et al., 2017), as the increase in the moderator leads to a negative association between the independent and dependent variables while the decrease leads to a positive association at the same rate as the dependent variable and with the same gradient to the slope.

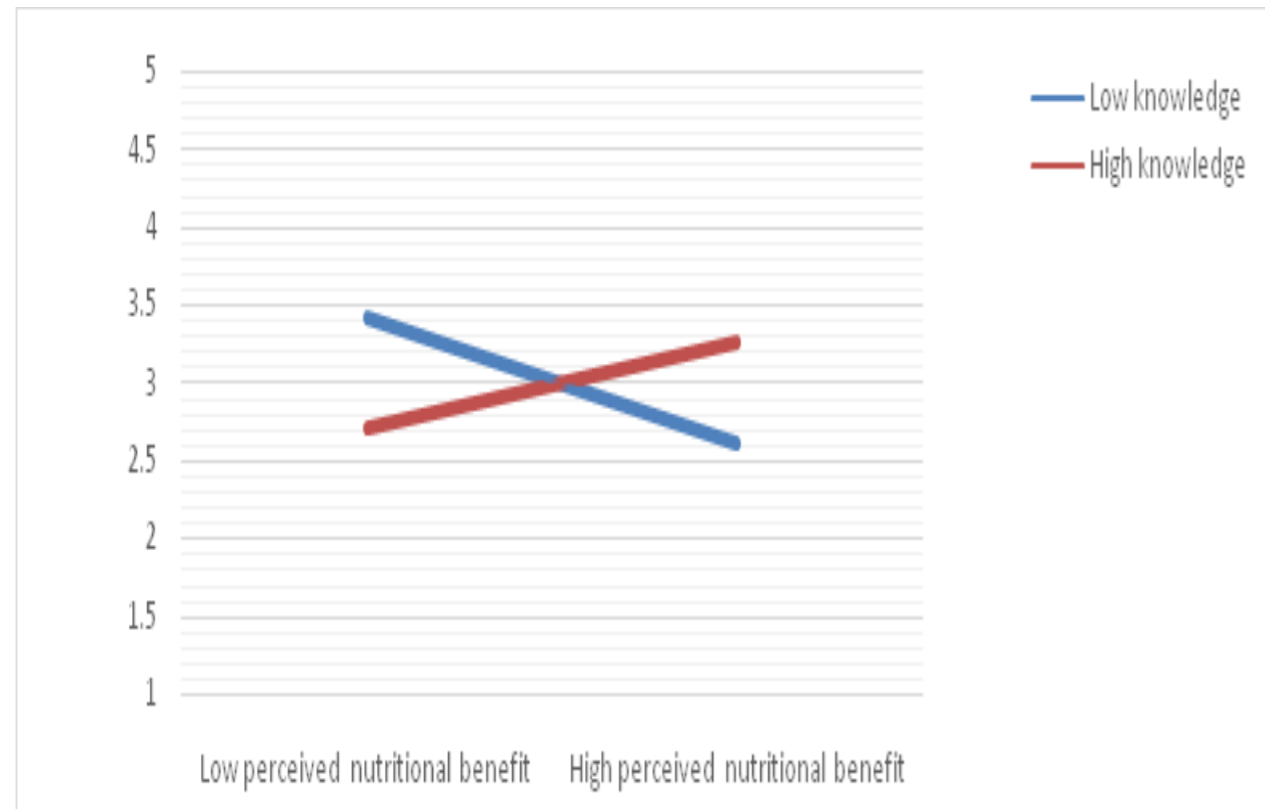
Graph 4.22.: The graph shows the dispersion of the relationship between consumption constraints and organic food acceptance, moderated by knowledge of organics



Graph 4.42 above also provided a similar antagonistic moderation effect (Wu, 2018) of knowledge on changes in perceived level of constraints to the acceptance of organic food. The peculiarity of this scenario is that, the graph revealed that consumers with a high level of knowledge accept organic food more even when the constraints they face in getting it increase, while consumers with a low level of knowledge accept the food less when the constraints, they face in getting it increases. The explanation for this can be traced to availability and high cost as constraints were the highest ranked in the study. And with the study

selecting respondent researchers and academics with above-average income, this is like controlling for knowledge and purchase capability. The majority of the respondents with high knowledge will understandably pay for an organic product that others perceive as expensive. They will have the capacity and network to source it when it is not available, while low-knowledge consumers who probably attach less value to the food will immediately opt for conventional food at a slight perception of excessive price and scarcity.

Graph 4.23.: The graph shows the dispersion of the relationship between perceived nutrition and health benefits and organic food acceptance, moderated by knowledge



Graph 4.23 revealed that knowledge also plays another antagonistic moderation effect on the perceived nutritional and health benefits of consumers and their acceptance of organic food. Consumers with high levels of knowledge increase their acceptance as their perceived nutritional benefit increases while consumers with low level of knowledge reduces their acceptance as their perceived nutritional benefit increases. Hence, a high level of knowledge has a positive effect on the relationship between acceptance and perceived nutritional benefit, just as a low level of knowledge has a negative effect on the relationship between acceptance and perceived nutritional benefit. This, by implication, means that consumers with a high

level of knowledge accept the organic food more as they perceive it been more beneficial to them nutritionally and health-wise. While consumers with low level of knowledge accept organic food less, even as their perception of its nutritional benefits increases. This is probably due to the value they attached to the food by the consumers with a higher level of knowledge.

Summary, Conclusion and Recommendations

The result revealed that knowledge plays a potentially important role in the acceptability of organic food products, particularly in relation to the perceived nutritional and health benefits of these products. By

increasing knowledge and awareness about these benefits, organic food consumers can make more informed decisions, and organic agriculture stakeholders can develop more effective strategies to promote organic food products. In relation to the constraints associated with organic food production and distribution, by increasing knowledge and awareness about these constraints, organic food consumers can make more informed decisions.

Organic food consumers should try to increase their knowledge about organic food by accessing educational resources, attending organic workshops, and using online resources, to understand the benefits of organic food and how it can impact their health and the environment. By doing so, they can make more informed decisions and choose organic food products based on a holistic assessment of the product. Organic agriculture stakeholders should not solely rely on the availability of organic food products as a marketing strategy by assuming their benefits will market them, but should intentionally focus on increasing knowledge and awareness about the benefits of organic food products through the encouragement of advertisement, sponsored exhibition shows, and enlightenment programmes, to create a more informed and

knowledgeable consumer base. They should also emphasize the benefits of organic food products, by emphasizing the specific nutritional and health benefits, and by providing consumers with accurate and up-to-date information about these benefits, despite any identified constraints. This can help to create a more informed and understanding consumer base, which in turn may lead to increased acceptance of organic food.

The study recommends that organic food consumers should strive to increase their knowledge about organic food production practices, including the constraints associated with production, processing and distribution. By doing so, they may have a better understanding of why these constraints exist and be more likely to accept and appreciate the benefits of organic food products. They should also not solely rely on the availability of organic food products in making their purchase decisions. It is important to also consider other factors, such as the nutritional and health benefits, as well as the price and taste of organic food products. This can be done by researching and reading about the specific benefits of organic food, as well as consulting with healthcare professionals and nutritionists who can provide expert advice on the subject.

