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Regional Consultation on Opportunity Crops in Africa

Convened by the Food and Agriculture Organization of the United Nations (FAO) and the Forum for Agricultural Research in Africa (FARA)

9th - 11th June, 2026

Accra, Ghana

Book of Extended Abstracts

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Editorial note

The abstracts in this volume were submitted for the Regional Consultation on Opportunity Crops in Africa. They have been organized thematically and formatted for consistency. Light editorial corrections have been applied to titles, headings, spacing and institutional names. The scientific arguments, data, interpretations and references remain the responsibility of the respective authors. The designations employed and the presentation of material do not imply the expression of any opinion by FAO or FARA concerning the legal or development status of any country, territory, institution or authority.

About the Consultation

Africa's rich agricultural biodiversity includes many indigenous and traditionally cultivated species with substantial potential to strengthen nutrition, climate resilience, livelihoods and economic opportunity. Yet many remain marginal to research, breeding, seed systems, markets, education and public investment. The Regional Consultation on Opportunity Crops in Africa brought together researchers, policymakers, universities, farmer organizations, private-sector actors and development institutions to identify practical pathways for repositioning these crops within Africa's agrifood transformation agenda.

This volume brings together the extended abstracts contributed to the consultation. Collectively, the papers examine the strategic, scientific, institutional and commercial foundations required to conserve crop diversity, improve varieties, strengthen seed and production systems, develop markets, enhance nutrition and translate continental commitments into coordinated action.

Thematic scope

- **Strategic Framing, Policy and Institutional Transformation** (9 papers)
- **Conservation, Genetic Resources, Seed Systems and Breeding** (9 papers)
- **Production Systems, Agronomy and Mechanization** (6 papers)
- **Nutrition, Markets, Value Addition and Consumer Uptake** (6 papers)

Contents

PART I

Strategic Framing, Policy and Institutional Transformation

1. Opportunity Crops for the Transition of African Agrifood Systems

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Background

The challenge facing Africa is not simply to increase agricultural production, but to transform agrifood systems to deliver resilient livelihoods, healthy diets, and sustainable environmental outcomes. Despite decades of investment in a limited number of staple crops, diets remain insufficiently diverse, agricultural systems are increasingly vulnerable to climatic and market shocks, and micronutrient deficiencies persist across much of the continent. Opportunity crops, including indigenous, traditional, neglected, and underutilized species, offer a strategic pathway for accelerating this transformation. Historically marginalized in research, policy, and investment agendas, these crops possess unique characteristics that address many contemporary food system challenges.

Five Transitions Enabled by Opportunity Crops

Opportunity crops can catalyze five interconnected transitions that are essential for transforming African agrifood systems: production, nutrition, environmental, economic, and social transitions. By promoting diversified cropping systems, they can reduce production risks, improve soil fertility, enhance resource-use efficiency, and strengthen resilience to drought, heat, pests, and market shocks. As nutrient-dense foods, opportunity crops can contribute significantly to improved dietary diversity and reduced micronutrient deficiencies. They also support biodiversity conservation, climate adaptation, and ecosystem health while creating new economic opportunities through strengthened value chains. Growing demand for products derived from these crops can stimulate rural economies and generate employment, particularly for women and youth. In addition, opportunity crops help preserve local food cultures, strengthen indigenous knowledge systems, promote gender inclusion, and enhance community participation in agricultural innovation and decision-making.

From Conservation Agenda to Food Systems Transformation

A growing number of global and regional initiatives are increasingly recognizing opportunity crops not as niche conservation priorities, but as strategic assets for achieving nutrition security, climate resilience, biodiversity conservation, and inclusive economic development. This shift reflects a broader recognition that diversified food systems are fundamental to sustainable agrifood systems transformation.

Conclusion

Realizing the full potential of opportunity crops will require coordinated investments in breeding, genomics, seed systems, agronomy, value chain development, nutrition education, policy integration, and capacity strengthening. Opportunity crops provide a practical and scalable entry point for building resilient, climate-smart, nutritious, and inclusive agrifood systems. The question is no longer whether these crops matter, but how rapidly research, policy, and investment systems can reposition them from the margins to the centre of Africa's agrifood systems transition.

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2. From Policy to Practice: Scaling Opportunity Crops through Coordinated Action

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Policy Note

Africa's transition toward resilient, inclusive, and nutrition-sensitive agrifood systems will require more than incremental improvements to dominant (often referred as major economic crops like maize, wheat, and rice) staple crops. Opportunity crops, including neglected and underutilized species (NUS), offer practical pathways to diversify production, improve diets, strengthen climate resilience, and sustain agrobiodiversity. These include cereals and grains (millet, teff, sorghum, and fonio), legumes and pulses (Bambara groundnuts, cowpeas, and pigeon peas), roots and tubers (cassava and sweet potato), and vegetables and fruits (amaranth, jute mallow, baobab, and moringa). Yet despite their strategic value, these crops remain marginalized in policy frameworks, receive minimum support from investment systems, and are insufficiently recognized in legal and regulatory regimes.

The CAADP Kampala Declaration, along with the Strategy and Action Plan (2026–2035), calls for stronger integration of nutritious traditional and indigenous crops to transform Africa's agrifood systems. It underscores that the question is no longer whether opportunity crops matter, but whether African countries and institutions are ready to act with purpose and coordination to implement what our policy commitments already recognize. In this regard, AUDA-NEPAD has a distinctive mandate by hosting the Secretariat of the African Union Seed and Biotechnology Programme's Partnership Platform (ASBPP). The Agency is strategically positioned to convene stakeholders, support policy harmonization, advance implementation pathways, and help translate continental commitments on opportunity crops and farmer-managed seed systems into practical action at the regional and national levels.

The central proposition is that scaling opportunity crops is not merely a technical or agronomic task but a matter of institutional choice, systemic reform, and political commitment. Moving from policy to practice requires coordinated action among AU institutions, regional bodies, member states, research organizations, farmers' organizations, civil society, and the private sector. It also requires practical platforms that link policy ambition to implementation. The ASBPP and its working group on farmer-managed seed systems and opportunity crops offer the platform for promoting legal recognition, fit-for-purpose quality assurance, investment reform, and stronger integration into NASIPs, RASIPs, the AU Vision for Adapted Crops and Soils (VACS) and the broader agrifood systems transformation agendas.

The task is to move beyond mere recognition toward implementation by embedding these crops in law, policy, finance, research, markets, and delivery systems. AUDA-NEPAD, acting on its mandate and by hosting the ASBPP Secretariat, plays an important role in turning this agenda into coordinated action across countries and regions. Scaling up opportunity crops is not only about promoting additional crops but also about reshaping agrifood systems so that crop diversity, nutrition, resilience, and local knowledge are fully integrated as foundations of Africa's food systems transformation.

3. A Transition Framework for Integrating Neglected and Underutilised Species into Agrifood Systems

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Extended Abstract

Neglected and underutilized crop species (NUS) – also called 'orphan', 'underutilized', 'neglected', 'minor', 'abandoned', 'lost', 'forgotten', 'local', 'underdeveloped', 'traditional', 'alternative', 'niche' or 'opportunity' crops – include crops to which little attention is paid or which are entirely ignored by agricultural researchers, plant breeders and policymakers. Thousands of NUS exist across the globe, yet only a limited number gain recognition and prominence. This phenomenon likely stems from the complexities involved in transforming a NUS into a major crop. Nonetheless, there exists no specific framework to grasp these dynamics. To address this discrepancy, this paper proposes a transition framework designed for NUS.

The research, developed within the SUSTLIVES project (Sustaining and improving local crop patrimony in Burkina Faso and Niger for better lives and ecosystems) promoted by the Italian Agency for Development Cooperation (AICS) and CIHEAM Bari, and funded by the European Union under the global DeSIRA Initiative programme,is based on a search on NUS and transition/transformation conducted in the Web of Science database. The eligible articles were examined through the lens of the Multi-Level Perspective (MLP) on sociotechnical transitions, focusing on its three elements, namely niche, socio-technical regime, and sociotechnical landscape. Niches pertain to NUS; the sociotechnical regime involves the established, prevailing system of major crops and encompasses elements that impede the incorporation and mainstreaming of NUS into agri-food systems; and the socio-technical landscape refers to the policies and broad trends that influence both the niche and the regime.

The analysis suggests that the dynamics and success of transition depend not only on the characteristics of niche NUS, the sociotechnical regime, and the sociotechnical landscape, but also on the interconnections and relationships among these three elements. Distinct traits of the niche NUS influence not only their viability but also their ability to stand the rules of the dominant system (i.e., socio-technical system) and compete with major crops. These aspects are linked to the inherent strengths and weaknesses of NUS. The features of the sociotechnical regime that affect the mainstreaming and integration of niche NUS pertain to the constraints it imposes, which obstruct the development of NUS, as well as the competitive edge held by the established major crops that have already adjusted to the regime context. The factors within the sociotechnical landscape that are significant to the transition of NUS relate to broad societal, economic, cultural, and environmental trends and processes that exert pressure on the existing agri-food system and the dominant crops, thereby eventually creating opportunities for the niche NUS. Policy frameworks represent a crucial aspect of the sociotechnical landscape that is central to the integration and mainstreaming of the NUS.

The insufficient research represents a significant obstacle to the development of NUS. However, merely enhancing research is not sufficient to facilitate the integration of NUS into agri-food systems; it should be supported by initiatives focused on developing the supply chains of NUS, spanning from production through processing to distribution and consumption. Indeed, the levers of change that can foster and accelerate NUS transitions are rooted in the domains of policy, finance and market, technology and practices, culture, as well as science and innovation. For that, development strategies for NUS should integrate, inter alia, research and knowledge creation, effective communication and outreach, market expansion, policy advocacy, partnerships, and capacity enhancement and institutional strengthening.

The suggested transition framework has the potential to enhance the effectiveness, efficiency, and sustainability of efforts focused on promoting NUS and integrating them into agri-food systems, thus leading to environmental, social, and economic advantages at household, local, and national scales. Indeed, promoting NUS can trigger the transformation of agri-food systems towards greater resilience and sustainability.

Keywords: *Food system transformation, Forgotten foods, Multi-Level Perspective, Niche crop, NUS, Opportunity crops, Policy, Sustainability transitions, Sustainable agriculture, Sustainable food systems.*

4. Unlocking Africa's Plant Genetic Resources for Food and Agriculture

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Abstract

Africa continues to face severe food insecurity and malnutrition. In 2024, more than 20 percent of the continent's population was undernourished, and by 2030 Africa is projected to account for approximately 60 percent of the world's chronically undernourished population (FAO, IFAD, UNICEF, WFP and WHO, 2025). Progress towards the hunger and malnutrition targets of the Sustainable Development Goals is therefore markedly off track. These challenges have been compounded by the aftereffects of the COVID-19 pandemic, the war in Ukraine, the ongoing Middle East crisis, increasingly erratic extreme weather events, civil strife and persistent socioeconomic pressures. Within this context, African governments and development partners are seeking practical and context-responsive strategies to strengthen the productivity and resilience of cropping systems (FAO, 2024b). This extended abstract argues that Africa's largely underutilized plant genetic resources for food and agriculture represent a strategic asset for improving domestic food production, nutrition and agrifood system resilience. It reviews relevant FAO processes and evidence, including deliberations through FAO governing bodies (FAO, 2024a,b) and the findings of the Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture (FAO, 2025), which identifies important regional gaps and priorities in the conservation and sustainable use of these resources. It further examines FAO's One Country One Priority Product flaggship initiative as an operational framework for translating the inherent potentials of crops into tangible food security, nutrition and livelihood outcomes (FAO, 2022). In addition, the African Orphan Crops Consortium (Dawson et al., 2018; Hendre et al., 2019) and the Vision for Adapted Crops and Soils (GAIN, 2024; The Rockefeller Foundation, 2024) are considered as complementary partnership models for broadening the scientific, institutional and policy foundations needed to support agrifood system transformation. The paper concludes that context-appropriate scientific innovations, supported by effective partnerships and regional collaboration, will be essential to unlocking Africa's crop diversity and scaling more resilient and productive agrifood systems.

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5. Developing a Specialized Capacity Instrument for NARES and Institutions Advancing Opportunity Crops

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Abstract

Africa's ambition to achieve agricultural productivity, food security, resilient livelihoods, and job creation depends on strong research and innovation systems. Despite remarkable gains in productivity, challenges continue to threaten food and nutrition security, through persistent yield gaps and declining nutritional quality of crops. These, challenges and concerns remain over weak research investment, limited technological responsiveness, and low innovation outputs.

There is a need for a strategic framework for the development of a specialized capacity instrument for institutions promoting forgotten foods (or opportunity crops) in African food systems through foresight-driven planning and multi-stakeholder collaboration, institutional capacity and technology demand systems, and data systems on, scientific knowledge and instruments for sharing lessons learned at different levels. These are mainly addressed through the following: (i) digital advisory tools and data-driven approaches to understanding the science behind challenges and offering best-practice solutions; (ii) data policy in problem identification, policy development and mainstreaming of good practices; (iii) data science through modelling for developing research-led solutions to supporting sustainable development and strengthening of the NARES systems, for informed collective strategies to strengthen Africa's ownership of forgotten crops transformation through science, technology, and innovation; and (iv) capacity development by boosting infrastructure and institutions by all key actors (including the private sectors) involved in research for development and extension.

Early-career and experienced researchers need to acquire skills to address interdisciplinary research challenges related to forgotten crops and their integration into agricultural development, while policymakers and institutional leaders need to understand the role and benefits of integrating these into research and development strategies on multi-stakeholder platforms beyond pilot project sites.

The resultant effect of all these is to ensure opportunity crops serve as strategic levers for transformation, through development, and policy frameworks and approaches across value chains for a sustainable and just food system.

6. Progress on Integration of Opportunity Crops into Agrifood Systems in Eastern and Central Africa

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Context and Rationale

The current food systems are vulnerable to external shocks triggered by climate change, emergence of exotic pests and diseases, severe soil degradation, limited access to quality seed and un developed markets (CCRP, 2026). These food systems promote intensive mono-culture based farming that prioritize dense calories and fail to provide nutrient rich diets which has led to increase in malnutrition across the continent. Opportunity crops provide the opportunity to transform food systems to resilient, sustainable and nutrient dense agrifood systems. These crops are nutrient dense and locally adapted to their environments and can withstand impacts of climate change (Ndolovu et. al, 2024). Most opportunity crops are drought tolerant and can do better under conditions of limited moisture. Despite their potential, opportunity crops suffer from various challenges ranging from systemic research weakness, policy neglect, weak value chains (Glatzel et. al, 2025). There is an urgent need to attract research investments for production, value chain development and integration into policy and strategic frameworks for agrifood systems transformation. These crops also lack strategic support from policy makers and decision makers and are marginalized in terms of market access. They are often referred to as a "poor man's crops and their production is often relegated to women. This paper presents the regional status of integration of opportunity crops in Agrifood Systems in Eastern and Central Africa.

The specific objectives of the paper were to: (i) provide a status on regional progress made towards integration of opportunity crops in policy and strategic frameworks for agri-food systems; (ii) highlight progress towards implementation of research programs and projects for opportunity crops/NUS in ECA; (iii) identify the current constraints affecting integration of opportunity crops in national agrifood systems agenda; (iv) provide future perspectives on regional integration of the opportunity crops in agri-food systems; and (v) propose policy actions for enhancing institutional adoption and scaling of opportunity crops.

Materials and Methods

The methodology adopted for this paper is mixed method approach that combines a desk review and key informant interviews. Data was collected from the 15 ASARECA member states (13 VACS countries and 2 Non-VACS countries). The VACS countries include: Kenya, Ethiopia, Uganda, Tanzania, Democratic Republic of Congo, Burundi, Rwanda, Cameroon, South Sudan, Sudan, Eritrea, Somalia. The non-VACS countries were identified as: Madagascar and Republic of Congo. to highlight progress in integration of the NUS into the agrifood systems in the ECA. The desk review was undertaken to highlight the status of integration of opportunity crops in the national agrifood systems policy and strategic frameworks in the target countries. Data collected from the desk review was augmented with information from the 20 key experts that were consulted during the review. The review considered the period 2004 to 2025 with 2003 (the year CAADP was first launched) considered as a base year.

Key Findings

Progress towards Integration of Opportunity Crops into Policy and Strategic Frameworks

The status on integration of opportunity crops into national agri-food food systems across the Eastern and Central Africa region remains low despite renewed efforts by some development partners (FAO, NORAD Rockefeller Foundation, CGIAR) to promote these crops. Key findings show that there is explicit lack of policy support for the Neglected and Under-Utilized Species (NUS) or Opportunity Crops across the ECA region.