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Efficacy of *Bacillus thuringiensis* var *kurstaki* AS A BIOPESTICIDE OF LEPIDOPTEROUS INSECT PESTS OF OKRA (*Abelmoschus esculentus* (L.) Moench)

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Abstract

Field evaluation of *Bacillus thuringiensis* var *kurstaki* on Okra seedlings was conducted during the early and late seasons of 2015 in a randomized complete block design with three replicates at the Teaching and Research Farm, University of Ibadan, Nigeria. *Bacillus thuringiensis* var *kurstaki* (LIPEL) at the rate of 1.0, 1.5 and 2.0g/L of water, Lambda-cyhalothrin+dimethoate, a synthetic insecticide at the rate of 3ml/L of water as a standard check, and a control (1L of water only), were applied to okra seedlings at weekly intervals from flowering stage to harvest. Insect fauna on okra plant was sampled using a sweep net and hand capture. Data on fruit yield and damage by lepidopterous and non-lepidopterous pests were recorded at each harvest. Data were analysed using descriptive statistics, ANOVA at $p < 0.05$ and PAST Software version 3.11. Insect species were evenly distributed among the *Bacillus thuringiensis* treated plants which is in contrast to the Lambda-cyhalothrin+dimethoate treated plants five days after treatments application on Okra during this period. The highest percentage of damaged fruits by lepidopterous larvae was recorded in the control (32.3%). In comparison, the least were recorded on *Bacillus thuringiensis* at 2.0g/L plots (1.8%), but it was not significantly different ($p < 0.05$) from synthetic plots (3.7%). *Bacillus thuringiensis* at 1g/L (30.2%) and 1.5g/L (9.5%) lowered fruit damage but were not significantly different from the control (32.3%). Plants treated with the synthetic insecticide resulted in the least percentage of fruit damaged by both lepidopterous and non-lepidopterous insects (12.30%) but were not significantly different from *Bacillus thuringiensis* at 1.5g/L (28.67) and 2.0g/L (12.5%).

Bacillus thuringiensis at 2.0g/L effectively reduced okra fruit damage and larval populations and was compared favourably with the synthetic insecticide. *Bacillus thuringiensis* treated plots encouraged diversity of insect species and enhance biodiversity in the okra cropping system.

Keywords: Okra, *Bacillus thuringiensis*, Biopesticide, Teaching and Research Farm

EFFICACITÉ DU *Bacillus thuringiensis* var *kurstaki* EN TANT QUE BIOPESTICIDE CONTRE LES INSECTES RÉPONDANTS À LA FAMILLE DES LÉPIDOPTÈRES NUISIBLES À L'OKRA (*Abelmoschus esculentus* (L.) Moench)

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Résumé

Une évaluation sur le terrain du *Bacillus thuringiensis* var *kurstaki* sur des semis d'okra a été menée au début et à la fin de la saison 2015 dans le cadre d'un plan en blocs aléatoires complets avec trois répétitions à la ferme d'enseignement et de recherche de l'université d'Ibadan, au Nigeria. Le *Bacillus thuringiensis* var *kurstaki* (LIPEL) à raison de 1,0, 1,5 et 2,0 g/L d'eau, la lambda-cyhalothrine + diméthoate, un insecticide synthétique à raison de 3 ml/L d'eau comme contrôle standard, et un témoin (1 L d'eau uniquement), ont été appliqués sur les semis d'okra à intervalles hebdomadaires, du stade de floraison à la récolte. La faune insecte présente sur les plants d'okra a été échantillonnée à l'aide d'un filet fauchoir et d'une capture manuelle. Les données sur le rendement en fruits et les dommages causés par les ravageurs lépidoptères et non lépidoptères ont été enregistrées à chaque récolte. Les données ont été analysées à l'aide de statistiques descriptives, d'une ANOVA à $p < 0,05$ et du logiciel PAST version 3.11. Les espèces d'insectes étaient réparties de manière uniforme parmi les plantes traitées au *Bacillus thuringiensis*, contrairement aux plantes traitées à la lambda-cyhalothrine + diméthoate cinq jours après l'application des traitements sur les gombos pendant cette période. Le pourcentage le plus élevé de fruits endommagés par les larves de lépidoptères a été enregistré dans le groupe témoin (32,3 %). En comparaison, le pourcentage le plus faible a été enregistré dans les parcelles traitées avec *Bacillus thuringiensis* à 2,0 g/L (1,8 %), mais il n'était pas significativement différent ($p < 0,05$) de celui des parcelles synthétiques (3,7 %). Le *Bacillus thuringiensis* à 1 g/L (30,2 %) et 1,5 g/L (9,5 %) a réduit les dommages causés aux fruits, mais sans différence significative par rapport au témoin (32,3 %). Les plantes traitées avec l'insecticide synthétique ont présenté le pourcentage le plus faible de fruits endommagés par les insectes lépidoptères et non lépidoptères (12,30 %), mais cette différence n'était pas significative par rapport au *Bacillus thuringiensis* à 1,5 g/L (28,67) et 2,0 g/L (12,5 %).

Le *Bacillus thuringiensis* à 2,0 g/L a efficacement réduit les dommages causés aux fruits d'okra et les populations de larves, et a été comparé favorablement à l'insecticide synthétique. Les parcelles traitées au *Bacillus thuringiensis* ont favorisé la diversité des espèces d'insectes et amélioré la biodiversité dans le système de culture de l'okra.

Mots-clés: Okro, *Bacillus thuringiensis*, Biopesticide, Ferme d'enseignement et de recherche

Introduction

Okra, *Abelmoschus esculentus* (L.) Moench is an economically important vegetable crop that belongs to the family Malvaceae (Omotoso et al., 2018). The crop originated from tropical Africa and was first cultivated by the Egyptians in the 12th century AD (Benchasvi, 2012). Okra is widely cultivated throughout the tropics, subtropics, and warmer parts of the temperate regions (Komolafe et al., 2021). It is known in various names as okra, okro, bhindee, lady's fingers and quinbambo (Remisonet al., 2005). India is the largest okra

producer, producing 4.18 million tons annually (70% of the total world production) from 0.35 m/ha area (FAOSTAT, 2020). Over the years, okra production in Nigeria has increased due to its nutritional value and about 1.9 million tons of okra is produced per year in Nigeria. (FAOSTAT, 2020).

Okra is also an important vegetable crop in Nigeria (Umeriet al., 2023). The crop is quite popular due to its easy cultivation, dependable yield, adaptability to varying moisture conditions (resistant to drought and waterlogging), and soil types. Successful production

has also been recorded in China, Thailand, Egypt, South Africa, Cyprus, Brazil and the Caribbean (Sreenivasa et al., 2010).

The economic importance of okra cannot be overemphasized; all the plant parts are useful (Farinde et al., 2007). Okra plants are mainly cultivated throughout the world for their tender pods. Its tender fruits are very popular as a vegetable among all classes of people around the world (Talukder et al., 2003). It can be preserved by freezing or canning as it is done in the United States of America (Spivey et al., 1957). Fresh leaves can be used as spinach in soups, while seeds are said to be good sources of oil (Oyolu, 1977; Umeri et al., 2023). Okra plays an important role in regulating of blood sugar thereby preventing diabetics (Ngok et al., 2008). It is a nutritious, rich vegetable which provides an important source of carbohydrates, protein, vitamins A, B1 and C, calcium, potassium, dietary fibre, and minerals; hence it plays a vital role in the human diet (Rashwan, 2011). Young, immature pods are important fresh fruit vegetables that can be consumed in many different forms; raw, steamed, boiled or fried (Farinde et al., 2007). Okra's medicinal value has also been reported in curing ulcers and relief of haemorrhoids and other ailments (Adams, 1975).

Despite its importance, many pests have been reported to attack the crop at different stages of growth (Dabire-Binso et al., 2009, Echezona et al., 2010). They include species that damage the foliage, shoots, flowers and pods. Janet et al. (2022) also reported that Okra has a wide range of lepidopterous pests and the most important are *Syleptaderogata* (Fallen), *Anomisleona* (Schaus), *Heliothis armigera* Hubner, *Spodoptera littoralis* (Fallen), *Eariasinsulana* Boisduval and *E. biplaga*.

A number of chemical insecticides have been reported to be effective against these pests (Ahmed et al., 2021). However, the excessive use of the insecticides is not desirable because of residual effects on harvested fruits and also there is a possibility of their accumulation in

food chains. Keeping these facts in view, emphasis is shifting toward environment friendly control tactics, such as the use of bio-control agents, which fit well in pest management programmes.

LIPEL™ is a biological pesticide (biopesticide) based on a selected strain of naturally-occurring beneficial soil bacterium, *Bacillus thuringiensis* var *Kurstaki* that protects crops from several insect pests belonging to Orders Lepidoptera (moths and butterflies), Diptera (flies and mosquitoes), Coleoptera (beetles) and Hymenoptera (wasps, bees, ants and sawflies). It is used as an effective foliar spray. LIPEL™ contains endospores of *Bacillus thuringiensis* var *Kurstaki*. It is formulated as 18,000 IU/mg Wettable Powder Formulation. LIPEL™ is registered by Indian Pesticides Regulatory Authority - Central Insecticides Board, Govt of India. It is produced by AgriLife BioSolutions for Soils and Crops. LIPEL™ is approved for use in organic agriculture. Therefore, the efficacy of *Bacillus thuringiensis* as biopesticide of lepidopterous insect pests of okra, was investigated.

MATERIALS AND METHODS

Study location and source of okra seeds

The Field experiment was carried out at the Teaching and Research Farm of the University of Ibadan, Nigeria. Plots were laid out in a randomized complete block design with three replications. Okra seeds, Clemson Spineless variety used for the experiment were sourced from Premier Seeds, Jericho, Ibadan. The first field experiment was carried out between March and June and the second trial was between July and October.

Cultural practices and treatments applications

The land (18m by 12m) was cleared, ploughed, harrowed and shaped into beds (2m by 2m) and a total of 15 beds were made. The Okra seeds, Clemson spineless variety, were sown directly on beds that were 30cm high. Three seeds were sown per hole at 50cm

between rows and 40cm within row, and later thinned to one in each bed (consisting of 5 rows and 6 plants per row, giving a plant population density of 30 plants/bed). Supplying was done within 3 weeks of first sowing. Weeding of the field was carried out using hoe and okra plot. Each bed was spaced at 1m apart to ease movement during cultural practices and data collection. Also to prevent treatment drift, a border of 2m was maintained.

Five sprays of each treatment (*B. thuringiensis var kurstaki* (LIPEL) at the rate of 1.0, 1.5 and 2.0g/L of water, Lambda-cyhalothrin+dimethoate, a synthetic insecticide at the rate of 3ml/L of water as standard check, and a control [1L of water only] were applied to okra seedlings at weekly intervals from the onset of flowering until the end of harvesting. The treatments at the different dosages were applied by using hand sprayer.

Field survey for abundance and diversity of insects associated with okra after application of treatments

The survey involved collection and identification of insect pests associated with *Abelmoschus esculentus* grown in Ibadan, Southwest Nigeria. In this study, two methods of insects trapping were employed after application of treatments, namely, visual counting was used hand capture for wingless insects, aerial sweep net for flying insects.

Six okra plants tagged at the central row of each treatment were observed weekly, and insects found on them were collected. Sampling of insects was done generally on all beds (treatments) a week before the application of treatments and five days thereafter. Observations were conducted and sampling done from 6.00 am to 9.00am to coincide with the time of day when insects remain less active. Insects encountered were carefully collected into labelled glass vials containing ethyl acetate.

The numbers of insects collected on okra plants treated with the various treatments at different sampling periods using the different sampling techniques were pooled according to their species and the diversity indices calculated.

Insect Identification

All samples of adult insect collected were identified at the Insect Reference Collection Centre of the Department of Crop Protection and Environmental Biology, University of Ibadan. Taxonomic keys and comparison of morphological characteristics of specimens with insect paratypes were done. Hand lens as well as light microscope was used for identification. Larvae collected were identified using key to identification of larvae according to Treadwell (1996) and Key to the identification of *Helicoverpa armigera* Passoa (2014). Thereafter, the insects were prepared and mounted in insect boxes.

Effect of application of *Bacillus thuringiensis* on fruit damage and fruit yield of okra

Fruit damage and fruit yield data were recorded from six okra plants at the central row (50 cm spacing) of each treatment. Data on fruit damage and fruit yield were recorded at each harvesting. Cumulative yield of each harvest were recorded in grams and transformed to kilogram per hectare according to Asante et al., 2001. Fruits from the harvests were evaluated; fruit were first inspected for external damage (by both lepidopterous and non lepidopterous insects) and then cut open to determine presence of lepidopteran larvae or damage and then separated into damaged, undamaged and lepidopteran larvae damaged fruits depending on the presence or absence of feeding punctures on the fruits; the presence of clean cut round circular holes, presence of larva and or its excreta. The percentage fruit damaged by both lepidopterous and non lepidopterous insects was calculated on the total number of fruits harvested. To stabilize the variance, all count data on

the insect pests and yield were transformed using the square root transformation while percentage data were transformed with angular transformation (arcsine) before statistical analysis. The data obtained were analyzed using descriptive statistics, analysis of variance (ANOVA) and standard diversity indices. Significant means were separated using Duncan's Multiple Range Test, DMRT at $P < 0.05$.

RESULTS

Diversity of Insect fauna on okra Plants

The species of insects collected on okra plants in both seasons belonged to seven orders namely, Coleoptera, Diptera, Hemiptera, Lepidoptera, Orthoptera, Odonata and Hymenoptera (Table 1). *Podagrica jostedti* and *Podagrica uniformafed* on the leaves, the larva of lepidopterous insects fed on flowers, leaves and later bored into the fruit. The hemipterans were mainly fruit

feeders and sap suckers. The nymphs and adults of the variegated grasshopper, *Zonocerus variegatus* (L.), caused extensive defoliation to okra plants, while beneficial insects like *Apis mellifera* (honey bee), wasp and dragon flies were found on the plants.

Insects associated with *Abelmoschus esculentus* during the field trials between March and October, 2015 is presented in Table 2, even though they varied among treatments. The most abundant insect species across all treatments was *Dysdercus* spp followed by *Hymenarecurvalis* in the first season while *Podagrica jostedti*, *Podagrica uniforma*, *Campotonussp* and *Aphis gossypii* were the most abundant during the second season in which most of the insects were found to be in the control where there was no insecticide application

Table 1: Insects associated with okra in Teaching and Research Farm, University of Ibadan during early and late seasons of 2015.