Table 1: Progress towards integration of Opportunity Crops in Policy and Strategic Frameworks in ECA (2005-2025)

Country	**Agricultural Policy and Strategic Framework**	**Agricultural Policy and Strategic Framework**	**Agricultural Policy and Strategic Framework**	**Agricultural Policy and Strategic Framework**	**Agricultural Policy and Strategic Framework**	**Agricultural Policy and Strategic Framework**	**Agricultural Policy and Strategic Framework**	**Agricultural Policy and Strategic Framework**
Country	Policy	Program	Strategic Plan (NAIP)	Climate Investment Plan/Action Plan	NUS Project level Initiatives	Seed legislation (Seed Acts)	Dakar 2 Food Compacts	Other policy frameworks
Ethiopia	-	-	-	-	+++	-	-	-
Uganda	-	-	-	-	+++	-	-	-
Kenya	-	-	-	-	+++	+	-	-
Tanzania	-	-	-	-	+++	-	-	-
Rwanda	-	-	-	-	+	-	-	-
Cameroon	-	-	-	-	+++	-	-	-
Burundi	-	-	-	-	+	-	-	-
Madagascar	-	-	-	-	++	-	-	-
South Sudan	-	-	-	-	+	-	-	-
DRC	-	-	-	-	++	-	-	-
Sudan	-	-	-	-	++	-	-	-
ROC	-	-	-	-	++	-	-	-
Somalia	-	-	-	-	++	-	-	-
Eritrea	-	-	-	-	++	-	-	-
CAR	-	-	-	-	+	-	-	-

Status in implementation of Opportunity Crops in ECA (2005-2025)

Progress towards implementation of NUS/Opportunity Crops Research Programs and Projects shows that over 60 initiatives have been implemented between 2005 and 2025. Most of these initiatives were implemented in Kenya, Uganda, Ethiopia, Tanzania, DRC and Cameroon suggesting existence of a robust and active NUS/Opportunity Crops research network in these countries.

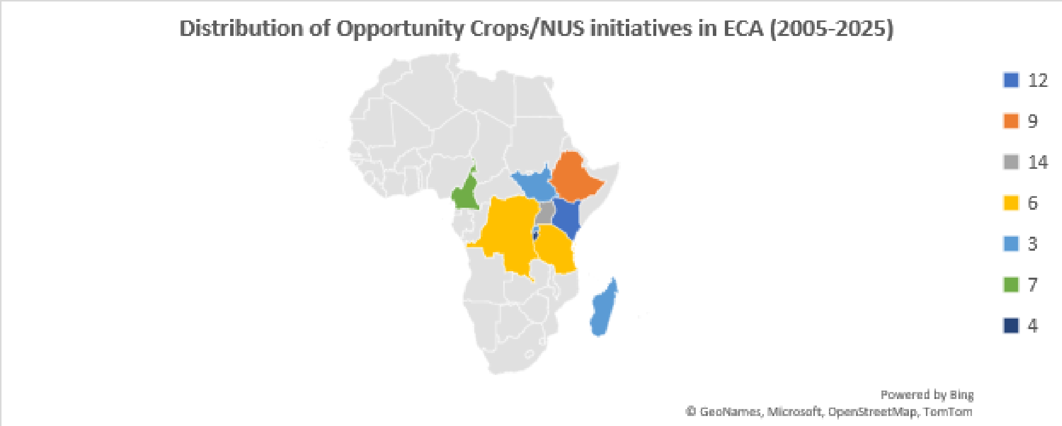

Fig 1(a): Distribution of the Research Programs/Projects/Iniatives on Opportunity Crops (2005-2025)

Fig 1(b): Progress on Implementation of the R&D Programs on Opportunity Crops (2005-2025)

Progress on breeding work

There has been commendable progress in this area with the Launch of the African Orphan Crops Consortium (AOCC) in 2011 and subsequent operations initiated in 2013. The AOCC was endorsed by the African Union (AU) and has a potential to support integration of the NUS into African food systems. The AOCC aims to undertake genomic sequencing of 101 African Traditional Under Researched African Foods, a majority of which includes Orphan Crops. Since it's inception, African Crop Breeding Academy was established to train African scientists (breeders) on genomic sequencing with the aim of improving productivity. Six (6) of ASARECA member Countries are actively participating in the AOCC Programs. Within the NARIs, there is on-going breeding work especially for the tubers, legumes (cowpeas, pigeon peas and cereals- finger millet and sorghum) supported by the CGIAR (ICRISAT, IITA and CIAT Bioversity).

Table 2: Participation in AOCC Programs

Sn	Country	Participating (Yes-1, No. 2,)	Level of Participation (1. Low, 2. Medium, 3. High)	Comments
1	Burundi	1	1	Only capacity building
2	Cameroon	1	2	
3	Central Africa Republic	2		
4	DRC	1	1	
5	Eritrea	2		
6	Ethiopia	1	1	

Sn	Country	Participating (Yes-1, No. 2,)	Level of Participation (1. Low, 2. Medium, 3. High)	Comments
7	Madagascar	1	1	
8	Kenya	1	3	
9	Republic of Congo	2		
10	Rwanda	1	1	Only capacity building
11	South Sudan	2		
12	Sudan	2		
13	Somalia	2		
14	Tanzania	1	3	
15	Uganda	1	3	

Constraints

Production and utilization of orphaned crops is constrained by several barriers including: limited production, weak seed systems, limited value addition and access to markets and policy neglect.

S/n	Constraint	Weight	Importance*	Score	Rank
1	Under-developed value chains	10	2	20	3
2	Limited access to markets	10	2	20	3
3	Stigmatization as a "poor man's food"	5	1	5	4
4	Neglect by Policy Makers (not adequately supported by policy/strategic frameworks)	25	3	75	2
5	Lack of quality seed/weak seed systems	50	3	150	1

*Importance rating: 1. Low, 2. Moderate, 3. High

Future Perspectives

Future efforts on transformation of food systems will focus on the role of the opportunity crops. The key priority areas will include: breeding to ensure yield stability and improve productivity. Priority should also be accorded to strengthening seed systems across all priority NUS/Opportunity crops value chains; value addition and linkage to niche markets. Enhancing supportive policy environment remains critical for integration into national agrifood systems.

Conclusions and Recommendations

Conclusion

The Opportunity Crops have a high potential for transformation of food systems in ECA region. However, these opportunity crops suffer from systemic research neglect, inadequate value addition (inadequate infrastructure for processing) policy marginalization and weak and fragmented value chains. There is limited progress towards establishment of policy and strategic frameworks to facilitate their inclusion in the agrifood systems agenda. Nearly, all countries sampled did not have a solid policy or strategic NUS framework that supports integration of Opportunity Crops in Agrifood systems. Most of the interventions for Opportunity Crops is driven by research projects. This strongly suggests need for intentional engagement of policy stakeholders to influence policy landscape and support the integration of NUS in the Africa's Agrifood Systems.

Recommendations

Organize policy to adequately sensitize relevant policy makers on the critical role of opportunity crops in agrifood systems transformation agenda and make a business case for their integration into agrifood policy and strategic frameworks.

Engage National Governments to initiate a process of policy review for agriculture, food and nutrition policies & strategies to address the current policy gaps. This will create an opportunity for integration of Opportunity Crops/Orphan Crops into national policy and strategic frameworks such as the NAIPs, Agriculture, Food security and Nutrition Policies, National Biotechnology and Safety Plans.

National Governments with support from development partners should establish and fund a program fully committed to the improvement of the value chains for opportunity crops (seed systems strengthening, value addition, market development). The program should be led by the National Agricultural Research Institutions (NARIs) which are the nationally mandated institutions for agricultural research and development in the countries.

Popularise the opportunity crops.

Address seed systems failures. Most of the opportunity crops are OPVs which do not attract demand/interest from private sector seed multipliers. There is need to promote community-based seed production and multiplication schemes such as Quality Declared Seed to address this challenge. In absence of quality, it's practically difficult to start talking about value chain development and market access.

Integration of the opportunity crops in the mainstream national extension services to streamline production and marketing of these crops.

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Annex 1: NUS Project Level Interventions in Kenya (2006-2026)

Country	**Period**	**Research Project/Initiative**	**Lead Research Institution**	**Focus NUS Crops**
Kenya 1	2003-2025	African Indigenous Vegetables Research Program- On-going	JKUAT	Nightshade, Spider plant, Cowpea, Amaranth
2	2003-2025	Traditional/African Leafy Vegetable Program	World Vegetable Centre (AVRDC)	Amaranth, Cowpea, Spider Plant
3	2005-2025	Dryland Cereals and Legumes- On-going	ICRISAT	Sorghum, Finger millet, Cowpea, Pigeon peas, Pearl Millet
4	2012-2019	Biodiversity for Food and Nutrition (BFN)	Bioversity (CGIAR)	African Leafy Vegetables, Bambara Nuts, Groundnuts, Finger Millet, Cowpea
5	2013-2025	African Orphan Crops Consortium (AOCC)- On-going	AOCC/ICRAF	African Orphan Crops
6	2013-2025	KALRO NUS Research Program- On-going	KALRO/GeRRI	Amaranth, Finger Millet, Cowpea, Sorghum, Bambara Nuts
7	2014-2016	NUS Value Chain Capacities Project	Bioversity/ANAPE/UoN	Bambara Nuts, Amaranth
8	2020-2025	Greener Greens- Phase 1&2	World Vegetable Center, ICIPE, KOAN	African Leafy Vegetables, Moringa
9	2021-2023	Adding Value to NUS	Alliance Bioversity	Finger Millet, Sorghum, African Leafy Vegetables, Africa Rice
10	2023-2025	VACs Opportunity Crops- On-going	CIMMYT/KALRO	Finger Millet Okra
11	2025-2030	Power of Diversity Funding Facility (PDFF)	Crop Trust/Alliance/KALRO	Finger Millet Amaranth
12	2009-2023	Horticulture Innovation Lab	USAID	African Leafy Vegetables
Uganda	2004-2025	Uganda National Gene Bank Collections	NARO/NARL/PGRC	All NUS in National Collections

7. From Forgotten Foods to Opportunity Crops: Awareness, Institutional Transformation and the Mainstreaming of Diversified African Food Systems

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Summary

The renewed global interest in opportunity crops—also referred to as neglected and underutilized species (NUS), orphan crops, indigenous crops, or forgotten foods—has emerged as one of the most important developments in contemporary African food systems discourse. Since the United Nations Food Systems Summit (UNFSS) of 2021 and the UNFSS+2 Stocktaking Moment of 2023, these crops have increasingly been repositioned from marginalized subsistence commodities toward strategic assets for climate resilience, nutrition security, biodiversity conservation, agroecology, and sustainable rural development. This extended abstract synthesizes recent conceptual, institutional, and strategic developments shaping the opportunity crops agenda in Africa between 2021 and 2026. It argues that awareness raising is not merely an informational activity, but a transformational process aimed at reshaping public perceptions, scientific legitimacy, governance systems, market structures, and cultural narratives surrounding indigenous foods and agricultural diversity. The paper further demonstrates that the evolving terminology surrounding "forgotten foods," "orphan crops," "opportunity crops," and "reality crops" reflects deeper political and institutional shifts in how agricultural diversification is understood and operationalized. Although substantial progress has been achieved through continental advocacy, donor investment, scientific research, and policy engagement, the mainstreaming of opportunity crops will ultimately depend on integrated institutional reforms involving seed systems, extension services, public procurement, commercialization, consumer revaluation, and long-term governance transformation.

1. Introduction

Global food systems are increasingly confronted by interconnected crises involving climate change, biodiversity loss, ecological degradation, nutritional insecurity, and rising dependence on a narrow range of staple crops such as maize, wheat, and rice (Khoury et al., 2014; Pingali, 2012). While agricultural modernization and the Green Revolution significantly increased calorie production, they also contributed to the erosion of agrobiodiversity and dietary diversity, thereby increasing vulnerability to climatic and economic shocks. In response to these challenges, growing attention has emerged around agricultural diversification and the strategic role of indigenous and underutilized crops in building more resilient and sustainable food systems.

Across Africa, this renewed interest accelerated substantially following the UN Food Systems Summit of 2021. Opportunity crops, including sorghum, millet, bambara groundnut, cowpea, teff, fonio, amaranth, African leafy vegetables, and several indigenous legumes, increasingly became framed not merely as traditional or heritage foods but as future-oriented solutions to climate instability, malnutrition, and ecological fragility. The contemporary momentum surrounding these crops reflects broader shifts in food systems thinking, sustainability discourse, and agricultural governance. This paper examines the institutional expansion, conceptual evolution, and awareness-raising strategies associated with opportunity crops in Africa while assessing their implications for food systems transformation.

2. Conceptual and Institutional Evolution of Opportunity Crops

The contemporary revival of agricultural diversification has been accompanied by a proliferation of overlapping labels, including "forgotten foods," "forgotten crops," "orphan crops," "neglected and underutilized species" (NUS), "opportunity crops," and "reality crops" (Ojijo, 2026). Although often used interchangeably, these terms encode distinct assumptions regarding institutional neglect, scientific legitimacy, commercialization, and agrifood-system transformation.

The term "forgotten foods" emphasizes institutional invisibility and dietary neglect. Recent FAO publications clarify that these foods were not forgotten by local communities themselves, but rather by research institutions, funding agencies, agricultural development systems, and public policy frameworks (FAO, 2024a; FAO, 2024b). This framing relocates responsibility for marginalization from communities toward formal governance systems and agricultural modernization paradigms. By contrast, the term "orphan crops" highlights exclusion from scientific infrastructures, including breeding systems, genomic research, and crop improvement pipelines (Tadele, 2019). The category of "neglected and underutilized species" (NUS) emerged as a broader technocratic umbrella suitable for policy coordination and development programming, although scholars argue that its breadth risks flattening important distinctions among crops and food systems (Padulosi et al., 2013).

More recently, the language of "opportunity crops" has become increasingly influential because it reframes marginalized crops as strategic assets capable of contributing to climate resilience, nutritional improvement, biodiversity conservation, and rural enterprise development. This future-oriented framing has gained substantial momentum through initiatives such as the Rockefeller Foundation's Vision for Adapted Crops and Soils (VACS), the CROPS4HD initiative coordinated through the Alliance of Bioversity International and CIAT, and the Africa Manifesto and Plan of Action on Forgotten Foods coordinated by the Forum for Agricultural Research in Africa (FARA). The newer concept of "reality crops" further reflects a growing emphasis on implementation and institutionalization, arguing that rhetorical recognition alone is insufficient unless these crops are integrated into functioning seed systems, extension programs, markets, processing systems, and consumer food environments (Rutsaert et al., 2026).

Following the UN Food Systems Summit, Africa experienced substantial institutional mobilization around opportunity crops. Major developments included the establishment of the Africa Community of Practice on Forgotten Foods, increasing involvement of CGIAR-associated institutions in orphan crop research, expansion of donor-backed agrobiodiversity initiatives, and growing incorporation of indigenous crops into national food systems transformation pathways. During this period, scientific literature increasingly demonstrated the contributions of underutilized crops to drought resilience, micronutrient diversity, agroecosystem sustainability, and water-use efficiency (Ndlovu et al., 2024). Simultaneously, opportunity crops became increasingly integrated into broader agendas involving agroecology, regenerative agriculture, nutrition-sensitive food systems, and climate adaptation.

3. Awareness Raising as Food Systems Transformation

The literature consistently demonstrates that the marginalization of opportunity crops stems not from lack of value, but from historical neglect associated with colonial agricultural legacies, modernization biases favouring globally dominant staples, weak investment, and erosion of indigenous knowledge systems (Mabhaudhi et al., 2019; Mudau et al., 2022). Consequently, awareness raising has emerged as one of the foundational requirements for mainstreaming opportunity crops within African food systems.

Importantly, awareness raising extends far beyond the dissemination of information. It is fundamentally transformational because it seeks to reshape public attitudes toward food, agriculture, health, ecology, and development. Researchers increasingly argue that opportunity crops must be repositioned from "poor people's foods" toward healthy, climate-smart, culturally valuable, and economically viable foods. Public awareness campaigns therefore increasingly emphasize nutritional density, climate resilience, nutraceutical potential, agroecological sustainability, and culinary heritage.

Consumer-oriented strategies have become especially important in urban food environments where indigenous foods are often stigmatized as backward or old-fashioned. Food festivals, cooking demonstrations, social media campaigns, celebrity chefs, recipe competitions, supermarket promotions, and school feeding initiatives are increasingly used to normalize indigenous foods and make them attractive to younger generations and urban consumers. The literature also emphasizes the importance of aspirational framing. Terms such as "future-smart foods," "heritage foods," and "superfoods" are increasingly preferred over deficit-oriented labels associated with poverty or subsistence agriculture.