Early season, 2015			
Order	Family	Species	Damage/Remark
Coleoptera	Chrysomelidae	<i>Podagrica uniforma</i>	Feeds on leaves
	Chrysomelidae	<i>Podagrica jostedti</i>	Feeds on leaves
	Chrysomelidae	<i>Cryptocephalus gladiatorius</i>	Defoliator
Hemiptera	Pyrrhocoridae	<i>Dysdercus superstitionis F.</i>	Sucks Sap
	Pentatomidae	<i>Nezara viridula</i>	Sucks Sap
	Reduviidae	<i>Rhynocovissp.</i>	Vagrant
	Coreidae	<i>Cletomorpha unifasciata</i>	Vagrant
	Lygaeidae	<i>Graptostethus spp</i>	Vagrant

Lepidoptera	Noctuidae	<i>Helicoverpa armigera</i>	Fruitborer
	Noctuidae	<i>Eariasspp</i>	Vagrant
	Acraeidae	<i>Acraepentapoois</i>	Vagrant
	Pyralidae	<i>Hymenia recurvalis</i>	Defoliator
	Pyralidae	<i>Psara bipunctalis</i>	Defoliator
	Danaidae	<i>Palymnasalcippus</i>	Vagrant
Orthoptera	Acrididae	<i>Cantantopsmelanostictus</i>	Defoliator
	Mantidae	<i>Spodromantis lineola</i>	Beneficial
	Pyrgomorphidae	<i>Zonocerus variegatus</i>	Defoliator
Odonata	Aeshnidae	<i>Austroaeschna inermis</i>	Beneficial
Hymenoptera	Apidae	<i>Apis mellifera</i>	Beneficial
	Vespidae	<i>Belonogaster pusillus</i>	Beneficial

Late season 2015

Order	Family	Species	Damage/Remark
Coleoptera	Coccinellidae	<i>Cheilomeneshunata</i>	Beneficial
	Chrysomelidae	<i>Podagricasjosdeti</i>	Defoliator
	Chrysomelidae	<i>PodagricasUniforma</i>	Defoliator
Diptera	Muscidae	<i>Musca sp</i>	Vagrant
Hemiptera	Aphididae	<i>Aphis gossypii</i>	Sucks Sap
	Pyrrhocoridae	<i>Dysdercussuperstitiosus</i>	Sucks Sap
	Pentatomidae	<i>Halyomorphaannulicornis</i>	Sucks Sap
	Reduviidae	<i>Phonoctonus</i>	Beneficial
Hymenoptera	Formicidae	<i>Campotonussp</i>	Vagrant
	Apidae	<i>Apis mellifera</i>	Beneficial
Lepidoptera	Noctuidae	<i>Eariasspp</i>	Defoliator
Odonata	Aeshnidae	<i>Austroaeschna inermis</i>	Vagrant
Orthoptera	Acrididae	<i>Cantantopsmelanostictus</i>	Defoliator

Table 2: Abundance of insects associated with *Abelmoschus esculentus* during the early and late season of 2015 in Ibadan.

Insectspecies	Early season				
	Mean±SD of insects per plant				
	Control	Synthetic	Bt1g/L	Bt1.5g/L	Bt2g/L
<i>Podagricasuniforma</i>	1.33±0.58b	0.33±0.58a	0.67±0.58a	0.33±0.58a	0.00±0.00a
<i>Podagricasjostedi</i>	0.67±0.58a	0.00±0.00a	0.00±0.00a	0.67±0.58a	0.00±0.00a
<i>Cryptocephalusgladiatorius</i>	0.00±0.00a	0.00±0.00a	0.33±0.58a	0.33±0.58a	0.00±0.00a
<i>Dysdercus superstitiosus F.</i>	2.33±0.58c	0.33±0.58a	1.33±0.58b	1.00±0.00ab	1.00±0.00ab
<i>Nezara viridula</i>	0.67±0.58b	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
<i>Rhynocovis Carmelita</i>	0.33±0.58a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
<i>Cletomorphaunifasciata</i>	0.33±0.58a	0.00±0.00a	0.33±0.58a	0.00±0.00a	0.00±0.00a
<i>Graptostethusspp</i>	0.33±0.58a	0.00±0.00a	0.33±0.58a	0.00±0.00a	0.00±0.00a
<i>Helicoverpa armigera</i>	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
<i>Eariasspp</i>	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a	0.00±0.00a
<i>Acraepentapoois</i>	0.67±0.58a	0.33±0.58a	0.67±0.58a	0.00±0.00a	0.33±0.58a
<i>Hymenia recurvalis</i>	2.33±0.58b	0.67±0.58a	1.00±0.00a	0.67±0.58a	0.67±0.58a
<i>Psara bipunctalis</i>	2.00±0.00b	0.00±0.00a	0.33±0.58a	0.33±0.58a	0.00±0.00a
<i>Palymnasalcippus</i>	0.67±0.58a	0.33±0.58a	0.67±1.15a	0.33±0.58a	0.67±0.58a
<i>Cantantopsmelanostictus</i>	1.00±0.00b	0.67±0.58ab	0.67±0.58ab	0.33±0.58ab	0.00±0.00a
<i>Spodromantis lineola</i>	1.00±0.00a	0.00±0.00a	0.67±1.15a	0.00±0.00a	0.67±1.15a
<i>Zonocerus variegates</i>	2.67±0.58c	0.33±0.58ab	1.00±0.00a	0.33±0.58a	0.33±0.58a
<i>Austroaeschna inermis</i>	0.33±0.58a	0.00±0.00a	0.33±0.58a	0.33±0.58a	0.00±0.00a
<i>Apis mellifera</i>	0.67±1.15a	0.00±0.00a	0.33±0.58a	0.33±0.58a	0.00±0.00a
<i>Belonogaster pusillus</i>	0.67±0.58a	0.00±0.00a	0.33±0.58a	0.00±0.00a	0.00±0.00a
Insectspecies	Late season				
	Mean±SD of insects per plant				
	Control	Synthetic	LIPEL 1g/L	LIPEL 1.5g/L	LIPEL 2g/L
<i>Aphis gossypii</i>	2.67±1.15b	1.00±0.00a	2.67±0.58b	2.33±0.58b	2.00±0.00ab
<i>Austroaeschna inermis</i>	0.33±0.58a	0.00±0.00a	0.00±0.00a	0.33±0.58a	0.00±0.00a
<i>Eariasspp</i>	0.00±0.00a	0.00±0.00a	0.33±0.58a	0.00±0.00a	0.00±0.00a

<i>Musca sp</i>	0.67±0.58a	0.33±0.58a	0.67±0.58a	0.33±0.58a	0.33±0.58a
<i>Podagricauniforma</i>	2.67±0.58b	1.33±0.58a	4.33±0.58c	2.00±0.00ab	2.00±0.00ab
<i>Podagricasjosdeti</i>	5.33±0.58b	2.33±0.58a	3.00±0.00a	3.00±0.00a	2.67±0.58a
<i>Apis mellifera</i>	0.00±0.00a	0.67±0.58b	0.00±0.00a	0.00±0.00a	0.00±0.00a
<i>Campotonusspp</i>	3.67±0.58b	1.67±0.58a	3.00±0.00b	3.33±0.58b	1.00±0.00a
<i>Cantatopsspp</i>	0.00±0.00a	0.00±0.00a	0.67±0.58a	0.67±0.58a	0.33±0.58a
<i>Chelomonasspp</i>	0.67±0.58a	0.00±0.00a	0.67±0.58a	0.33±0.58a	0.67±0.58a
<i>Dysdercusspp</i>	1.33±0.58a	0.67±0.58a	1.33±0.58a	1.00±0.00a	1.00±0.00a
<i>Halyomorphaanmulicornis</i>	0.67±0.58a	0.00±0.00a	0.67±0.58a	0.00±0.00a	0.00±0.00a
<i>Phonoctonusspp</i>	1.33±0.58b	0.00±0.00a	0.67±0.58ab	0.67±0.58b	0.67±0.58abc

Means ± standard deviation within the same row followed by the same letter(s) are not significantly different at P < 0.05 using Duncan's New Multiple range test; number of replicates = 3, Bt = *Bacillus thuringiensis*

Table 3: Abundance of insect by orders associated with *Abelmoschus esculentus* five days after application of treatments during both seasons in Ibadan.