Awareness raising also involves restoring and valuing indigenous knowledge systems. Many opportunity crops remain deeply embedded within local ecological knowledge, culinary traditions, medicinal practices, and farmer-managed seed systems. Efforts to strengthen intergenerational knowledge transfer through community seed fairs, farmer-to-farmer learning platforms, indigenous food festivals, and local-language media have therefore become increasingly important. Scholars further emphasize that educational institutions must play a more active role in mainstreaming opportunity crops. African school curricula and agricultural training systems have historically privileged globally dominant crops while neglecting indigenous food systems. Integrating opportunity crops into school feeding programs, agricultural colleges, university curricula, and nutrition education is increasingly viewed as essential for long-term transformation.

4. Stakeholder Strategies, Commercialization, and Systemic Challenges

Awareness raising is most effective when tailored to specific stakeholder groups. Farmers, for example, respond most strongly to messages centered on yield stability, drought tolerance, lower input costs, and income diversification. Demonstration plots, farmer field schools, local radio, seed fairs, and peer learning systems are therefore widely recommended. Extension systems similarly require institutional retooling through crop fact sheets, nutrition-sensitive extension modules, post-harvest guidance, and localized agronomic packages.

Policy makers are generally most responsive when opportunity crops are linked to national priorities such as climate adaptation, food sovereignty, school feeding, public health, import substitution, and local economic development. Public procurement has emerged as one of the strongest institutional mechanisms for mainstreaming indigenous foods because integrating opportunity crops into school meals, hospitals, prisons, and relief systems simultaneously creates markets, legitimacy, and visibility.

By 2025 and 2026, the opportunity crops movement increasingly shifted from awareness and advocacy toward commercialization, innovation ecosystems, and market integration. Research priorities expanded beyond conservation into crop breeding, genomics, post-harvest technologies, climate modeling, consumer acceptance, digital agriculture, and value-chain development. At the same time, entrepreneurs and food processors increasingly explored opportunities in functional foods, nutraceuticals, indigenous flours and snacks, sustainable processing, and diaspora food markets.

Despite this growing momentum, substantial structural constraints remain. Weak seed systems, inadequate processing infrastructure, fragmented markets, limited breeding programs, poor mechanization, low extension support, insufficient policy integration, and persistent consumer stigma continue to limit scaling efforts. Scholars increasingly argue that awareness alone cannot transform food systems unless paired with long-term institutional investment and governance reform capable of integrating opportunity crops into research systems, commercial value chains, public procurement frameworks, and urban food environments.

5. Conclusions and Recommendations

The resurgence of opportunity crops represents one of the most important developments in African food systems transformation since the UN Food Systems Summit of 2021. Indigenous and underutilized crops are increasingly recognized as strategic resources for addressing climate vulnerability, nutritional insecurity, biodiversity erosion, and sustainable rural development. The transition from "forgotten foods" toward "opportunity crops" and "reality crops" reflects broader shifts in agricultural thought from narratives of neglect and marginality toward frameworks emphasizing resilience, commercialization, institutionalization, and implementation.

However, the future mainstreaming of opportunity crops depends not simply on rhetorical recognition or awareness campaigns, but on coordinated institutional transformation. Long-term progress will require strengthening decentralized seed systems, expanding participatory breeding programs, integrating opportunity crops into climate adaptation and food security policies, investing in processing technologies and market infrastructure, supporting youth-led and women-centered enterprises, mainstreaming indigenous food systems into educational curricula, and strengthening public procurement systems that incorporate indigenous foods into school feeding and institutional consumption.

Ultimately, opportunity crops should not be treated as marginal alternatives to dominant staples, but as central components of diversified, resilient, and sustainable African food systems capable of contributing simultaneously to climate resilience, nutritional justice, agrobiodiversity conservation, cultural preservation, and inclusive economic development.

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8. Integrating Opportunity Crops into Agrifood Systems in West and Central Africa: Evidence and Pathways for Scaling Resilient Food Systems

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Introduction

West and Central Africa (WCA) continues to face increasing pressure on agri-food systems due to climate change, land degradation, population growth, market volatility, and persistent food and nutrition insecurity. In this context, opportunity crops including neglected and underutilized species are gaining renewed attention as strategic entry points for building more resilient, diversified, and nutrition-sensitive agri-food systems. Across the region, CORAF is increasingly integrating opportunity crops such as millet, sorghum, cowpea, fonio, cassava, bambara groundnut, orange-fleshed sweet potato, and indigenous leafy vegetables into agricultural development programs and value chains because of their adaptability to harsh agroecological conditions or low external inputs, nutritional properties, and economic potential.

Materials and Methods

CORAF-supported initiatives to improve the integration of opportunity crops into agri-food systems in West and Central Africa involve seed systems development through breeding programs, participatory varietal selection, climate-smart production technologies and inclusive value chain approaches. This has been done through CORAF's core approaches of scaling:

Agricultural Technology and Innovation Parks (ATP) and Innovation Platforms (IP), Community Immersion Hub (PIC) and climate smart village (CSV).

Agricultural Technology Parks (ATPs) are specialized zones designed to facilitate the adoption of cutting-edge technologies while promoting sustainable agricultural practices and improving livelihoods in rural communities (CORAF, 2024). Key components of ATPs include research and development facilities, technology demonstration centers, incubation support for agri-tech startups, and training programs for capacity building.

Innovation platforms are frameworks for fostering collaboration, driving innovation, and scaling impactful practices. These structured, multi-stakeholder forums are designed to foster collaborative problem-solving and create an environment where diverse actors (input suppliers, producers, breeders and traders) can work together to "scale up", meaning significantly increase the reach and impact of new technologies and practices (CORAF, 2024).

PIC are community-based spaces that bring T&I closer to end-users through tailored agricultural advice and demonstration sites for production and processing and Climate-smart villages are sites dedicated to promoting climate-smart agriculture (CSA) practices, strengthening the resilience of vulnerable farmers through agrometeorological services (CORAF, 2024).

The analysis draws on implementation reports, varietal dissemination records, innovation platform activities, and evidence generated from multi-country interventions under the TARSPro project.

Results and Discussion

CORAF, within the framework of the TARSPro project has contributed significantly to integrating NUS such as cassava, orange-fleshed sweet potato (OFSP), cowpea, okra and amaranth into regional food systems by deploying climate-resilient and nutrition-sensitive technologies across the region.

Table 1: Promoted Varieties and Nutritional Profiles

Crop Type	Specific Varieties Promoted	Key Attributes	Target Countries
Cassava	I011412, I070539, RB 89509, RB CONA 84, BOCOU-5	High beta-carotene (approx. 10 µg/g); drought-resistant; early maturing.	Benin, Burkina Faso
OFSP (Orange- fleshed Sweet Potato)	Tuskegee Purple, Bagre, Tiebele, Mother Delight, Nooma, Irene	Rich in Vitamin A and beta-carotene; pest-resistant. Tuskegee Purple is noted for superior nutritional profiles over local ecotypes.	Burkina Faso, Chad
Cowpea	Komcallé, TN 5-78, TN 3-78, IT93K452- 1, Thiye 54, Léona	Dual-purpose (grain and fodder); early maturing; high yield potential in arid conditions.	Benin, Burkina Faso, Mali, Niger, Chad
Okra	Sassilon, Gan kourouni, Batoumabe, Konni	Diversification crop; high performing; noted for resilience and nutritional value.	Mali, Niger, Burkina Faso
Amaranth	A2002, TO 2004	Nutrition-sensitive; rapid-growth; high nutritional value leafy vegetable used to address micronutrient deficiencies.	Mali, Burkina Faso

Conclusion

Scientific evidence from multiple initiatives demonstrates that opportunity crops contribute significantly to strengthening resilience among smallholder farmers. Improved and locally adapted varieties have shown enhanced tolerance to drought, heat stress, and poor soils while maintaining stable yields under variable climatic conditions. While progress has been recorded, several constraints continue to limit large-scale integration of opportunity crops and marketing activities. Scaling opportunity crops will require stronger regional policy alignment, sustained investment in seed systems and value chains, and greater integration of neglected and underutilized species into national food security and climate resilience strategies.

Keywords

Opportunity crops; Agri-food systems; Climate-smart agriculture; Resilience; Food security;

Neglected and Underutilized Species; West and Central Africa; CORAF.

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9. Building the First Open-Source Curriculum on Opportunity Crops (Neglected and Underutilized Species): Evidence from a Multi-Regional Network of Universities

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Introduction

Opportunity crops, also known as neglected and underutilized species (NUS), offer proven contributions to food security, dietary diversity, climate resilience, and rural livelihoods. Yet they remain largely absent from formal higher education: graduates enter agrifood research, policy, and enterprise with narrow crop knowledge and few skills to engage with NUS value chains. Only 33% of surveyed universities have a dedicated NUS module; nearly half have none at all. With one in five Africans facing hunger and over one billion people unable to afford a healthy diet (FAO, 2025), this is a gap the higher education system can no longer afford to leave unaddressed.

The Collective Action on Transformative Education, managed by RUFORUM and GFAiR and funded by the European Commission and the International Foundation for Science (IFS, Sweden), is building the first openly accessible, multi-regional NUS curriculum through a network of universities across Africa, Asia, Latin America, and the Caribbean. This paper presents evidence from the network's two post-launch diagnostic studies conducted between January and April 2026, which form the empirical foundation for curriculum design.

Materials and Methods

Two complementary evidence exercises were conducted. A baseline institutional survey gathered responses from 57 universities across 25 countries, examining NUS teaching, infrastructure, open resource assets, and pilot readiness. A curriculum contributors scoping exercise mapped 42 subject-matter contributors across 26 countries and seven knowledge areas, generating module proposals and identifying content gaps. Data were analysed descriptively and used to construct a tiered readiness framework to guide pilot sequencing.

Results and Discussion

The baseline shows that NUS teaching already exists in many institutions but mostly in embedded, partial, or unlabelled forms: only 33% have a dedicated NUS module, while 84% expressed interest in co-developing open NUS content for embedding in existing courses. The top institutional priority for new short courses was processing and value addition (37 of 57 institutions), followed by entrepreneurship and product development (29), agronomy (26), and value chains and markets (23). The scoping exercise revealed that climate and biodiversity attracted the highest contributor demand (21%), with production, post-harvest, and value addition each drawing 18%.

Based on these findings, the curriculum is structured into eight blocks: Foundations, Production, Post-Harvest, Value Addition, Nutrition, Climate, Policy, and an integrating Capstone. Key gaps identified include enterprise depth, investment literacy, compliance expertise, and nutrition science, all of which are being addressed through targeted contributor recruitment. The readiness analysis produced three pilot tiers: 24 institutions are immediately ready for a September 2026 pilot, 18 need light support, and 6 are targeted for the 2027 cohort. The main constraint reported by 50 of 57 institutions was funding, followed by internal approvals (30) and staff time (26).

Table 1. NUS curriculum priorities and institutional readiness at a glance

Indicator	Africa	Asia / LAC / Other	Total
Institutions surveyed	40	17	57
Interest in co-developing NUS modules	84%	84%	84%
Willing to pilot (Sept 2026)	74%	71%	74%
Top micro-course priority	Processing & value addition (18%)	Processing & value addition (18%)	Processing & value addition (18%)
Tier 1 pilot-ready institutions	18	6	24
Curriculum contributors mapped	30	12	42
Highest contributor demand area	Climate & biodiversity (21%)	Climate & biodiversity (21%)	Climate & biodiversity (21%)

Source: NUS Network Baseline Survey (2026) and Curriculum Contributors Scoping Exercise (2026).

Conclusion

The evidence confirms both the need and the institutional readiness for a structured opportunity crops curriculum. The challenge is no longer generating interest, 84% of surveyed universities are already willing to co-develop and pilot content. The challenge is converting that interest into delivery through modular, low-barrier curriculum materials, targeted capacity support, and realistic phased implementation. The network's open-source approach means that Africa's pilot experience feeds directly into a global public good, ensuring that the knowledge generated by African institutions is both recognised and reused. By September 2026, the first cohort of pilot institutions will be delivering NUS content, a concrete contribution to the continental agenda on opportunity crops.

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PART II

Conservation, Genetic Resources, Seed Systems and Breeding

10. Opportunity Crops: Strategies to Promote Conservation and Use of Plant Genetic Resources

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Introduction

Plant genetic resources underpin global agriculture by providing the diversity necessary for developing varieties adapted to changing environments, pests, diseases and nutritional needs. Conservation efforts of plant genetic resources rely on complementary in situ and ex situ strategies, each fulfilling distinct but synergistic roles. Despite their importance, opportunity crops lag behind staple crops in conservation attention and representation in genebanks.

Materials and Methods

This presentation synthesizes global data on plant genetic resource conservation, drawing from the Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture, WIEWS records, and assessments of national genebanks. It also reviews ongoing interventions under the Power of Diversity Fund Facility and the Building Opportunities for Lesser-known Diversity in Edible Resources (BOLDER) initiatives. Methods include gap analyses, stakeholder workshops for crop prioritization, planned collecting missions for under-represented genetic diversity, value chain and food systems analysis, value chain intervention design, germplasm participatory evaluations, crop modelling for climate change adaptation and PhD fellowships.

Results and Discussion

Globally, 869 genebanks conserve an estimated 5.9 million accessions, of which only 2.2 million are unique and fewer than half are safely duplicated. Staple crops such as maize, rice and wheat collectively hold ca. 910,000 accessions, whereas opportunity crops like Bambara groundnut, jute mallow and amaranth account for only 20,000. The Multilateral System (MLS) of the ITPGRFA has facilitated access to 2.5 million accessions, distributing more than 9.2 million samples between 2012 and 2019. National genebanks—especially in countries where opportunity crops are widely cultivated—hold untapped potential but often operate below capacity. The Power of Diversity Funding Facility and BOLDER address these gaps by strengthening conservation, characterization, safety duplication, on-farm testing of landraces, value-chain interventions and policy support across nine countries and 22 crops.

Conclusion

Complementary conservation strategies, supported by targeted capacity-building initiatives, are essential to safeguard and utilize the genetic diversity of opportunity crops. Strengthened national genebanks and enhanced integration of in situ and ex situ approaches can improve long-term conservation and use.

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11. Complementarity of On-Farm Management and Ex Situ Conservation

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Introduction

Global food security amid challenges of climate change requires and holistic approach to Plant Genetic Resources (PGR) conservation, integration of both on-farm management and ex situ conservation is an essential complementary system for securing agricultural biodiversity for future generation. On-farm conservation of agricultural genetic material allows crops to adapt to environmental changes due to climate change while ex situ conservation freeze them within controlled facilities. (FAO 2010).

In on-farm (in situ) conservation management, PGR are maintained and evolved within their local micro-environment and production system, this is why farmers are important actors, while in ex situ conservation, PGR are conserved outside their original habitat (e.g., field genebanks, in vitro collections; seed banks, cryopreservation, botanic gardens, etc).

Despite Africa's rich plant genetic resources, investment in research has historically favored introduced staple crops like maize, wheat, rice, potatoes, and bananas while hundreds of climate-adapted indigenous species vital to local African diets and traditions have been neglected. Over 70 indigenous crops in Sub-saharan Africa are used as essential sources of food, medicine, and livelihoods, however investment in scientific research and policy support has been limited, hence they are tagged and classified as neglected and underutilized Species (NUS). Most of the genetic resources of these NUS are conserved by farmers on-farm. (Mahlangu et al., 2020)

Both on-farm and ex-situ conservation are complementary to each other as the they both enhances resilience, utilization and long term security of agrobiodiversity hence safeguarding Africa's agricultural biodiversity requires the integration of both on-farm and ex situ conservation.

Africa's Progress

On-farm and ex-situ (genebank) genetic resources conservation operations previously existed independent of each other, integration efforts have been adopted by many African countries in order to bridge the gap between the two systems for the benefit of food security in the region.

Integration of on-farm and ex situ PGR conservation

Integration of both on-farm and ex situ PGR conservation by African Nations is now been employed by linking farmers directly with the formal genebanks. Some countries national genebanks (e.g. South Africa and Uganda) have commenced collaboration with community seed banks on the conservation of tree and crop varieties. This collaboration effort is been established through informal participation in meetings, seed and food fairs and through a number of joint activities including the establishment of community seeds banks. (CTDT et al., 2020) Community seeds banks have been integrated by some African countries like

Zimbabwe, South Africa and Ethiopia to serve as intermediate link between local on-farm landraces directly with national ex situ genebank collections. (Vernooy et al., 2015).

Identification of overlapping conservation hotspots through strategic mapping projects especially for West African Crop Wild Relatives (CWR) has led to the design of new reserve sites to compliment the ex situ genebank collections. The use of specialized ecogeographical planning software e. g CAPITOGEN3 has been helpful for plant breeders cross-reference ex situ accessions with on-farm realities to fill up genetic gaps. (Nduche et al., 2022).

In Nigeria, the International Institute of Tropical Agriculture in collaboration with the National Center for Plant Genetic Resources and Biotechnology NACGRAB has intensified effort in working with s farmers to incorporate indigenous land races from the on-farm collection of crop varieties into the ex-situ collection in the genebank through germplasm exploration, a total of 273 accessions of local cultivars of pigeon peas were collected from 18 states across Nigeria's agro-ecological zones in 2025. (Figure 1) (Bhadmus, A., et al. 2026).

Constraints

Achieving a fully optimized, complimentary system has been limited by several institutional, ecological and socioeconomical bottlenecks. Poor database integration between ministries of agriculture and the ministries of environment resulting into strong disconnect and isolated database system thereby making PRG utilization synchrony practically impossible. Increasing rate of urbanization and the expansion of commercial cash-crop monocultures and the effect of climate change has eroded on-farm biodiversity. A huge amount of African ex situ accessions are under-characterized, this limits local breeders unaware of the available resources in the ex-situ collection. Economic pressures sometimes make smallholder farmers abandon diverse traditional landraces.

Proposed Solutions

To bridge the gap and achieve seamless harmony between ex-situ conservation and on-farm evolution in Africa, some structural changes need to be implemented. There will be need to formalize cross-ministerial framework that will connect genebanks with local agricultural extension workers so as to follow up with farmers and monitor crop distribution.

Conclusion

Integration of on-farm management (in situ) and genebank storage (ex situ) is essential for safeguarding Africa's rich agricultural biodiversity. On-farm management allows crops and livestock to continuously adapt to changing African climates, while ex situ conservation provides a secure safety backup for sustaining PGR for the future.

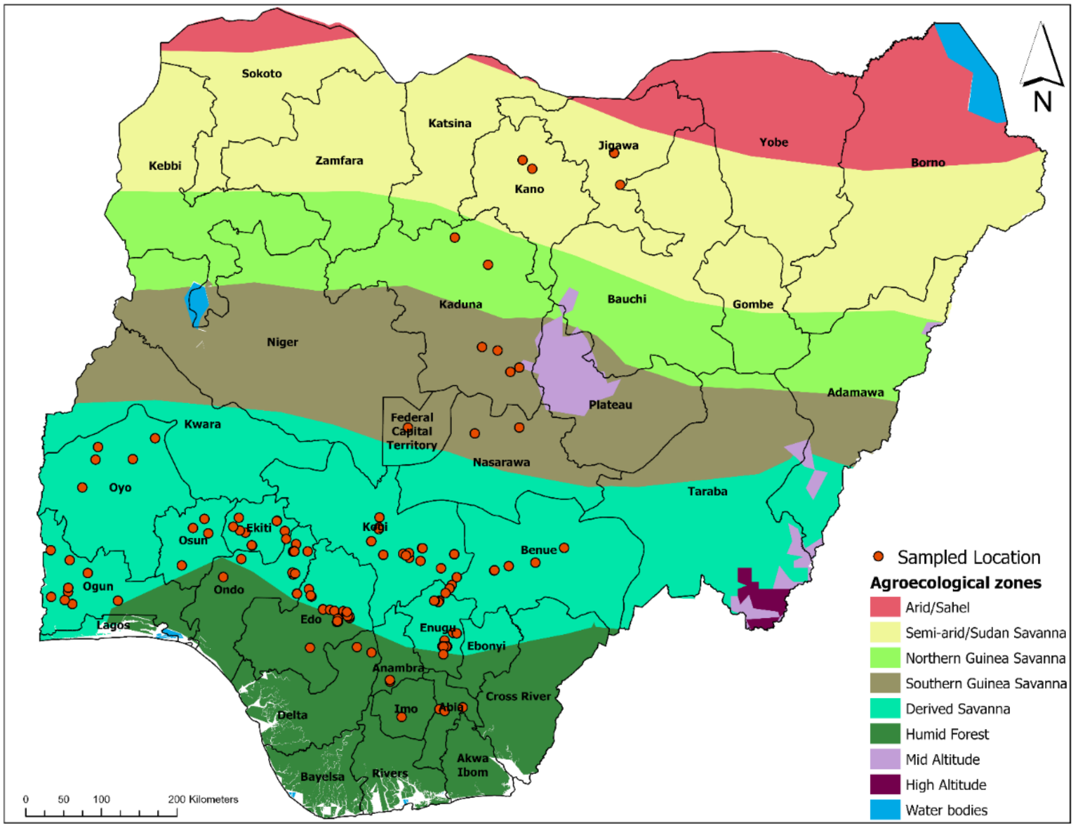

Fig. 1 Spatial distribution of collection sites across Nigeria, overlaid on major agro-ecological zones (orange dots represent sampling locations (farms and local markets))

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12. Harnessing the Diversity of Opportunity Crops for Resilience

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Abstract

The increasing impact of climate change and rapid population growth poses a significant threat to food production, particularly in sub-Saharan Africa (SSA), where frequent and intense droughts coupled with rising temperatures are adversely affecting crop productivity. It is therefore essential to promote crop diversification and accelerate the development of climate-resilient crops that are adapted to changing environmental conditions. Meeting the increasing food demand in Africa requires greater research investment in opportunity crops due to their potential to enhance food production, improve nutrition, and strengthen resilient food systems. The genebank at the International Institute of Tropical Agriculture (IITA) conserves diverse collections of opportunity crops indigenous to Africa, including the world's largest collection of cowpea. Harnessing the available genetic diversity within these crops is a critical step toward unlocking their potential as climate adaptation strategies for resilient agricultural production.

Several studies have identified climate change as a major constraint to agricultural productivity and a significant threat to food security in SSA without significant action to adaptation (Abberton et al., 2022). In addition, crop improvement programs for opportunity crops has remained limited due to insufficient diversity information and the lack of well-structured pre-breeding pipelines for trait discovery and product development. To address these challenges, ongoing efforts at the IITA Genebank are integrating phenotypic evaluation, molecular breeding, high-throughput phenotyping, and farmer-participatory approaches to identify novel sources of beneficial traits and favourable alleles within opportunity crops. As a case study, we present ongoing research in cowpea focused on exploiting natural genetic variation for photosynthetic efficiency across a large and diverse germplasm collection.

We found new sources that combine productivity and resilience; these findings are being advanced to understand the genetic mechanisms driving resilience in the identified cowpea lines. This effort is providing a roadmap for breeding strategies to harness traits/genes driving resilience in a large diversity panel of cowpea, which will be deployed to other opportunity crops conserved within the genebank to further enhance their adoption for resilient and sustainable food production across SSA.

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13. From Crowdsourced Varieties to Continental Assets: On-Farm Diversity Management as the Foundation for Africa's Opportunity Crop Transformation

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Introduction

Africa has domesticated between 60 and 100 plant species, a heritage routinely framed as a conservation challenge. This paper argues it is more precisely an untapped productive asset. The marginalisation of African opportunity crops reflects institutional path dependency and chronic underinvestment rather than biological limitation. Releasing this potential requires farmer-centred methodologies that treat communities as knowledge co-producers.

Materials and Methods

Between 2020 and 2023, winner varieties of durum wheat, finger millet, faba bean, and chickpea, identified through prior TRICOT crowdsourced trials, were upscaled across ten districts in Amhara and Oromia, Ethiopia. Eighteen varieties were distributed to over 4,500 households. Grain yield data and household surveys assessed adoption, productivity, income, and resilience outcomes.

Results and Discussion

Adoption rates reached 89% for durum wheat (Mangudo), 70% for faba bean (Gora), and 67% for chickpea (Ejere). Mean varietal portfolios increased by 2.67 varieties per crop in intervention districts. Grain yields exceeded national averages: Mangudo reached 8.30 t/ha against a national wheat average of 3.11 t/ha. Forty percent of farmers increased annual income by USD 361–722, with reduced agrochemical dependence and improved drought and frost resilience. These results constitute a proof of concept for a scalable investment model: genebank diversity, participatory selection, and farmer knowledge combined deliver rapid, measurable, and broadly distributed returns.

Conclusion

Africa's on-farm crop diversity is the foundation of a food system transformation already underway wherever the right tools exist. Scaling this approach across the full portfolio of opportunity crops, supported by investment in value chains and market linkages, is the most direct pathway to food system resilience rooted in African agricultural heritage. The ingredients are already in the ground. The question is whether the investment architecture is willing to meet them there.

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14. Using Spatial Targeting to Guide Opportunity Crop Breeding for Climate-Resilient Dryland Agriculture

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Introduction

Dryland farming systems in sub-Saharan Africa face increasing pressure from climate variability, soil degradation, declining agrobiodiversity, weak markets and changing food and nutrition needs (Mugiyo et al., 2021). These pressures are acute in smallholder systems, where farmers balance food, income, labour, livestock, soil fertility and risk under uncertainty. Within the Vision for Adapted Crops and Soils, opportunity crops provide a pathway to diversify production, strengthen resilience and improve nutrition. However, breeding priorities are often poorly matched to spatial variation in climate, soils and farmer needs (Mugiyo et al., 2022). This scoping review examines how spatial targeting can inform participatory breeding of locally adapted opportunity crops.

Materials and Methods

A scoping review approach was used to synthesise evidence from literature repositories including Scopus, Web of Science and Science Direct. The review focused on four questions: which opportunity crops and traits are relevant for dryland systems; how spatial and climate suitability evidence can guide breeding priorities and variety targeting; how participatory breeding can respond to farmer priorities across locations; and how this framing aligns with VACS. Evidence was extracted on crop suitability methods, climatic risk, underutilised crop distribution, farmer-centred research, agrobiodiversity and systems-fit traits.

Results and Discussion

The review shows that spatial targeting can strengthen opportunity crop breeding by identifying where crops fit, which traits matter, and which environments require specific breeding responses. Crops such as sorghum, cowpea, millets, amaranth, pigeon pea and bambara groundnut can strengthen climate adaptation, dietary diversity, soil fertility and livelihoods. Evidence from land suitability and spatial modelling shows that breeding priorities must consider agroecology, rainfall, soils, markets, labour and farmer preferences. Future suitability projections suggest gains for sorghum, cowpea and amaranth, while climate-risk evidence from Zimbabwe highlights maize vulnerability during El Niño seasons. Spatial targeting can guide trait prioritisation and testing.

Conclusion

Spatial targeting can inform participatory breeding by aligning crop improvement with agroecological fit, farmer priorities, soil health, nutrition, climate risk and market opportunities. This requires suitability analysis, climate-risk information, gender- and youth-responsive trait prioritisation, and stronger seed systems. Opportunity crop breeding should be designed as a spatially informed systems process that identifies target environments, defines local traits with farmers, tests varieties across contrasting conditions, and links promising materials to seed, agronomy and markets.

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15. Registration of Local Varieties of Opportunity Crops: An Integrated Approach

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Introduction

Nigeria is endowed with a large number of indigenous or long-adapted plant species that served as foods several years ago, but are presently neglected and going extinct. The major challenge is that they are considered as food for low-income earners because they received little or no research, policy, or commercial attention despite their nutrition and resilience. These Neglected and underutilized crop species (NUCS), otherwise known as opportunity crops, play a crucial role in enhancing food security and nutrition in Africa. They contribute to household food security and health, and their contribution can be unlocked with proper research, commercialization, and policy. They include crops such as African walnut, African breadfruit, African pear, African Yam bean, Ginger, Sesame, Fonio, Tiger nuts, Bambara groundnuts, Cocoa yam, and Pigeon pea. These crops are not only nutritious but also have significant economic potential. Unfortunately, the NUCS remain in the informal system as neglected and underutilized since only seeds of registered and released varieties under the formal seed system are allowed to be legally produced and sold in Nigerian market.

Review

Nigeria's crop variety registration and release system feature a range of actors across the public and private sectors who coordinate, nominate, and evaluate crop varieties for release. The process ensures that only high-performing and well-adapted varieties enter the seed system and become available for multiplication and distribution to farmers and food producers. It involves three mandatory trials: DUS on-station trials, VCU multi-location trials, and on-farm trials, all of which are conducted by the developing breeders and organizations, in collaboration with the mandated National Agricultural Research Institute (NARI) (SCANL, 2021). Nigeria's process is one of the lengthiest in Africa, taking anything from 3 to 4 years to complete, with the mandatory trials accounting for more than 80% of the total duration. Maize, cowpea, rice and cassava are among the top crops with large number of varieties released.

Formal Variety registration is the gateway for seed certification, market access and extension support for the neglected and underutilized crops. However, not much is done in Africa, Nigeria inclusive, in terms of their formal registration and release. Nigeria's variety release system has so far registered only two different landrace crops in the past i.e., Ginger and Yam. Nepal is a model country where regulators modified the rules to favor local varieties, an example where regulatory relaxation and coordinated stakeholder effort enabled farmers to legally register landraces and access seed markets. The National Seed Board in Nepal approved six farmer landraces (24 Mar 2021) under a simplified "Schedule D" pathway. The registered NUCS included proso and foxtail millets, amaranth, finger millet and common bean; some first-ever registrations for these crops. Legal recognition enables commercialization, seed certification and farmer benefit-sharing; although it also requires outreach and technical support to work at scale. Nigeria can adopt a similar enabling policy coupled with proactively addressing capacity and institutional support gaps so as to enable local actors use the relaxed pathways effectively.

Crop variety release procedure in Nigeria _ Key Steps:

Nigeria's crop variety registration and release system feature a range of actors across the public and private sectors who coordinate, nominate, and evaluate crop varieties for release. The key steps of the process are as follows:

Committee Composition: The National Crop Varieties and Livestock Breeds Registration and Release Committee (NVRC) comprise of government Ministries, Departments and Agencies (MDAs) such as Federal Ministry of Agriculture and Food Security - FMAFS (Federal Department of Agriculture - FDA, National Agricultural Seeds Council - NASC, Agricultural Research Council of Nigeria - ARCN, National Agricultural Research Institutes - NARIs, National Agricultural Quarantine Services - NAQS); Federal Ministry of Science, Technology & Innovation - FMSTI (National Centre for Genetic Resources and Biotechnology - NACGRAB, National Biotechnology Research and Development Agency - NBRDA); other organizations (Seed Entrepreneurs Association of Nigeria - SEEDAN, All Farmers Association of Nigeria - AFAN); and professional Societies (Genetic Society of Nigeria - GSN, Biotechnology Society of Nigeria - BSN); University Faculties of Agriculture; etc.

Application Process: Applicants must follow the expected guidelines and submit their applications to the NVRC. The committee reviews the applications and determines the suitability of the varieties for registration and release.

Trial Requirements: Before release, new varieties must undergo mandatory trials, including DUS on-station trials, VCU multi-location trials, and on-farm trials.

Registration and Release: Once the trials are completed and the varieties are deemed suitable, they can be registered and officially released for use by farmers and industries.

Cost and Responsibility: The cost of variety registration and release is borne by the developing breeders and organizations, with private seed companies and CGIAR centers incurring higher costs, as their materials are proprietary and benefits from moratorium period.

The NVRC's activities are coordinated by NACGRAB, a parastatal under the Federal Ministry of Science, Technology and Innovation, which serves as its secretariat.

Benefits of registering NUCS and key success factors

Registering and documenting the NUCS, or “opportunity crops,” is important for protecting crop diversity, supporting climate-resilient food systems, and strengthening global food security. Modern agriculture depends heavily on major crops like rice, wheat, maize and cassava; thus, cataloging NUS helps to reduce vulnerability and brings these valuable crops into policy, research, and legal protection. Success of mainstreaming NUCS into Africa’s variety registration and use systems will require national regulatory flexibility (simplified requirements); strong farmer organization and Community Seed Banks (CSBs) engagement; technical backstopping from genebanks, research institutes and regulators; support of Local governments; and facilitation of development partners.

Implication for Nigeria: A Schedule D–style provision as demonstrated by Nepal; plus, targeted capacity building can mainstream NUCS into formal seed systems while protecting farmer rights.

A simplified registration & release pathway for NUCS in Nigeria

Nigeria can adopt a simplified registration process for farmers' landraces and NUCS with reduced scientific burden using the following streamlined steps:

Prioritization: identify pilot NUS (3–5) with farmer confirmation.

Documentation: Prior informed consent (PIC), Access and Benefit-Sharing (ABS) arrangements.

Characterization: genebank/NARIs provide support for morphological descriptors and basic genetic information (on station trials).

Participatory trials: on-farm (farmer-led trials)

Dossier submission: simplified application to NVRC with genebank/NARI endorsement.

Decision: NVRC decision on release and registration

Seed multiplication and certification: anchor source seed with Community Seed Banks and certified local producers.

Post-release monitoring: 1st-year intensive monitoring and reviews at subsequent years (2, 3, 5).

Core institutions and roles:

NVRC: lead registration and standard protocols

NASC: certification.

NACGRAB (Genebank) / NARIs: characterization and technical backstopping.

NARIs: characterization, on-station trials and technical backstopping.

State Ministries/extension: on-farm trials, CSB linkage etc.