Early season						
Treatments	Coleoptera	Hemiptera	Lepidoptera	Orthoptera	Odonata	Hymenoptera
Control	4.00±1.00b	4.00±2.65b	5.67±1.53b	4.67±0.58d	0.33±0.58a	1.33±1.53a
Synthetic	2.33±0.58a	0.33±0.58a	1.33±1.53a	1.00±1.00abc	0.00±0.00a	0.00±0.00a
Bt1g/L	3.00±1.00ab	2.00±1.00ab	2.67±1.15a	2.33±1.53b	0.33±0.58a	0.67±1.15a
Bt1.5g/L	3.33±0.58ab	1.00±0.00a	1.33±1.53a	0.67±1.15a	0.33±0.58a	0.33±0.58a
Bt2g/L	2.00±1.00a	1.00±0.00a	1.67±1.53a	1.00±1.73ab	0.00±0.00a	0.00±0.00a

Late season							
TRT	Coleoptera	Diptera	Hemiptera	Hymenoptera	Lepidoptera	Odonata	Orthoptera
Control	8.67±0.58c	0.67±0.58a	6.67±0.58c	3.33±0.58b	0.00±0.00a	0.33±0.58a	0.00±0.00a
Synthetic	3.67±0.58a	0.33±0.58a	2.00±0.00a	1.67±0.58a	0.00±0.00a	0.00±0.00a	0.00±0.00a
Bt1.5g/l	5.33±0.58b	0.33±0.58a	4.33±0.58b	3.33±0.58b	0.00±0.00a	0.33±0.58a	0.67±0.58a
Bt1g/l	8.00±0.00c	0.67±0.58a	6.00±0.00c	3.00±0.00b	0.33±0.58a	0.00±0.00a	0.67±0.58a
Bt2g/l	5.33±0.58b	0.33±0.58a	4.67±0.58b	1.00±0.00a	0.00±0.00a	0.00±0.00a	0.33±0.58a

Means ± standard deviation within the same column followed by the same letter(s) are not significantly different at P < 0.05 using Duncan's New Multiple range test; number of replicates = 3, Bt = *Bacillus thuringiensis*

In both seasons, the summary of species diversity five days after application of treatments obtained from Palentological statistical software(PAST) (Hammer et

al., 2001). Table 4 revealed that the number of insects species found on each tomato plot (Taxa_S). The total number of individuals of all insect species found was higher in the plots treated with *B. thuringiensis* than in the Lambda cyhalothrin + dimethoate treated plots. There was no dominating species on the tomato field (Dominance_D). Even distribution of all species was recorded throughout the field trials.

Table 4: Diversity indices of insects associated with *Abelmoschus esculentus* five days after application of treatments during early and late seasons of 2015 in Ibadan.

	Early season					Late season				
	Control	Synthetic	Bt1g/L	Bt1.5g/L	Bt2g/L	Ctrl	Synth	Bt1g/L	Bt1.5g/L	Bt2g/L
Taxa_S	17	7	15	15	11	10	6	11	10	10
Individuals	54	9	27	34	20	58	22	54	42	34
Dominance_D	0.08916	0.1605	0.08368	0.0917	0.11	0.1635	0.2149	0.1481	0.1621	0.1453
Simpson_1-D	0.9108	0.8395	0.9163	0.9083	0.89	0.8365	0.7851	0.8519	0.8379	0.8547
Shannon_H	2.599	1.889	2.59	2.533	2.303	2.004	1.641	2.1	1.994	2.089
Evenness_e^H/S	0.7908	0.9448	0.8883	0.8394	0.9091	0.7421	0.8603	0.7424	0.7344	0.8073

Bt = *Bacillus thuringiensis*

Insect damage to fruit of okra

During the early season, there were no significant differences in the total fruit weight among the control (5997.0kg/ha), the synthetic insecticide (5483.6kg/ha) and *Bacillus thuringiensis* at 2g/L (6,207.3kg/ha) and 1g/L (5174.7kg/ha), however 1.5 g/L showed a significant reduction in the weight of fruit (4316.5kg/ha) harvested (Table 5). Plants treated with synthetic insecticide resulted in the least percentage of fruit damaged (12.30%) but was not significantly different from *Bacillus thuringiensis* at 1.5 (28.67%) and 2g/L (12.5%). Plants treated with 1g/L of *Bacillus*

thuringiensis had low percentage fruit damage (39.4%) as compared to the untreated control but it was not significantly different from the untreated control (43.4%). Also, the highest larval damaged fruit was recorded on the control (32.3%) but it was not significantly different from *Bacillus thuringiensis* at 1g/L (30.2%) and *Bacillus thuringiensis* at 1.5g/L (9.5%). The least larval damaged fruits were recorded on *Bacillus thuringiensis* at 2g/L plots (1.8%) but it was not significantly different from the synthetic plots (3.7%).

During the late season, there were no significant differences in the total fruit weight among the control (6325.04kg/ha), the synthetic insecticide (6489.83kg/ha) and *Bacillus thuringiensis* at 1g/L (6524.08kg/ha) and 1.5g/L (7930.38kg/ha) and 2 g/L (7886.67kg/ha) (Table 5). Plants treated with synthetic insecticide resulted in the least percentage of fruit damaged (5.45%). *Bacillus thuringiensis* at 1g/L

(30.03%), 1.5g/L (20.66%) and 2g/L (18.89%) lowered fruit damage when compared to the control and were not significantly different from each other. Plants treated with 1g/L of *Bacillus thuringiensis* had lower percentage fruit damage (30.03%) as compared to the untreated control but it was not significantly different from the Control (45.29%). However, no larva damaged fruits were observed in the second season.

Table 5: Effect of *Bacillus thuringiensis* on levels of damage caused by the various insect pests on the yield of okra during both seasons in Ibadan.

Early season			
Treatment	Total fruit weight (kg/ha)	Total fruit damaged (%)	Total larva damaged fruit (%)
Control	5997.0±16.29b	43.3±14.32b	32.3±6.79b
Lambda cyhalothrin + dimethoate	5483.6±11.69ab	12.3±11.38a	3.7±6.42a
Bt 1g/L	5174.7±15.62ab	39.4±14.32b	30.2±14.55b
Bt1.5g/L	4316.5±2.08a	28.6±14.29ab	9.5±8.25ab
Bt2g/L	6207.3±18.82b	12.5±3.07a	1.8±3.04a
Late season			
Treatment	Total fruit weight (kg/ha)	Total fruit damaged (%)	
Control	6325.04±79.53a	45.29±14.43c	
Lambda cyhalothrin + dimethoate	6489.83±80.56a	5.45±6.99a	
Bt (1g/L)	6524.08±80.77a	30.03±6.03bc	
Bt (1.5g/L)	7930.38±89.05a	20.66±3.53b	
Bt (2g/L)	7886.67±88.81a	18.89±8.29b	

Means ± standard deviation within the same column followed by the same letter(s) are not significantly different at $P < 0.05$ using Duncan's New Multiple range test; number of replicates = 3, Bt = *Bacillus thuringiensis*

Larva population of lepidopterous pest on the fruit of okra plant

In the early season trial, synthetic insecticide, *Bacillus thuringiensis* at 1.5g/L and 2g/L caused a significant reduction in the number of larvae per plant when

compared to the control but there was no significant reduction in the mean number of larvae between 1g/L of *Bacillus thuringiensis* and the Control (Table 6). However no larvae damaged fruit were recorded in the second season.

Table 6: Effect of insecticides on the larvae population of lepidopteran pest on okra in early season in Ibadan.

Treatment	Mean no of larvae in fruit	
	<i>Helicoverpa armigera</i>	<i>Eariaspp</i>
Control	1.3±0.58b	1.3±1.15b
Lambda cyhalothrin + dimethoate	0.0±0.00a	0.0±0.00a
Bt1g/L	1.3±0.58b	0.3±0.58ab
Bt1.5g/L	0.0±0.00a	0.0±0.00a
Bt2g/L	0.0±0.00a	0.0±0.00a

DISCUSSION

Indiscriminate use of chemical insecticides for the managing insect pests has generated many problems like development of insecticide resistance (Saini and Chopra, 1988), human health hazards, destruction of the beneficial fauna, resurgence of minor pests, and environmental pollution (Alabi et al., 2003). Microbial pesticides are ecologically safe making them more acceptable for pest management.