CSBs, farmer organizations and private seed enterprises: seed production and marketing.

One Year Action Plan:

Convene national task team comprising stakeholders including NVRC, FMAFS, NARIs, NASC, FMSTI, NACGRAB, NBRDA, NAQS, NBMA, 3 pilot States, farmer reps, CBOs, etc.

Select 3 pilot States and shortlist 3–5 NUS landraces per state with farmer confirmation.

Run a 3-day capacity workshop (regulators, CSBs, farmer reps, NARIs etc, (adapt the Nepal workshop model).

NVRC develops in collaboration with relevant stakeholders a simplified registration template.

Design seed-multiplication plans and identify modest public/partner seed grants.

Indicators of success:

At least 3 pilot dossiers submitted.

Trained CSBs managing sourced seed on quality protocols.

Local government or state funding committed for seed production and promotion.

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16. From Forgotten to Formal: Integrating Orphan Crops into Africa's Seed Trade Systems

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Abstract

Introduction

Orphan crops, also referred to as neglected and underutilized species, represent a strategically important yet persistently marginalized component of Africa's agricultural biodiversity. These crops have sustained millions of rural households for generations and continue to contribute to food security, dietary diversity, nutrition, and climate resilience, particularly in environments where major staples underperform. Despite their agronomic and nutritional value, orphan crops remain weakly integrated into formal seed trade systems due to regulatory, technical, market, and institutional barriers.

Materials and Methods

A scoping review was conducted to compile evidence from academic sources and expert insights. The search utilized various major databases available online. The review aimed to identify the technical and market factors needed for orphan crops to be incorporated into formal, regulated commercial seed systems in Africa. It specifically looked at the triggers and enabling conditions essential for facilitating this integration.

Results and Discussion

Current seed policies and variety release systems often privilege uniform, commercially bred crops, while orphan crops and farmer-managed varieties frequently fail to fit conventional DUS/VCU requirements, lack harmonized certification standards, and face exclusion from regional trade frameworks. At the same time, limited research investment, weak private-sector incentives, fragmented value chains, and low consumer awareness continue to suppress demand and constrain commercialization. This paper argues that integrating orphan crops into Africa's seed trade systems requires a more enabling policy environment that balances innovation, biodiversity conservation, and inclusive market development. It highlights the potential of biotechnology, plant breeding innovations, participatory approaches, public-private partnerships, and consumer-focused market strategies to improve productivity, palatability, and acceptance.

Conclusion

In a world facing climate uncertainty and increasing pressure on food systems, these resources are not optional; they are essential. Yet, they remain under-recognized, under-characterized, and underutilized.

Formalizing orphan crops within seed systems offers a pathway to transform these overlooked crops from subsistence resources into scalable instruments for resilience, nutrition, and agricultural transformation across Africa. However, there is a need for harmonized regulations, science-based seed standards, and

stronger intellectual property frameworks to stimulate investment while ensuring equitable access. The path forward is clear (i) preserve local and indigenous crops as vital genetic capital (ii) invest in their scientific characterization and improvement, (iii) integrate them into market-driven, climate-resilient food systems, (iv) engage the Private sector as innovators, investors, and catalysts, (v) empower local communities as custodians and game changers of these resources and, (vi) promote multisectoral collaboration to join action to shift the focus from mere conservation to strategic use for resilience, productivity, and inclusive growth.

Today, we have the opportunity to act collectively. This conversation is critical for partners such as research organizations, development partners, the private sector, farmer organizations, civil society, government agencies, and all actors working at the intersection of crops, climate, and livelihoods.

This is bigger than not just about crops. It is about the future of the global food systems, ecosystems, and livelihoods.

Keywords: *orphan crops; neglected and underutilized species; seed systems; seed trade; variety release; DUS/VCU; seed certification; biotechnology; plant breeding; food security; climate resilience; Africa.*

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17. Exploration of Stable Blast Resistance in Uganda Finger Millet Germplasm

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Introduction

Small millets, especially finger millet (Eleusine coracana (L.) Gaertn), are gaining recognition as climate-resilient "nutri-cereals" contributing significantly to food, nutrition, and income security of smallholder farmers (Hamba et al., 2024). However, finger millet blast disease, caused by the fungus Magnaporthe grisea, remains the major biotic constraint affecting finger millet production globally, causing up to 90% yield loss (Babu et al., 2013; Takan et al., 2004). The pathogen is highly variable and affects finger millet at all growth stages, from seedling through grain formation (Adikini et al., 2021). Current blast management mainly relies on cultural practices such as the use of clean seed and maintaining an appropriate plant population (Kasule et al., 2023). However, poor adoption of these practices by farmers has further promoted pathogen spread. Chemical control, though effective, is very costly and not safe for the environment. Host-plant resistance is the most cost-effective, secure, and practical way to manage the disease. Therefore, identifying stable and broad-spectrum resistance is crucial for sustaining productivity and ensuring food security. This study, therefore, aimed at determining new stable sources of blast resistance in selected finger millet genotypes in Uganda.

Materials and Methods

In this study, a total of ninety-seven diverse finger millet genotypes, including introductions, landraces, improved varieties, and gene bank materials, were evaluated for resistance to leaf, neck, and finger blast across two locations: the semi-arid (NaSARRI) and the humid (Ikulwe) environments. The assessment was conducted for two seasons, 2023A and 2023B, using an alpha-lattice design, and a susceptible finger millet genotype (MASENO 60D) was used as a spreader row in each 2 m-long row plots, with three replications. Data on disease incidence was taken by counting and recording the number of infected plants per plot. Disease severity was assessed using a 1-9 scale for leaf blast, 1-5 for neck, and visual percentage of blast florets for finger blast, which was then adjusted to a 1-5 scale. Stability analysis by Eberhart and Russell (1966) was performed to detect consistent genotypic response to the disease pressure.

Results and Discussion

Significant genetic variability was observed among the genotypes for agronomic and disease resistance traits, indicating substantial potential for genetic improvement. This was observed in the field with some genotypes exhibiting only mild symptoms that never advanced further, a finding similar to that of Manyasa et al. (2019). Genotypic performance differed significantly ($p \leq 0.001$) across environments, and significant genotype × environment (G × E) interactions were observed for leaf, neck, and finger blast incidence and severity. This was attributed to prevailing environmental conditions such as rainfall, relative humidity, and high temperature, which favor blast development (Ojha et al., 2024). Similar findings were reported in rice, where more rainfall was found to favor blast development (Miah et al., 2017).

Table 1. Mean squares for the distribution of blast and agronomic traits recorded on 97 finger millet genotypes evaluated across four environments

Source of variation	**d.f**	**LBSEV**	**NBSEV**	**FBSEV**	**DTF**	**PH**	**YLD**	**SDW**	**PT**
Genotype (Gen)	96	2.68***	2.60***	2.42***	319***	403***	1.61***	0.29**	3.40***
Environment (Env)	3	89.62***	7.79***	6.42***	4865***	19490***	43.51***	22.48***	407.0***
Gen x Env (G x E)	278	0.90***	0.35**	0.53***	46*	76***	0.59***	0.24*	2.50***
Residual	717	0.53	0.26	0.35	38	48	0.27	0.2	1.6
Mean		3.1	2.13	2.66	85.47	84.06	1.4	3.33	2.96
CV %		23.48	24.12	22.5	7.17	8.24	37.13	13.31	42.38

*, **, and *** = significance at P ≤ 0.05, ≤ 0.01, and ≤ 0.001, respectively, LBSEV – Leaf blast severity, NBSEV – Neck blast severity, FBSEV – Finger blast severity, DTF – Days to 50% flowering, PH – Plant height, YLD – Yield (t/ha), and SDW – Thousand seed weight '000', PT – Productive tillers

Furthermore, stability analysis revealed 22 genotypes with consistently stable resistance to blast across varying environments, reflecting stable expression of their genetic potential and highlighting their suitability for sustainable finger millet cultivation.

Figure 1: A pie chart showing the different possible sources of stable blast resistance in Uganda finger millet germplasm

Conclusion

This study highlights the stable sources of resistance to leaf, neck, and finger blast in finger millet germplasm. The observed significant genotypic variation for blast occurrence across environments reveals the possibility of stable resistance in some unique genotypes. Validation of this stable resistance in other agro-ecological zones (AEZs) and with diverse pathogen strains will be valuable for breeders in their conventional breeding for blast resistance in finger millet. These genotypes can also serve as valuable donors for breeding climate-resilient finger millet cultivars tailored to specific agroclimatic zones. Additionally, native finger millet genotypes emerged as valuable sources of stable blast resistance, emphasizing their vital role in crop improvement. Their conservation and enhancement will ultimately improve productivity, profitability, food and nutritional security in marginal ecosystems across Africa.

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18. Strengthening Plant Breeding Capacity for Opportunity Crops in Africa

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Extended Abstract

The idea for the African Orphan Crops Consortium (AOCC) was conceived by Howard-Yana Shapiro in 2011 after hearing a seminar about the dire problem of childhood stunting due to malnutrition plaguing Africa. A plant breeder/geneticist by training and then Chief Agricultural Officer for Mars Inc., Dr. Shapiro saw a science-based solution through genomic application to increase productivity and expand availability of naturally nutritious, traditional African food crops that had been considered 'orphan crops' due to the lack of scientific attention/study.

Endorsed by the African Union Development Agency AUDA-NEPAD and supported through an uncommon collaboration of 48 public/private/government organizations, the AOCC advanced a 3-pronged approach. 101 traditional African crops addressing key nutrient deficiencies were identified, and targeted for DNA sequencing. Efforts to sequence and annotate these African Orphan/Opportunity Crops (AOCs) were undertaken by consortium members and network partners. At the same time, African scientists were trained through the AOCC's African Plant Breeding Academy in the latest proven technologies, software, and methods to effectively utilize DNA-based information and approaches for faster development of varieties with the combination of traits that farmers want and consumers need. The Academy offers 2 intensive 6-week programs to working professionals, one directed to plant breeders and the other to plant molecular biologists.

To date, 183 African scientists employed in national programs in 28 countries have been empowered in their fight against malnutrition in their communities. Collectively, they work to improve yield, disease resistance, stress tolerance and quality in their respective crops of national priority, using the genomic resources generated to date for 77+ AOCs. Multi-disciplinary teams assemble the traits demanded by value chain stakeholders, and national programs distribute seed of improved varieties regionally. Some of the national programs now represent centers of agricultural innovation as cutting-edge genomic technologies are applied to address nutritional needs.

The AOCC's Academy also sparked another unexpected yet critical outcome: collaboration. A Movement has begun, with African scientists networking across the continent to pool testing resources, devise breeding strategies, and share information. AOCC Alumni established the continent-wide African Plant Breeding Association (APBA) and hold biennial meetings to facilitate ongoing learning, collaboration, and information sharing.

Collaborations amongst Alumni have contributed to $190+ million USD in external funding for national programs being raised, and significantly greater advancement that could be made individually. Over 239 new, improved varieties representing 29 different crops have been released by Academy Alumni since

completion of the AOCC course. And 665 peer-reviewed publications have been authored by Academy Alumni, many in premier scientific journals and demonstrating leadership in key R&D areas.

In 2027, the AOCC will launch its Phase 2, focusing on mentorship and technical support of multi-disciplinary crop teams through varietal release and helping to facilitate value chain development, with particular emphasis on the needs and success of smallholder farmers growing these new varieties and their households. A survey of AOCC Alumni in July 2025 revealed greater pressure on smallholder farmers due to climate disasters and political conflicts. Crop improvement scientists have highlighted the need for more support to the farmers they serve, especially in access to quality seed of improved varieties, agronomic management, and market growth.

In Phase 2 from 2027 to 2032, AOCC aims to establish 2 hubs, one in East Africa centered in Kenya/Ethiopia and one in West Africa centered in Ghana/Benin/Nigeria, with each hub coordinating multi-disciplinary teams for 3 to 4 crops of high importance to the region. Hubs will spotlight innovation in national programs and focus on demand-led varietal improvement.

Surveys are required to thoroughly understand regional nutritional gaps to be addressed through dietary inclusion of African Orphan/Opportunity Crops (AOCs) in formulating an overall strategy to achieve year-round balanced diets supporting good health.

AOCC is exploring potential new partners with connections throughout crop value chains, including organizations involved in foundation seed production and seed/clonal delivery systems, extension, and entrepreneurial development. Extension efforts will include outreach to smallholder households to maximize nutritional benefits and address nutritional gaps in rural communities by region, as well as support to farmers in managing crop production to boost their productivity and profitability.

The AOCC Movement continues to strengthen plant breeding capacity across the African continent, equipping and enabling African crop improvement scientists in their quest to quell hunger and malnutrition. The AOCC is about empowering Africans as they ignite and fuel a Green Revolution for Africa.

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PART III

Production Systems, Agronomy and Mechanization

19. Technical Efficiency of Sorghum Production in Nigeria: Evidence from Stochastic Frontier Analysis

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1. Introduction

Sorghum is among the oldest cultivated cereals globally and plays a critical role in ensuring food security in semi-arid regions. Nigeria is one of the world's leading producers of sorghum; however, the crop remains relatively underutilized compared to maize and rice despite its adaptability to drought, poor soils, and climate variability (FAO, 2022). Sorghum contributes significantly to traditional diets, livestock feed, and industrial applications such as brewing and flour processing. Nevertheless, productivity remains low due to inefficient resource utilization, poor access to improved technologies, and weak value chain integration (Akinseye et al., 2020). Measuring farm-level efficiency provides insights into how existing resources can be better utilized without necessarily increasing input quantities. The Stochastic Frontier Analysis (SFA) model is widely applied in agricultural efficiency studies because it separates random shocks from managerial inefficiency (Coelli et al., 2005).

This study therefore, assesses the technical efficiency of sorghum farmers in Nigeria and identifies key factors influencing productivity. Evaluate production efficiency of sorghum farmers in Nigeria using Stochastic Frontier Analysis (SFA), Identify key production inputs influencing output, Provide policy recommendations for improving efficiency.

2. Material and Method

2.1 Study Area:

The study was conducted in Nigeria among sorghum-producing farmers. Sorghum (Sorghum bicolor L. Moench) is one of the most important cereal crops cultivated across the savannah agro-ecological zones of the country, where it serves as a major source of food, feed, and industrial raw material. The study area is characterized by a tropical climate with distinct wet and dry seasons, suitable for sorghum production. Farming activities in the area are predominantly undertaken by smallholder farmers who rely on family and hired labour for crop production.

Sample and procedures:

Primary data were collected from 300 sorghum farmers using a structured questionnaire. Information obtained included farmers' socio-economic characteristics such as age, educational level, farming experience, household size, access to extension services, gender, and access to credit. Farm-level production data on output, farm size, quantity of fertilizer applied, seed used, chemical inputs, family labour, and hired labour were also collected for the production season under study.

2.2 Analytical Framework

A Cobb–Douglas stochastic frontier production function was employed to estimate technical efficiency. Parameters were estimated using Maximum Likelihood Estimation.

Model Specification:

$\ln Y = \beta 0 + \beta 1 FarmSize + \beta 2 Fertilizer + \beta 3 Seed + \beta 4 Chemical + \beta 5 FamilyLabour + \beta 6 HiredLabour + vi - ui$

3. Results and Discussion

Variable	Coefficient	Effect on output
Constant	1.8398	Baseline productivity
Farm Size	1.2294	Strong positive effect
Fertilizer	0.0818	Yield-enhancing input
Seed	-0.1116	Inefficient utilization
Chemical	0.0429	Improves production
Family Labour	-0.0684	Labour inefficiency
Hired Labour	0.0075	Slight productivity gain

3.2 Discussion

Farm size exhibited the highest positive elasticity, suggesting economies of scale in sorghum production. This finding aligns with previous studies indicating that land expansion enhances cereal productivity in Nigeria (Abdulai & Huffman, 2014).

Fertilizer application positively influenced output, highlighting the importance of soil fertility management in savannah agro-ecological zones. However, the small coefficient implies suboptimal fertilizer application rates.

The negative seed coefficient indicates possible problems with seed quality, inappropriate spacing, or lack of improved sorghum varieties. Similar inefficiencies have been reported among smallholder cereal farmers in West Africa (Akinseye et al., 2020).

Family labour showed a negative effect on productivity, suggesting labour redundancy or low technical skills among household workers. This supports findings that labour productivity rather than labour quantity determines efficiency outcomes.

Overall, the results reveal that sorghum farmers operate below the production frontier, indicating significant potential for output improvement without increasing production costs.

4.0 Policy Implications for Enhancing Sorghum Production

Sorghum is a resilint cereal crop with the potential to significantly contribute to food security and economic development. The following policy implications outline strategic measures to optimize sorghum production and support farmers.

Strengthen dissemination of improved sorghum varieties.

Promote climate-smart sorghum production technologies.

Improve farmer access to extension and advisory services.

Encourage mechanization to reduce labour inefficiency.

Develop sorghum value chains linking farmers to industry.

5.0 Conclusion

Sorghum remains a strategic but underutilized crop capable of enhancing Nigeria's food system resilience. The SFA results demonstrate substantial technical inefficiency among farmers driven mainly by improper input allocation. Improving production efficiency through research support, institutional interventions, and technology adoption can transform sorghum into a competitive commercial crop.

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20. Mechanization Pathways for Opportunity Crops: Unlocking Smallholder Agriculture Transformation in Eastern and Southern Africa

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Introduction

Smallholder farmers in Eastern and Southern Africa are the custodians of local or Indigenous crops/ seed which in this paper are referred as opportunity crops. Despite their efforts, their farming is under-mechanized, agricultural mechanization is increasingly recognized as a critical driver for transforming smallholder agriculture in Eastern and Southern Africa.

Despite agriculture contributing significantly to employment and livelihoods, many farmers continue to rely on manual labor and animal traction, resulting in low productivity, high post- harvest losses and limited participation in agricultural value chains.

Opportunity crops such as maize, rice, cassava, sorghum, millet, sunflower, sesame, cotton, pulses, fruits, vegetables and sugarcane present significant potential for food security, industrialization, trade and income generation. However, realizing this potential requires mechanization pathways that are crop-specific, scale-appropriate, climate-resilient and integrated across the value chain.

Recent continental and regional Agri-food System Strategies, including the CAADP Kampala Declaration 2026 -2035, East African Community Regional Agri-Food Systems Investment Plan (EAC RASIP 2026 - 2035) and the Southern African Development Community Regional Agricultural Investment Plan (SADC RASIP 2026 - 2035), identify mechanization as a key enabler of agricultural transformation and rural development.

Materials and Methods

This paper draws on consultations done with smallholder farmers members of ESAFF in eastern and southern Africa, review of regional agricultural investment frameworks, mechanization strategies, value chain studies and smallholder farming systems across Eastern and Southern Africa.

Particular attention was given to opportunity crops prioritized for food security, agro- industrialization, climate resilience and market competitiveness. The analysis examined mechanization requirements across the production, harvesting, post-harvest, processing, storage and marketing stages of selected crop value chains. Regional priorities contained within the EAC and SADC agricultural investment frameworks were also reviewed to identify policy directions for mechanization development.

Results and Discussion

For smallholder farmers, mechanization is about providing the right technologies for the right crops, farming systems, and value chains. When appropriately designed and implemented, mechanization can increase productivity, reduce drudgery, strengthen climate resilience, reduce post-harvest losses across Eastern and Southern Africa. Established in 2002 during the World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa, ESAFF is a small- scale farmer-initiated, farmer-led and farmer-owned movement. The organization was created to provide a common platform through which small-scale farmers can collectively influence agricultural and rural development policies and practices at local, national, regional, and global levels. https://esaff.org/index-php/about-esaff losses, improve value addition, create employment opportunities for women and youth and enhance the competitiveness of smallholder farmers in local, regional and international markets.

The following sections examine key opportunity crops in the region and the mechanization interventions required to unlock their potential for inclusive and sustainable agricultural transformation.

Opportunity Crop Clusters and Mechanization Requirements

The analysis shows that mechanization opportunities across ESAFF's 16 member countries are concentrated around several major crop and farming system clusters. These include rice-based systems, maize and cereal systems, root and tuber systems, oilseed systems, pulse and legume systems, cotton and fibre systems, sugarcane systems, horticulture systems and livestock production systems. While specific crops vary across countries, common mechanization challenges include labour shortages, low productivity, high post-harvest losses, limited processing capacity and inadequate access to machinery services.

Table 1: Opportunity crops and mechanization needs in Eastern and Southern Africa:

Cluster	**Countries**	**Major Opportunity Crops**	**Priority Mechanization Needs**
Rice-Based Systems	Madagascar, Tanzania, Uganda, Burundi, Rwanda, Kenya, DR Congo	Rice	Power tillers, rice transplanters, mechanical weeders, threshers, dryers, milling machines, irrigation systems
Maize and Cereal Systems	Tanzania, Kenya, Uganda, Zambia, Zimbabwe, Malawi, South Sudan,	Maize, Sorghum, Millet, Wheat	Tractors, planters, seed drills, shellers, threshers, combine harvesters, grain dryers, storage silos
Root and Tuber Systems	Uganda, Rwanda, Burundi, DR Congo, Madagascar, Malawi, Tanzania	Cassava, Sweet Potato, Irish Potato	Ridgers, planters, harvesters, chippers, graters, dryers, flour processing equipment
Oilseed Systems	Tanzania, Malawi, Zambia, Zimbabwe, Mozambique, South Africa, Eswatini	Sunflower, Sesame, Soybean, Groundnuts	Precision planters, threshers, oil presses, decorticators, packaging equipment
Pulse and Legume Systems	Tanzania, Kenya, Uganda, Rwanda, Malawi, Zambia, Zimbabwe	Beans, Cowpeas, Green Grams, Pigeon Peas	Planters, threshers, cleaners, graders, packaging equipment
Cotton and Fibre Systems	Tanzania, Zambia, Zimbabwe, Malawi, Mozambique, Uganda	Cotton	Planters, sprayers, harvesting equipment, transport systems, ginning machinery
Sugar and Industrial Crop Systems	Eswatini, Malawi, Zambia, Tanzania, Zimbabwe	Sugarcane	Land preparation equipment, irrigation systems, loaders, transport

Cluster	Countries	Major Opportunity Crops	Priority Mechanization Needs
			machinery, processing equipment
Horticulture Systems	Kenya, Tanzania, Uganda, Rwanda, Burundi, Madagascar, South Africa, Eswatini	Fruits, Vegetables, Avocado, Mango, Onion, Tomato, Irish Potato	Irrigation pumps, greenhouse technologies, sprayers, cold storage, grading, sorting, packaging equipment
Livestock and Dairy Systems	Kenya, Tanzania, Uganda, Rwanda, Zambia, Zimbabwe, Botswana, Eswatini, Lesotho	Dairy, Beef, Small Ruminants	Fodder choppers, feed mixers, milking machines, milk cooling tanks, feed processing equipment

Conclusion

Mechanization pathways for opportunity crops in Eastern and Southern Africa must go beyond simply increasing the number of tractors. Favourable national and district policies on opportunity crop mechanization for smallholder farmers, effective mechanization requires crop-specific, scale- appropriate, and climate-smart technologies that are integrated across agricultural value chains. For smallholder farmers, mechanization should increase productivity, reduce drudgery, strengthen resilience, and improve market participation.

Importantly, the CAADP Kampala Declaration 2026 – 2035, EAC Regional Agri-Food Systems Investment Plan (2026–2035) and the SADC Regional Agrifood Systems Investment Plan (2026– 2035) identify mechanization as a strategic priority for agri-food systems transformation. Their implementation will be critical for expanding access to appropriate technologies, reducing post- harvest losses, promoting value addition, and unlocking the potential of opportunity crops across Eastern and Southern Africa.

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21. From Neglect to Value: Unlocking Nigeria's Opportunity Crops

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Abstract

Nigeria possesses a wide range of underutilized and underexploited crops with significant nutritional, agronomic, and industrial potential. These crops, often referred to as opportunity crops, include indigenous fruits, vegetables, roots, spices, oil crops, grains, and fiber crops that can contribute substantially to food security, health, resilience, and economic development across Africa. Despite the country's rich biodiversity, only a small proportion of edible plant species are widely cultivated and commercialized. This work highlights selected Nigerian opportunity crops and proposes strategies for their sustainable utilization and value addition. Major barriers to the adoption of these crops include low awareness of their value, poor seed availability, limited processing technologies, and outdated post-harvest practices. In response to these challenges, strategies such as the establishment of gene banks, integration of opportunity crops into national research and development programs, development of improved processing technologies, and increased public awareness campaigns are recommended. As part of efforts to increase awareness and highlight their importance, a table was developed to summarize their nutritional benefits and industrial applications. The adoption of solar dryers and simple mechanized tools can also improve processing efficiency and reduce post-harvest losses. The sustainable development of opportunity crops can diversify food systems, reduce hunger and malnutrition, improve rural livelihoods, and strengthen climate resilience. Unlocking the potential of these neglected crops requires collaborative efforts among researchers, policymakers, farmers, and industry stakeholders.

Introduction

Biodiversity is the collective of ecosystems, species, and genes which together comprise the earth (Shannan and Grant, 2007). Crop biodiversity is the key to crop and dietary diversification, and indeed human well-being and survival (Lutaladio et al., 2010). Around 30,000 of the total of approximately 250,000 flowering plant species in existence are edible, yet only a few crop species are utilized for food production throughout the world (Padulosi et al., 2001). Biodiversity is fundamental for ecosystem functioning, sustainable production (Jacobsen et al., 2013) and the attainment for food and nutritional security (Chappell and LaValle, 2011). Biodiversity conservation achieves two of the United Nations SDGs: halving the proportion of people who suffer from hunger and ensuring environmental sustainability.

Objectives

Document the diversity and current status of Nigeria's underutilized crop species.

Assess their nutritional, agronomic, and economic potential.

Identify barriers to their utilization and propose practical solutions.

Strategies for Unlocking Nigeria's Opportunity Crops

Identify and cultivate opportunity crops through targeted farmer and research programs

Establish gene and field banks to conserve genetic diversities for full exploitation.

Integrate opportunity crops into national R&D programs with dedicated funding and policy support

Raise public awareness using media, social platforms, and extension agents

Link producers to industry for processing, marketing, and value addition

List of Selected Opportunity Crops

Fruits: African star apple, Pumpkin, Snake Tomato

Vegetables: Black nightshade, Fireweed

Roots: Sweet potato, Cocoyam

Spices: African basils, African nutmeg

Oil crops: Castor, Beniseed/Sesame

Grains: Sesame, Fonio

Fibres: Jute mallow, Kenaf, Raffia palm

Key Barriers and Proposed Solutions

Key barriers include low awareness of the crops and their values among stakeholders, seed availability, difficulties in processing due to hard fruit exocarp and labor-intensive methods and outdated post-harvest practices like sun drying of crops. Proposed solutions include the development of food composition table, agronomic packages and industrial potentials for the crops, establish seed banks and the use of biotechnology, introduce simple tools to ease cultivation and processing (Figure 1 and Figure 4) and adopt solar dryers and other improved methods to foster effective & sustainable value addition (Figure 2 and Figure

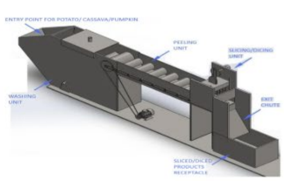

Figure 1: Processing Machine For pumpkin, sweet potato etc
Source: Oloyede & Olukayode, 2023

Figure 2: Parabolic Solar Drier (Inner View)
Source: Nigerian Stored Products Research Institute (NSPRI)

Figure 3: Parabolic Solar Drier (Outer View)
Source: Nigerian Stored Products Research Institute (NSPRI)

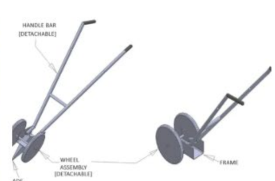

Figure 4: Manual tiller
Source: Oloyede & Olukayode, 2025

Table 1: Selected Nigerian Opportunity Crops: Nutritional Uses and Industrial Potential

	Selected Opportunity Crops	Usage & Nutritional Benefits	Industrial Potential
1	*Cucurbita pepo* L.-Pumpkin "Elegede"  a. Young shoot "Gboro" b. Young fruit "Kundu" c. Green pumpkin d. Orange Pumpkin e. Seeds "Egusi"	**Shoot as leafy vegetable "Gboro". Young fruit also as vegetable "kundu". The fruit of Orange cultivar used like tomato & carrot. The fruit of Green cultivar as Irish potato. Seed as "egusi" melon.** 20 to 30% protein 80 to 90% antioxidant activities The seed has over 50% fat content. The seed has about 60% omega-3 fatty acids i.e. twice that of cod liver oil	• Food: Wheat flour alternative • Animal feed (seeds) • Nutraceuticals (all parts) • Edible Oil (seeds) • Biodiesel (seeds)
2	*Trichosanthes cucumerina* L.-Snake tomato "Tomati elejo"  a. Unripe fruits b. Ripe fruit c. Red pulp in the fruit d. Seeds	**Fruit Vegetable used as alternative to the regular tomato** carbohydrate (-), protein (2.06%), crude fat (0.90%), moisture (88.8%), ash (0.76%) and crude fiber (1.63%). Total sugar (0.61%) Ascorbic acid (20.3 mg/100g)	• Food: Tomato Paste • Edible Oil (seeds) • Nutraceuticals (all parts) • Biodiesel (seeds)
3	*Solanum macrocarpon* L.-African eggplant "Igbagba "  a. Plant with it's flower b. Plant with it's fruit	**Used as leaf vegetables (potherb) alone and with "egusi" melon** Carbohydrates (58.15%), proteins (28.06%), crude fat (1.98%), moisture (5.03%), ash (4.80%) and crude fiber (1.96%). The mineral compositions are: iron (0.013 mg/100g), calcium (0.06 mg/100g), magnesium (253.20 mg/100g) and manganese (2.27 mg/100g).	• Green corrosion inhibitors for metal industries • Nutraceutical and functional food ingredients from leaf flour/extracts • Source of glycoalkaloids for pharmaceutical synthesis
4	*Sesamum indicum* L.-Sesame "Eku"  a. Matured Capsules b. Dried Seeds	**Grains used as flour, Wheat flour alternative and Domestic oil and snacks** Protein: whole seeds: 17-18%; Defatted: 40-50%; Carbohydrate (51.36 - 54.44%), Iron (6.41 - 6.44; mg/100g), Potassium (1.06 - 1.09 mg/100g) Flavonoids (12.34 - 12.37 mg/100g); Alkaloids (10.28 - 10.31 mg/100g); Antioxidant properties - DPPH (35.20 - 35.47%). Oil content 50-55% Mostly unsaturated:- ~42% oleic acid (Omega-9 fatty acid)and ~44% linoleic acid (Omega-6 fatty acid)	• Foods • Animal feeds (defatted seeds) • Medicine • Cosmetics • Confectionery, biscuits, and bread

Conclusion and Recommendations

Underutilized plant species have strong potential to reduce hunger, poverty, and nutritional deficiencies across Africa. Diversifying into opportunity crops, or adopting alternatives to over-cultivated staples, can help mitigate the impacts of climate change, pests, and diseases. The adoption of appropriate technologies and innovations is needed to improve and simplify crop processing. Collaborative research is essential for promoting the industrialization of African opportunity crops. Develop strong value chains linking farmers to markets and industry.

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22. Creating Novel Research, Development and Networking Pathways to Advance Agronomic Practices for Opportunity Crops

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Introduction

West Africa and the Sahel are experiencing some of the most intense impacts of climate change. Thus, agriculture, which heavily relies on rainfall, is highly susceptible to these changes. In this context, there is a widespread agreement that West African and Sahelian food systems need to be transformed to adapt to the changing climate. This is because current food systems heavily rely on the major staple crops such as wheat, maize, and rice, which have undergone advanced breeding programs to enhance yield and palatability but at the cost of genetic diversity (Krug et al., 2023).

For instance, among the mitigation approaches to climate change, especially to drought caused by El Nino, is cultivation of underutilized crops like fonio (Digitaria exilis) (World Food Programme, 2024). Despite its ancient heritage, and potential as a climate-smart crop, information on fonio cultivation, management, distribution, and genetic diversity are limited. Neglected and underutilized species (NUS) are receiving low attention from mainstream research in terms of innovative strategy to boost their productivity, breeding resources, and increase in its consumption (Sonko et al., 2022). Additionally, the inadequacy of scientific documentations on fonio cultivation and agronomic innovations complicate its acceptance into mainstream food production chain (Adoukonou-Sagbadja et al., 2006).

Neglected and underutilized species (NUS), such as fonio and bambara groundnut and tef can play a vital role in making Africa food systems more sustainable and resilient. However, these crops are not extensively studied therefore, their agronomic practices are not very advanced and have not been widely adopted.

Good agronomic practices are techniques that optimize crop production, maintain soil health, and promote sustainable farming, and include:

Crop rotation

Soil management and conservation

Integrated pest management (IPM)

Efficient water use

Use of high-quality seeds

Crop rotation

Alternating crops in a planned sequence improves soil fertility, balance nutrients use, and breaks pest and disease cycles, leading to healthier harvests and reducing chemical dependency.

Bambara groundnut (Vigna subterranea (L.) Verdc) contributes to soil fertility through biological nitrogen fixation making it beneficial in crop rotations and intercropping, hence farmers do not normally apply chemical nitrogen fertilizers to Bambara groundnut (Mkandawire, 2007).