The species of insects collected on okra plants from this study belong to seven orders namely, Coleoptera, Diptera, Hemiptera, Lepidoptera, Orthoptera, Odonata and Hymenoptera. Both species of *Podagrica* fed on the leaves, the larvae of lepidopterous insects fed on flowers, leaves and later bored into the fruit. The hemipterans were mainly fruit feeders and sap suckers. The nymphs and adults of the variegated grasshopper, *Zonocerus variegatus* (L.), caused extensive defoliation to okra plants. Also beneficial insects like *Apis mellifera* (honey bee), wasp and dragon flies were

found on the plants. The most abundant insect species across all treatments was *Dysdercus* spp, followed by *Hymeniarcurvalis* and most of the insect were found to be in the control where there was no insecticide application.

The species diversity indices five days after application of treatments revealed that the insect diversity were not destabilized in plots treated with *B. thuringiensis* unlike the synthetic insecticide plot. This confirms that *B. thuringiensis* supports the presence of natural enemies and biodiversity. Truter et al. (2014) and Reyes et al. (2004) reported that insect diversity was not affected on *B. thuringiensis* treated crops.

B. thuringiensis at various levels and the synthetic insecticide was not effective in improving the yield of okra. This could be as a result the time of application of treatments. This is in contrast to Obeng and Sackey (2003) that said *B. thuringiensis* at 1g/L improved the yield of okra when compared to non *B. thuringiensis*

treated plots. This may be attributed to the pest complex of okra and also the stage at which the treatments were sprayed.

Nevertheless, *B. thuringiensis* (LIPEL) was effective in reducing the total lepidopterous larvae damaged fruit with *Bacillus thuringiensis* at 2g/L to be the most effective. *Bacillus thuringiensis* at 1g/L and 1.5g/L lowered the damage also but not as effective as at 2g/L. This proves that mortality was dose dependent. Likewise, the larvae populations in the harvested fruits of *Bacillus thuringiensis* treated plots was low when compared to the plot treated with no insecticide. However *B. thuringiensis* at 1g/L was not as effective as *Bacillus thuringiensis* at 1.5 and 2g/L.

Conclusively, the results from the study showed that *B. thuringiensis* at 2g/L proved most effective in controlling the fruit damage, and larval populations of

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lepidopterous insect pest of okra comparable to that of synthetic insecticide (lambda cyhalothrin + dimethoate). This work correlates with that of Jalali and Singh (2003) and Arora et al., 2006 that *Bacillus thuringiensis* var *kurstaki* is effective against lepidopteran pests.

RECOMMENDATION

From this study, the potential of *Bacillus thuringiensis* in crop production is extremely high, and farmer's education and training on these products' economic and environmental benefits need to be intensified. It also further widens the scope for exploring the improvement of *Bacillus thuringiensis* (different strains) for its better efficacy over a wide range of insect pests. also, research should be undertaken on the early application of *Bacillus thuringiensis* (LIPEL) at higher dosages for its efficacy in boosting okra yields.

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PROSPECTS AND CHALLENGES OF ORGANIC AGRICULTURE IN NIGERIA: A THEORETICAL REVIEW

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Abstract

More than one third of all harvested crops in Nigeria are reportedly lost to pest and diseases which necessitated the formulation of synthetic chemicals (pesticides). However, because of its reported toxicity, persistency in soils and crops, and its non-biodegradability, there had been various calls/advocacies for adoption of alternative means of pest control and disease management alternatives that will be less toxic, biodegradable, and ecofriendly as such the development of interest in organic agriculture which will help in resolving the continuous problems of crop losses and food insecurity due to the aftermath of COVID-19 pandemic which led to approximately 120 million people falling below the threshold when compared to 2019 statistics and more than 3 billion people been unable to afford a healthy diet in Nigeria. Food security in Nigeria has been in a critical state in recent time with the northern states being the epicenter of the crisis having more than 26 million people projected to face acute-hunger by 2024 (an increase of 9 million people sliding down the train of food insecurity from the 17 million estimated to be critically food insecure in 2022), hence the need for adoption of various strategies of organic agriculture which will help in resolving global challenges of food insecurity, deforestation, and climate change while promoting sustainable agriculture and ecosystem conservation in Nigeria and as such bridging the gap in between crop protection and sustainable food production in the country as research radars are now focused on organic farming as a system of agriculture.

Keywords: Pesticides, Food insecurity, Eco-friendly, Climate change, Sustainable agriculture, Organic farming.

PERSPECTIVES ET DÉFIS DE L'AGRICULTURE BIOLOGIQUE AU NIGÉRIA : UNE REVUE THÉORIQUE

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Résumé

Plus d'un tiers de toutes les récoltes au Nigeria seraient perdues à cause des ravageurs et des maladies, ce qui a nécessité la formulation de produits chimiques synthétiques (pesticides). Cependant, en raison de leur toxicité, de leur persistance dans les sols et les cultures et de leur non-biodégradabilité, divers appels/plaidoyers ont été lancés en faveur de l'adoption de moyens alternatifs de lutte contre les ravageurs et de gestion des maladies qui soient moins toxiques, biodégradables et respectueux de l'environnement. Cela a suscité un intérêt pour l'agriculture biologique, qui contribuera à résoudre les problèmes persistants de pertes de récoltes et d'insécurité alimentaire dus aux conséquences de la pandémie de COVID-19, qui a fait passer environ 120 millions de personnes sous le seuil de pauvreté par rapport aux statistiques de 2019 et rendu plus de 3 milliards de personnes incapables de se nourrir sainement au Nigeria. La sécurité alimentaire au Nigeria est dans une situation critique depuis quelque temps, les États du nord étant l'épicentre de la crise, avec plus de 26 millions de personnes qui devraient être confrontées à une famine aiguë d'ici 2024 (soit une augmentation de 9 millions de personnes glissant vers l'insécurité alimentaire par rapport aux 17 millions estimées en situation d'insécurité alimentaire critique en 2022), d'où la nécessité d'adopter diverses stratégies d'agriculture biologique qui contribueront à résoudre les défis mondiaux de l'insécurité alimentaire, de la déforestation et du changement climatique, tout en promouvant l'agriculture durable et la conservation des écosystèmes au Nigeria, et ainsi combler le fossé entre la protection des cultures et la production alimentaire durable dans le pays, les radars de la recherche se concentrant désormais sur l'agriculture biologique en tant que système agricole.

Mots-Clés: Pesticides, Insécurité alimentaire, Respectueux de l'environnement, Changement climatique, Agriculture durable, Agriculture biologique.

Introduction

The aftermath of COVID-19 pandemic led to an increase in food insecurity with approximately 120 million people falling below the threshold when compared to 2019 statistics and more than 3 billion people been unable to afford a healthy diet in the world as food price inflation remains higher than 5% in more than an average of low-income countries such as Nigeria. Food security in Nigeria has been in a critical state in recent time with the northern states being the epicenter of the crisis having more than 26 million people projected to face acute-hunger by 2024 (an increase of 9 million people sliding down the train of food insecurity from the 17 million estimated to be critically food insecure in 2022), In 2023, twenty-five million of Nigerians were reported to be at risk of food insecurity, the figure increased to 26.5 million people in

the first half of the year and it is projected to surge to about 30 million Nigerians before the end of the current year (UNICEF,2023). Hence the need for an alternative means of agriculture (i.e organic agriculture) aside from the normal conservative agriculture which will help in resolving global challenges of food insecurity, deforestation, and climate change while promoting sustainable agriculture and ecosystem conservation.