Soil management and conservation

Soil fertility management should start with preserving the soil from erosion and degradation and include practices that feed the soil with organic matter.

Practices such as reduced and zero tillage and leaving crop residues on fields to preserve soil structure, prevent erosion, enhance moisture retention, and support beneficial soil organisms.

Nutrient management

Using organic fertilizers and applying chemical fertilizers according to soil tests ensuring crops receive adequate nutrients while minimizing environmental impact. This maintains long term soil fertility and productivity.

Bambara groundnut is also a legume crop that fixes atmospheric nitrogen for its growth. It fixes 20 – 100 kg N ha-1 (Musa et al., 2016) and improves soil nutrient status, especially nitrogen status, because of its nodulation process which traps nitrogen from atmosphere. Bambara groundnut can contribute to improving soil fertility through several mechanisms and processes, which would correlatively increase the yields of the crops in situ and subsequently. In the degraded and low fertility soil, Bambara groundnut can get better in the characteristics of soil and a good source of N, P and K for the plant (Aziz et al., 2017). It could be used to promote sustainable agriculture in the context of climate change, marked by poor soil and insufficient rainfall

Integrated pest management (IPM)

IPM combines biological, cultural, and mechanical methods to control pests and diseases, reducing reliance on chemical pesticides and protecting ecosystems.

IPM for fonio is a holistic approach that integrates prevention, monitoring, biological control, and judicious chemical use. By adopting these practices, farmers can protect fonio crops from pests like spider mites, scale insects, and fungus gnats while promoting sustainable and environmentally friendly cultivation. Regular monitoring and early intervention are key to successful pest management.

Healthy soil and crop rotation are vital for pest prevention and fonio health

Efficient water management

Techniques like drip irrigation, monitoring soil moisture, and preventing waterlogging, optimize water use, conserve resources, and maintain healthy plant growth.

As for Eragrostis tef (Tef) water conservation methods have a substantial impact on tef phenology, yield components, overall yield, and soil moisture content. Among the various soil water conservation methods, the ridge and furrow (RF) water conservation method, characterized by closed furrow ends, was found to conserve water effectively and enhance Tef yield compared to flat planting (Desta et al., 2025).

Use of high-quality seeds

Seed is the basic input in agriculture, seed quality plays a crucial role in modern agriculture, acting as the foundation for crop productivity, food security, and sustainable farming. Quality seed is defined as the seed with highest physical purity, genetic purity, vigour, viability and free from pests and diseases. Quality seed ensures uniform crop stand, resistance to biotic and abiotic stresses, and optimal use of agro-inputs, and resulting in higher yields. The production of quality seed involves strict genetic, agronomic, and physiological standards from field level to storage. However, factors like improper field conditions, mechanical mixtures, poor post-harvest handling, and improper storage can lower seed quality. Low quality seeds result in poor germination, uneven crop growth, disease incidence, which finally leads to lower yields (Rajesh et al., 2025).

Selecting disease-free, high-yielding seeds and planting at the correct depth and time ensures optimal germination and crop performance.

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23. Distribution and Yield Impact of Taro Leaf Blight in Nigeria: Evidence from Farm-Level Analysis

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Introduction

Taro (Colocasia esculenta [L.] Schott) is an important staple root crop cultivated extensively across tropical and subtropical regions for food, income generation, and nutritional security. In Nigeria, taro contributes significantly to rural livelihoods and household food supply, particularly in the southern and middle belt regions (Oladimeji et al., 2025; Brasier et al., 2022). Several biotic and abiotic constraints affect taro production and productivity. Taro Leaf Blight (TLB) caused by Phytophthora colocasiae is the most destructive disease affecting the crop (Singh et al., 2022).

TLB is characterised by rapid foliar necrosis, extensive leaf damage, reduced photosynthetic efficiency, and severe yield losses under favourable environmental conditions (Bandyopadhyay et al., 2011). The disease has become a major limitation to sustainable taro production, contributing to the abandonment of its cultivation in favour of other crops (Oladimeji et al., 2025). Although there are reports of the occurrence of TLB in Nigeria, limited information remains on its distribution, severity, and associated yield losses across major production zones. The current study therefore aimed to assess the incidence of TLB across major taro-producing states in Nigeria and determine its effect on yield. The findings are expected to provide baseline information for disease management, resistance breeding, and sustainable taro production strategies.

Materials and Methods

Field surveys and disease assessments were conducted between August and October 2025 across 15 major taro-producing states in Nigeria (Figure 1). Farms were selected through purposive sampling based on taro production intensity. Data were collected on farmers' demographic factors, disease management practices, factors affecting production, seed source, agronomic practices, and yield from infected and non-infected fields during the study period.

Mean yield values were estimated annually and comparatively analysed to determine the impact of the disease on taro productivity. Descriptive statistics and graphical analyses were used to summarize disease incidence and yield trends across years and locations. All analyses were performed with R version 4.5.2 (R Core Team, 2025).

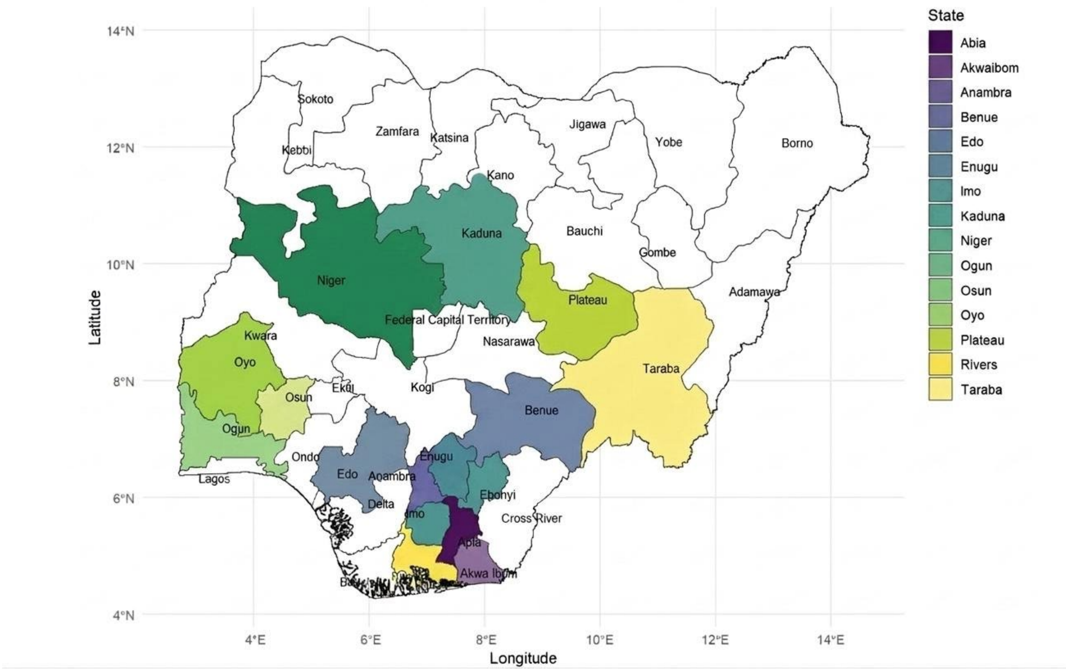

Figure 1: Map of Nigeria showing the surveyed states

Results and Discussion

The study revealed widespread occurrence of TLB across the surveyed states in Nigeria. In Rivers, Oyo, Osun, Niger, Imo, Anambra, and Akwa-Ibom states, disease incidence was of 100% (Figure 2). Enugu and Plateau states had disease incidence above 85%. Relatively lower incidence was observed in Taraba, Benue, and Abia states. TLB is highly prevalent across major taro-producing regions in Nigeria, with particularly severe outbreaks concentrated in the humid southern and central agroecological zones. The observed distribution is consistent with previous reports that humid tropical conditions favour the development and rapid spread of P.

colocasiae (Bandyopadhyay et al., 2011; Bose et al., 2023; Oladimeji et al., 2025). In addition to favourable environmental conditions for pathogen proliferation, continued cultivation of susceptible landraces and limited access to effective disease management practices could have contributed to the high prevalence of the disease across the sampled area.

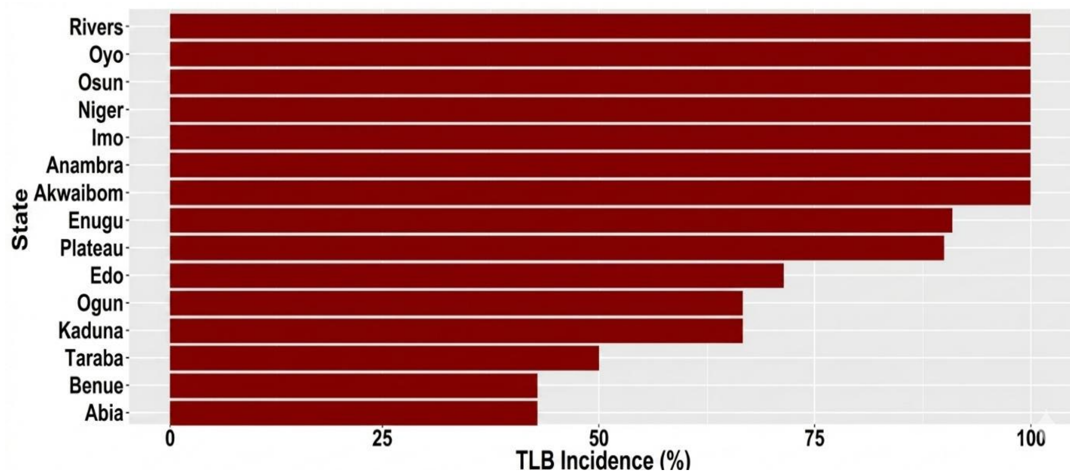

Figure 2. Taro Leaf Blight incidence across major taro-producing states in Nigeria

Farmer-reported taro yield showed a progressive decline from 2021 to 2024, with mean estimated yield decreasing from approximately 1,140 kg ha-1 to 805 kg ha-1 (Figure 3).

Respondents attributed the decline mainly to the increasing severity of TLB, which adversely affected crop growth and corm development. Furthermore, several farmers indicated that persistent TLB outbreaks had discouraged continued taro cultivation, leading to a shift toward alternative crops considered more productive and less vulnerable to diseases such as Maize, Yam and Cassava Both disease pressure and gradual abandonment of taro farming contributed to the declining average yield recorded in the study area. Similar yield declines in taro production associated with TLB outbreaks have been reported in Nigeria, where farmers identified TLB as a major constraint limiting taro cultivation and productivity (Oladimeji et al., 2025).

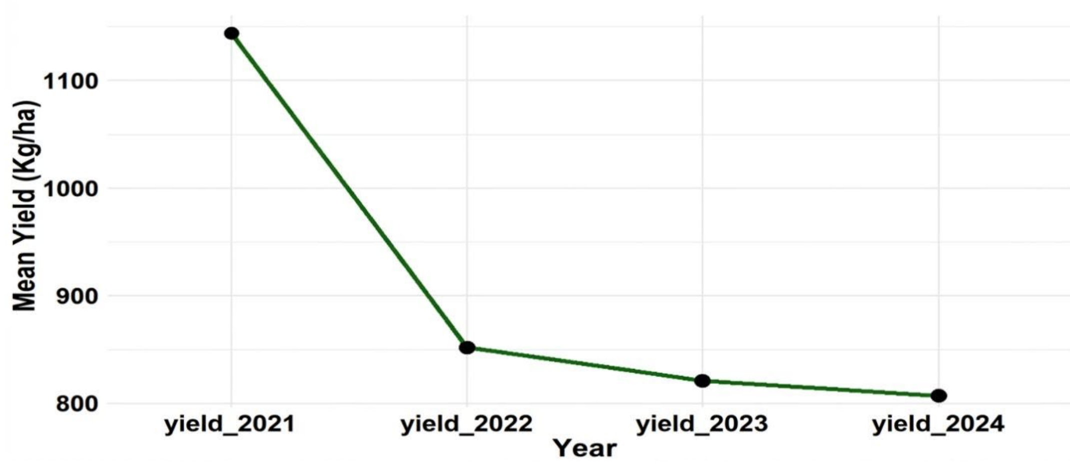

Figure 3. Mean taro yield trend between 2021 and 2024

Comparative yield analysis further showed that fields with less non-infected plants consistently produced higher yields than fields with TLB-infected plants throughout the study period. Mean yield in non-infected fields declined from approximately 2,500 kg ha-1 in 2021 to about 1,250 kg ha-1 in 2024, whereas infected fields consistently recorded lower yields ranging from approximately 650 to 900 kg ha-1 (Figure 3). The reduced yield observed in the infected plant fields indicates a detrimental effect of TLB on taro productivity. Severe foliar damage caused by P. colocasiae infection resulted in reduced photosynthetic efficiency, thereby limiting corm development and biomass accumulation (Bandyopadhyay et al., 2011; Bose et al., 2023;

Oladimeji et al., 2025). The persistent reduction in yield across fields with infected plants further indicates sustained disease pressure over the study period. The identification of TLB hotspot regions across Oyo Osun, Niger Imo, Anambra, and Akwa-Ibom states provides important information for targeted disease surveillance, breeding programs, and deployment of resistant germplasm, as previously emphasized in studies on TLB management strategies in taro production systems (Oladimeji et al., 2025). These findings highlight the urgent need for integrated disease management strategies involving resistant varieties, improved agronomic practices, and farmer awareness programs.

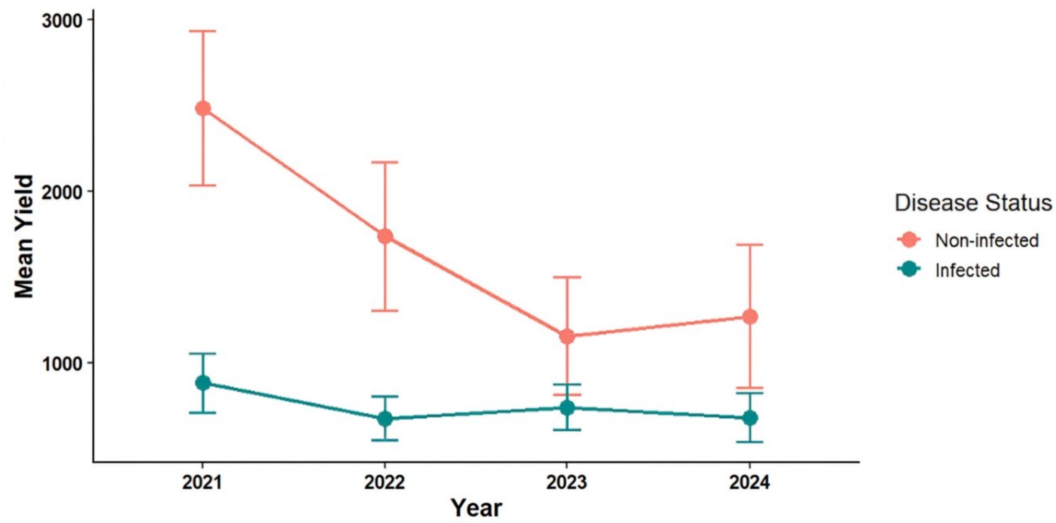

Figure 4. Decline in farmers' yield from 2021 to 2024

Conclusion

The current study provides additional evidence of the widespread occurrence and severe impact of TLB across major taro-producing states in Nigeria. Several states recorded extremely high disease incidence levels. The disease was associated with reduced taro productivity, as infected plants consistently produced lower yields compared to non-infected plants. The observed yield decline over time further suggests sustained disease pressure and highlights the vulnerability of commonly cultivated taro landraces to P. colocasiae infection. These findings underscore the need for strengthened disease surveillance, improved farmer awareness, and the development and deployment of TLB-resistant varieties to support sustainable taro production and food security in Nigeria.

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24. Local Producers' Capacity Building in Opportunity Crops: Integration and Agroecology Transition in Africa

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GROW West Africa

Background and Rationale

Africa's food systems face compounding challenges — soil degradation, climate volatility, and persistent malnutrition. A powerful yet underexploited solution exists within Africa's agricultural heritage: Neglected and Underutilised Species (NUS), or "opportunity crops," including cereals such as fonio and finger millet; legumes such as Bambara groundnut, pigeon pea, and African Yam Bean; and leafy vegetables such as African nightshade. Despite their documented micronutrient density and climate adaptability, globalisation has displaced these indigenous foodways in favour of Western dietary models (Maundu et al., 2013; Penafiel et al., 2011). Aligned with FAO's (2018) sustainable food systems framework, this study argues that NUS represent a biological bridge — supporting soil regeneration, agrobiodiversity, dietary diversification, and income generation for smallholder farmers, particularly women and youth — constituting a structural response to interlinked ecological and nutritional crises.