Organic agriculture is a farming that relies on natural processes (crop rotation, composting, and mulching) and biodiversity in maintaining soil health, control pests and diseases while ensuring ecological balance. It is a system that discourages the use of synthetic chemicals (pesticides, herbicides, fungicides, nematicides, bactericides, insecticides), disinfectants/protectants and genetically modified organisms (GMOs). It is a system that sustains the

adequate soil health and ecosystem as it relies on ecological processes (IFOAM International, 2018). Organic agriculture is not a traditional or low technology farming system but rather an holistic management system which enhances agroecosystem health by using a mixture of innovations that emphasizes management over technology, biological interrelation and chemical interventions (IFOAM, 2004; Roychodhry, 2013). Some stakeholders involved in the development of organic agriculture in Nigeria include among others; Association of Organic Agriculture Practitioners of Nigeria (NOAN), Organic and Agroecology Initiative (ORAIN), Organic Agricultural Project in Tertiary Institutions in Nigeria(OAPTIN), Health of Mother Earth Foundation (HOMEF),Olusegun Obasanjo Centre for Organic Agriculture Research and Development (OOCORD)

Nigeria and some organic farmers association or cooperative societies like Organic Fertilizer Producer Association of Nigeria (OFPAN), 'Nigeria Go Organic', and other government and Non- government organizations

Challenges/Constraints of Organic Agriculture in Nigeria and Propable Solutions

Despite progress, several barriers hinder organic production practices in Nigeria which includes limited Funding, weak policy support, knowledge gap among stakeholders, farmer resistance, market barriers among others. These challenges can broadly be categorized into Six (6) factors with the acronym 'PESTLE' as highlighted below:

Category of Challenges/ Constraints	Problems/Constraints	Probable Solutions
A. POLITICAL	<ul style="list-style-type: none"> Difficulty in accessing credit and finance particularly in research, certification and purchase of machineries/equipment. 	<ul style="list-style-type: none"> Provision of loans, grants, subsidies and other financial supports to farmers from both Federal and state governments.
	<ul style="list-style-type: none"> Non-robust support of organic farming. 	<ul style="list-style-type: none"> Renewed government support for organic agriculture in the country.
	<ul style="list-style-type: none"> Poor government policies gaps. Lack of government interest and clear policies on organic farming. 	<ul style="list-style-type: none"> A review of current government agricultural policies and programs and formulating policies that can boost organic farming as currently Nigerian Government has no policies in place to safeguard practices of organic agriculture.

	<ul style="list-style-type: none"> Low government patronage, advocacy, promotion and support for organic farming. 	<ul style="list-style-type: none"> Government at all levels from the federal to the Local need to patronize, advocate more and display more seriousness in their support for organic system of farming as a viable, economical and sustainable alternative of farming.
B. ECONOMICAL	<ul style="list-style-type: none"> High cost of organic farming techniques and materials. 	<ul style="list-style-type: none"> Subsidizing of materials as well as inputs for farmers in order to make organic fertilizers and pest control methods available and accessible.
	<ul style="list-style-type: none"> Limited market for organic produce. 	<ul style="list-style-type: none"> Creating a market for organic produce and products. There should be standardized sales outlet for organic products which bring producers (farmers) closer to potential buyers/consumers
A. SOCIAL	<ul style="list-style-type: none"> Lack of awareness and knowledge about organic farming practices among farmers. 	<ul style="list-style-type: none"> Organizing training and seminars where farmers are educated and trained on organic farming practices. Also, raising awareness through social media as well as print media(handbills,billboard,fliers,radio jingles,T.V) about the benefits of organic agriculture and rooting for the adoption of the practice amidst farmers.
	<ul style="list-style-type: none"> Limited access to organic inputs as well as materials. 	<ul style="list-style-type: none"> Government and other stakeholders(private and public) need to make organic inputs and materials more accessible and available to prospective and current organic farmers(gladiators).

	<ul style="list-style-type: none"> • Non-availability of organic seeds and seedlings. 	<ul style="list-style-type: none"> • Government at all levels need to invest in the acquisition of organic seeds and seedlings while ensuring that such seed/seedlings are made available to the end-users(farmers).
	<ul style="list-style-type: none"> • Stiff competition from conventional farming practices. 	<ul style="list-style-type: none"> • Although, organic agriculture is in its infancy stage and still growing, but with time it can, and will compete considerably well with the conventional systems of farming.
	<ul style="list-style-type: none"> • Low demand and lack of awareness for organic products. 	<ul style="list-style-type: none"> • Setting up of organic agriculture clusters,hubs, and debate groups. Encouraging youth involvement in organic farming. Development of organic agriculture value chains.
	<ul style="list-style-type: none"> • Poor storage system and limited infrastructures for processing organic produce. 	<ul style="list-style-type: none"> • Provision of social amenities as well as a sustainable storage system for storing organic produce/products to prevent spoilage/wastage.
	<ul style="list-style-type: none"> • Cohesive/ Incoherent advocacy. 	<ul style="list-style-type: none"> • Raising awareness as regard the advantage of organic farming over conventional farming practices.
D. TECHNOGICAL KNOW-HOW	<ul style="list-style-type: none"> • Limited technical expertise(technical know -how) by farmers as regard techniques involved in organic farming as well as extension services. 	<ul style="list-style-type: none"> • Researchers in various Institutes of Agriculture in Nigeria and experts in the field of organic farming need to transfer their knowledge/expertise to farmers through their extensionists in order to harm the farmers with the expertise and skills involved in organic farming so as to have a robust result.

	<ul style="list-style-type: none"> • Limited research and development in organic agriculture. 	<ul style="list-style-type: none"> • Conducting research to improve organic farming and providing extension services that will train farmers in the technicality of the processes involved in organic farming practices.
D. LEGISLATIVE AND REGULATORY	<ul style="list-style-type: none"> • Poor enforcement of the country’s regulation on pesticides usage as importation of Genetically modified products which devalues organic products produced within the country. 	<ul style="list-style-type: none"> • Establishing a certification and documentation process that will ensure that the organic products and produce complies with global/acceptable standard as there is currently no government approved body saddled with the responsibility of regulating and ensuring compliance with standard (Parrot and Marsden, 20 02; Bello, 2008).
	<ul style="list-style-type: none"> • Unhealthy relationship between producers(farmers),marketers(importers) and custom officers. 	<ul style="list-style-type: none"> • Agencies of government such as NAFDAC to set strict laws that will ensure safety and environment monitoring regulations are put in place before granting approval for the production of organic produce/products.
E. ENVIRONMENTAL FACTORS	<ul style="list-style-type: none"> • Inconsistent Weather 	<ul style="list-style-type: none"> • Advancement in weather predictions using innovative weather forecast machineries
	<ul style="list-style-type: none"> • Flood 	<ul style="list-style-type: none"> • Ensuring appropriate drainage facilities within and around farmlands
	<ul style="list-style-type: none"> • Drought 	<ul style="list-style-type: none"> • Provision of irrigation facilities

(Ref: Parrot and Marsden, 2002; Bello, 2008; Adeoye, 2011; Bouagnimbeck, 2011; Kutamaet al., 2013; UNCTAD, 2016; Onoja, 2018).

Prospects of Organic Agriculture in Nigeria
The act of organic agriculture farming is still new in the country with less than two decades of its practice on a commercial level, as such the potentials in the practice is still under-utilized (Mgbenka, 2015). In 2007, for instance, to serve as a pioneer project on a commercial scale level there were over 25 million hectares of land made available for organic agriculture in an organized manner in Nigeria although not yet certified as at then but only 3154 ha was cultivated in 2007 while 11979 was cultivated in 2010 (Olaito, 2014). Although the number of organic farmers in Nigeria is increasing, as well as producers of organic farm inputs such as organic fertilizer and compost plus, most farmers are not motivated by government policies but are driven by the principles of health, ecology, care and fairness. These principles encouraged some farmers to adopt the production system despite the fact that the government is prioritizing conventional/ industrial agricultural system over organic production. This is because their approach of tackling food insecurity by meeting the demands of its large population in Food supply does not encourage food sovereignty. There is therefore the need for increased awareness on organic agriculture production practices across the value chain in order to

give the stakeholders an in-depth knowledge of the advantages of the system as well as making it simplified as a technology that helps to tackle the menace of environmental problems that are related to agriculture as well as food safety. Hence, the need for the Nigerian government as well as the private sector not to only look keenly into the challenges/problems facing Organic agriculture in the country but to also consider the solutions proposed as solutions to the challenges, review current policies governing agricultural programs, establish departments of Organic Agriculture in higher institutions of learning where students will be taught about the techniques involved in the process of practicing organic agriculture as well as training of extension workers in organic farming practices in the various departments and ministries of agriculture and rural developments in public and private organizations as well as various higher institutions of learning. Presently, there are a few agricultural produce/products such as ginger, turmeric, lemon grass, tree crops, etc certified to be purely organic in Nigeria. Organic farming is beginning to evolve /metamorphosize into a "Superbug" as more farmers (than ever before) are adopting the practices/techniques after being trained by experts in the field of organic agriculture from various research institutions and organizations (Onoja, 2018). More conferences, fora, trainings, seminars and conventions need to be held in order to increase the awareness as well as promote organic agricultural practices

in Nigeria. Organic agriculture might not be the only answer to poverty and food insecurity but it does have the potential to contribute immensely to food security in Nigeria in quite a lot of ways including:

- " Increment in crop yields.
- " Reduction in post-harvest losses.
- " Environmental sustainability.
- " Improved food accessibility.
- " Rendition of support to small-scale farmers.
- " Improvement in nutritional quality of foods.
- " Promoting food availability.
- " Promote diversity and eco-system balance.
- " Improve farmer's livelihood economically.

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(Adeoye, 2011; Kutamaet al., 2013; Peace, 2014; Ibeawuchiet al., 2015; Mgenkaet al, 2015

Conclusion

Harnessing the potentials of organic agriculture and promoting it in Nigeria will enhance total well-being of the citizenry as there will be an improvement in food security and a sustainable agricultural practices. However, all hand must be on deck from the government → Researchers → Private sector → Farmers and other stakeholders in order to promote and support organic agriculture in Nigeria.

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INFLUENCE OF PLANTING POPULATION OF ONION (*Allium cepa* L.) AND SOIL NUTRIENT MINING ON POST-PLANTING SOIL FERTILITY STATUS

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Abstract

The nutrient requirement of onion (*Allium cepa* L.) largely depends on several factors, such as cultivar, plant population, crop environment, and soil fertility status. 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 planting population on post-planting soil fertility status. The experiment was carried out between February and May, 2022. Treatments were different plant populations of onion 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 collected were subjected to descriptive statistics and analysis of Variance (ANOVA) using GENSTAT 8th Edition and means were separated using Least Significance Difference. 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 leads to a considerable mining of soil nutrients which should be consistently replaced.

Keywords: Nutrient mining, Onion population, Soil fertility status, Soil Degradation

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. 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 staying in the soil. at the Organic Agriculture section of the Teaching and Research Farm of the University of Ibadan, 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 colour and texture as determinants. Apart from colour 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

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 ml of Bray P solution was added and placed on the Mechanical shaker for 15 mins, after which, the solution was filtered through 90 mm What man filter paper and allow it to drain completely., 5mls of filtrate was measured into a clean 50 ml volume beaker, then 5 ml of Murphy and Riley solution (colour reagent) was added and made up to 25 ml with distilled water. the solution was allowed to stand for about 10 mins for colour 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 ml of 1N potassium dichromate (K₂Cr₂O₇) with 20 ml of concentrated Sulphuric acid (H₂SO₄) 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 ml with distilled water and then allowed to cool for another one hour. Three drops of ferroine indicator (1-10 phenanthroline mono hydrate) was added and titrated with 2.5M Fe₂SO₄ (ferrous sulphate) solution until a maroon brown colour solution was obtained, titre values were recorded.

Total Nitrogen in Soil

Digestion: 0.5 gm of 0.5 mm sieved soil was weighed into a digestion tube and 5 ml of concentrated H₂SO₄ 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 ml of digest was measured into the distillation chamber, 5mls of 40% NaOH was added and distilled into a 100 ml conical flask containing 5mls of Boric acid indicator until 50 ml of a greenish colour solution was obtained.

Titration: The green colour solution was titrated with 0.01 N HCl until a pink colour was obtained, the final value was recorded.

Particle size distribution was analysed 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 ml of acid mixture of Nitric acid and perchloric acid on hot plate placed under a film cupboard at 60-70°C. A colour change from brown to colourless was observed and the digest was allowed to cool down and made up to 25 ml 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 ml of conc. H₂SO₄ 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? to 250? for about two hours. There was a colour change from brownish black to colourless 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 colour change to green and it was titrated with normal HCl and the greenish colour 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 4.1, 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 cmol/kg) are below critical level. The available phosphorus (9 mg/kg) was moderate which was within critical range.
 Post-Harvest Soil Analysis

Table 4.4 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 4.5 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
Total nitrogen (g/kg)	0.34	Low

Av. Phosphorus (mg/kg)	9	Moderate
Potassium (cmol/kg)	0.2	Very low
Calcium (cmol/kg)	0.1	
Magnesium (cmol/kg)	0.1	
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	Mg	Na	K	Ca	Mn	Fe	Cu	Zn	pH	Av.P (m	T.N
	(g/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)		g/kg)	(g/kg)
T1	3.2	0.7	0.3	0.2	0.2	0.3	0.9	0.1	0.9	5.6	2.4	0.36
T2	4.4	0.2	0.3	0.2	0	0.8	1.2	0.7	10.9	5.6	2.9	0.46
T3	3.9	0.7	0.3	0.2	0.3	11.2	10.4	20.6	0.5	5.5	3.1	0.46
T4	4.1	0.7	0.3	0.2	0	1.8	0.9	1	9.6	5.6	2.8	0.49
T5	4.5	0.2	0.3	0.2	0	0.5	5.3	7	0.6	5.9	3.4	0.51
Mean	4.02	0.5	0.29	0.18	0.04	2.92	3.74	5.88	4.5	5.64	2.92	0.45
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	Mg	K	Na	Mn	Fe	Cu	Zn	T.N	P
	(g/kg)	(g/kg)	(g/kg)	(g/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(g/kg)	(g/kg)
T2	0.2	0.1	0.9	0.2	6	304	3	17	2.0	*
T3	0.2	0.1	1.3	0.3	6	148	3	26	2	*
T4	0.2	0.2	1.3	0.3	8	415	5	30	1.8	*
T5	0.2	0.1	1.0	0.3	13	337	5	53	1.8	*
LSD	NS	NS	NS	0.03	NS	124	1	11	NS	*

* Not traceable

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

Oyedeji 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

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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EFFICACY OF *Bacillus thuringiensis* var *kurstaki* as a Biopesticide of Lepidopterous Insect Pests of Okra (*Abelmoschus esculentus* (L.) Moench)
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