Objectives

This study evaluates targeted capacity building as a catalyst for NUS integration, focusing on: (1) the effectiveness of participatory agroecological training; (2) yield and behaviour change outcomes among trained producers; and (3) structural barriers limiting the translation of agroecological gains into sustainable livelihoods.

Materials and Methods

Drawing on field data from GROW West Africa's participatory agroecology framework, the study employs a farmer-led experiential learning model bridging indigenous knowledge — seed-saving and traditional soil management — with modern low-external-input practices: composting, biofertilisers, bacterial inoculants, crop rotation, and mulching. Training spans three levels: a residential youth programme (Work, Learn & Earn) for farmers aged 18–35; an executive farm management course for mid-career practitioners; and community-based extension outreach for women's groups and cooperative networks.

Results and Discussion

Between 2023 and 2025, GROW West Africa trained 94 youth, 13 farm managers, and over 3,000 farmers and women's groups. On 0.5 acres of demonstration land, Bambara bean yields increased from 250 kg per crop cycle in 2024 to 290 kg in 2025, surpassing Ghana's national production average and affirming the model's scalability. Trained producers showed significantly reduced dependence on chemical inputs and greater adaptive capacity in response to climate shocks. NUS crops proved natural entry points into agroecological transition, aligning with regenerative principles due to their drought tolerance and compatibility with intercropping systems.

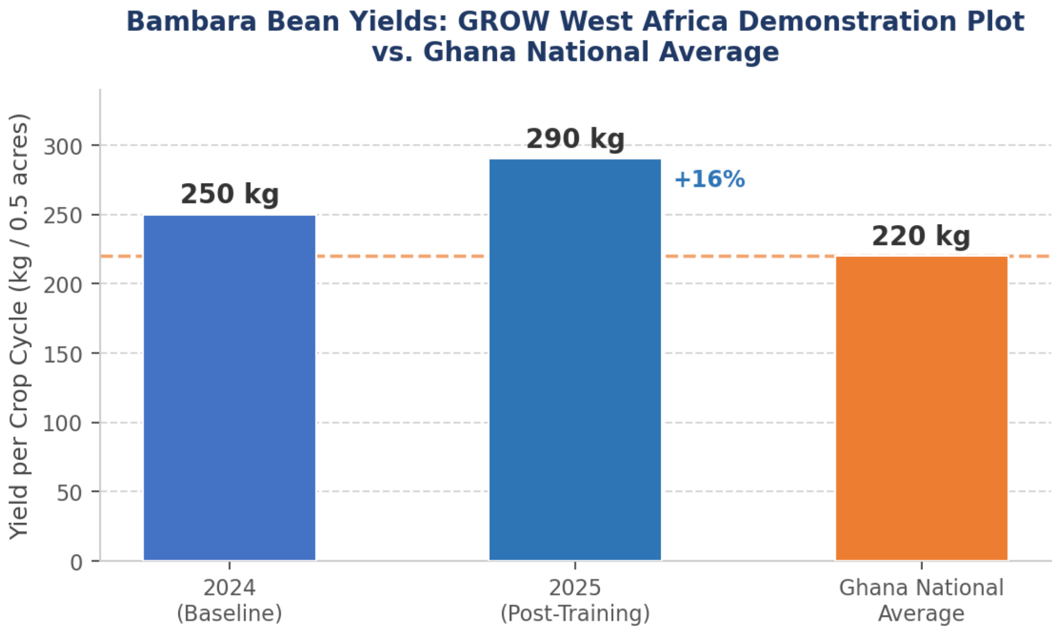

Figure 1. Bambara bean yields on GROW West Africa demonstration plot (2024–2025) vs. Ghana national average.

However, a critical "economic gap" persists: without post-harvest processing technology, value-addition infrastructure, and market linkages, producers cannot convert agronomic gains into sustainable livelihoods. This disconnect between farming progress and economic return remains the most urgent barrier to systemic change. Women and youth — primary custodians of seed diversity and food knowledge — are identified as lead agents for NUS commercialisation, underscoring the need for gender- and age-responsive programme design and targeted financing.

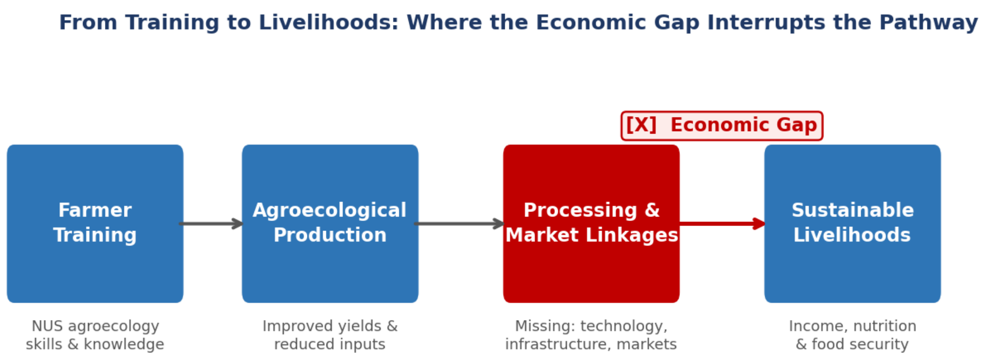

Figure 2. The pathway from farmer training to sustainable livelihoods, showing the critical economic gap.

Conclusion

Sustained NUS revitalisation demands systemic, multi-level action. This paper recommends formal integration of NUS into national agricultural extension services and school feeding programmes, scaling of farmer-to-farmer training networks, and prioritised investment in women- and youth-led processing enterprises. These interventions must be accompanied by policy frameworks recognising NUS as strategic crops, not niche commodities. Evidence from West Africa demonstrates that embedding opportunity crops within food system policy offers an evidence-based, equitable pathway to climate resilience, agrobiodiversity conservation, and inclusive rural economic development across sub-Saharan Africa.

Keywords: *Agroecology, Capacity Building, Biodiversity, Neglected and Underutilised Species (NUS), Smallholder Farmers*

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PART IV

Nutrition, Markets, Value Addition and Consumer Uptake

25. Seeds of Resilience: Market Opportunities in Neglected and Underutilized Cereal and Grain Crops in Africa

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Introduction

Africa's neglected and underutilized crop species (NUS) represent largely untapped source of nutritional and economic value. In context of FAO-FARA Regional Consultation on Opportunity Crops in Africa (Accra, June 2026), Seeds of Resilience Book series (Vol. 1 and Vol. 1–2) documents 30 NUS cereals and grains — including tef, fonio, sorghum, African rice (Oryza glaberrima), finger millet, Abyssinian oat, barnyard millet, dark-grain African rice, burga millet, and wild tef — spanning five crop families and three agroecological zones. Despite documented nutritional superiority, climate resilience, and agroecological fit, most of these crops remain locked at subsistence or undifferentiated commodity price levels. This paper, submitted under Theme 8 (Growing impact and building markets: business case for opportunity crops), presents quantitative market evidence for commercial potential of NUS cereals and identifies investment pathways to unlock that value.

Materials and Methods

Primary and secondary data compiled from Seeds of Resilience publication series (Vol. 1 and Vol. 1–2). The analytical framework comprised five components: (1) market intelligence and price benchmarking using retail and export price data from EU/US specialty food markets, diaspora retail channels, and African urban markets (2020–2026); (2) value chain mapping across five processing stages — farm gate, village-level processing, small processing units, export facilities, and full value chain enterprises; (3) comparative market analysis benchmarking NUS cereals against established specialty categories including quinoa, gluten-free grains, and functional food ingredients; (4) case study analysis of tef (Ethiopia), fonio (West Africa/EU), finger millet (East Africa), and dark-grain African rice (Nigeria/Kenya) as reference commercialisation trajectories; and (5) market sizing using FAOSTAT (2022) trade data, sector reports, and documented growth trend extrapolations. Crops classified by commercial readiness: Commercial (established value chains), Emerging (nascent formal markets), and Frontier (near-zero formal market but high replicable potential).

Results and Discussion

Global market backdrop is highly favourable. Gluten-free food market exceeds USD 7 billion growing at 8%/year; Anthocyanin ingredient market stood at USD 527 million in 2023, projected to reach USD 894 million by 2030 (7.8% CAGR); Beta-glucan functional food market stands at USD 500 million growing 8–10%/year; and global oat market is valued at USD 4.5 billion. African NUS crops hold verified entry points to all of these segments yet currently capture near-zero premium.

A steep price ladder exists from subsistence to premium market (Table 1). Farm-gate burga millet fetches USD 0.05–0.10/kg, while functional ingredients such as anthocyanin from dark-grain African rice command

USD 80–200/kg — a multiplier of 1,000–2,500x. EU retail tef flour reaches USD 8–18/kg and pharmaceutical-grade anthocyanin extracts up to USD 1,000–5,000/kg.

Table 1. NUS cereal price ladder from subsistence to premium market (2026 estimates)

Crop / Market Stage	Price (USD /kg)	Approx. Multiplier vs. Farm Gate
Burga millet — farm gate (Sahel)	0.05–0.10	1×
Sorghum — undifferentiated commodity	0.20–0.35	3–5×
Fonio / Finger millet — processed local urban	0.80–1.50	12–20×
African rice — quality export / diaspora	3.00–6.00	50–80×
Tef / Fonio — EU/US retail (branded, certified)	8.00–18.00	100–200×
Anthocyanin / Beta-glucan extract (functional ingredient)	80–200	1,000–2,500×

Source: Seeds of Resilience Vol. 1 & Vol. 1–2; FAOSTAT 2022

Crop-level findings confirm the scale of opportunity. Tef represents Ethiopia's most valuable cereal, with a domestic market of USD 2–3 billion and exports growing from near zero to USD 50–80 million in approximately a decade (20–30%/year growth). Fonio has accessed EU specialty retail at EUR 8–18/kg — comparable to quinoa — demonstrating the replicability of the premium trajectory. Sorghum, produced at 60 million tonnes per year across Africa, captures no heritage or quality premium despite the specialty grains sector growing at 8–12%/year. Dark-grain African rice (Ofada) constitutes a USD 50–150 million annual market in Nigeria alone, with anthocyanin ingredient potential in the USD 527 million global nutraceutical market. Frontier crops — burga millet, barnyard millet, and Abyssinian oat — currently have near-zero formal markets but carry USD 200–400 million, USD 20–50 million, and USD 10–30 million respective potential over 5–10-year horizons.

Investment analysis indicates accessible entry points at multiple scales: village-level mechanical huskers (USD 5,000–20,000) establish early export viability; small processing units (USD 50,000–200,000) generate 3–8× farm-gate gross margins; medium export facilities (USD 340,000–560,000) achieve 15–25% IRR with market linkages; and full value chain enterprises (USD 850,000–1.55 million) can reach USD 2–10 million in annual sales by years 5–10. Ambitious continental-scale value chain development could generate 2–3 million additional jobs across Africa.

Conclusion

Evidence demonstrates that billions of dollars in market value sit dormant in Africa's NUS cereal heritage. Commercialisation of tef, fonio, and Ofada rice proves trajectory is replicable. Conclusions of this work: (1) premium market access for NUS cereals is proven and scalable; (2) principal barrier is not demand but coordinated supply chain investment; (3) short supply chains and alternative retail structures that serve farmers — rather than commodity systems — are critical intervention point; (4) seed rescue and crop characterisation for frontier species must be treated as urgent, as genetic erosion forecloses future options;

and (5) public-private partnerships that share early-market risk while protecting smallholder value capture are most viable commercialisation model. It is recommended that regional roadmap emerging from this consultation include explicit targets for NUS market development, processing infrastructure investment, and export certification support at country level.

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26. Nutritional Quality and Consumer Acceptability of Turkey Berry Composite Tea

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Introduction

Micronutrient deficiencies in Sub-Saharan Africa remain a pressing public health issue. Neglected crops like turkey berry (Solanum torvum) offer promise of addressing this challenge due to their micro/macro nutrients and therapeutic potential. However, its bitterness limits direct consumption, though compositing with botanicals such as ginger and tangerine has been shown to improve sensory acceptability. Nevertheless, the effects of these composite formulations and brewing time on mineral release and consumer acceptance remain underexplored.

Objectives

Assess the effect of turkey berry composite formulations and brewing time on mineral release (Ca, Fe, Zn, P).

Evaluate consumer acceptability of turkey berry composite teas.

Materials and Methods

Ingredients were locally sourced, processed via solar or freeze-drying, and formulated into nine composites plus a control. A 10 × 3 factorial design tested brewing times, with nutritional analysis conducted using standard protocols. Consumer acceptability was evaluated with 120 untrained panelists using a 9-point hedonic scale, and data analyzed with Genstat, LSD, Duncan's test, and PCA.

Results and Discussion

Results revealed that extended brewing (10 min) and composites particularly, TCT A, D, E and I showed enhanced mineral release, consistent with prior findings of Soji et al. (2025). Sensory evaluations highlighted TCT D as most acceptable, excelling in aroma, flavour, and aftertaste, confirming synergistic improvements as suggested by Anggriani et al. (2023)

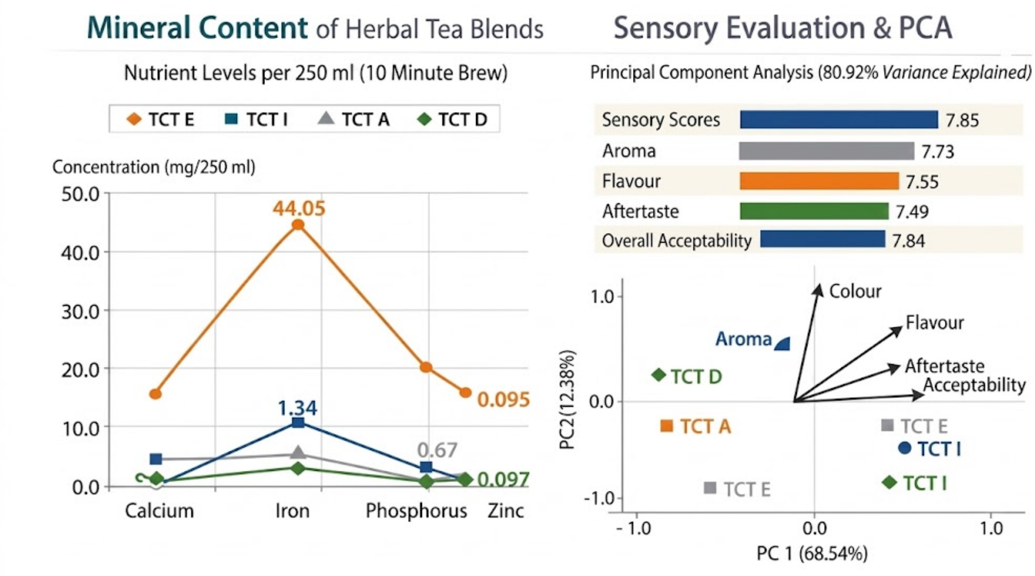

Figure 1: Mineral content and sensory evaluation of turkey berry composite tea. Where TCT A=59:21:20; TCT D=42:38:20; TCT E=51:29:30; TCT I=41:31:28 represent the ratios of turkey berry:ginger:tangerine.

Conclusion

In conclusion, turkey berry composite teas demonstrate enhanced nutritional yield and consumer appeal compared to pure turkey berry tea. Brewing time and composite ratios are critical, with TCT D and TCT E showing strong potential as nutraceutical beverages. Clinical validation is recommended to confirm dietary/nutraceutical benefits.

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27. Turkey Berry Knowledge, Attitudes, Practices and Product Development for Pregnancy Anaemia Prevention

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Background

Anaemia in pregnancy remains a major public health challenge in low- and middle-income countries, particularly in sub-Saharan Africa where nutritional deficiencies, infections, and poor dietary practices are prevalent (World Health Organization, 2023a). In Ghana, despite interventions such as iron–folate supplementation and antenatal nutrition education, anaemia among pregnant women remains persistently high due to poor adherence, inadequate dietary diversity, and socio-cultural factors (World Health Organization, 2023b). Food-based approaches using indigenous crops have increasingly gained attention as sustainable strategies for improving maternal nutrition. Turkey berry (Solanum torvum), a widely consumed indigenous vegetable in Ghana, is recognised in food systems literature as a nutrient-dense plant with micronutrient properties that support dietary diversity and maternal nutrition (Food and Agriculture Organization, 2025). However, regular consumption is constrained by bitterness, short shelf life, and preparation inconvenience.

This study therefore proposes the development of a turkey berry-based food product to improve convenience, utilisation, and acceptability among pregnant women. The proposed product will be a powdered turkey berry formulation designed for convenient dietary use, comparable to common seasoning powders on the market.

Materials and Methods

A mixed-method approach involving cross-sectional survey, laboratory analysis, product development, and sensory evaluation will be employed. Structured questionnaires will assess knowledge, attitudes, and practices among pregnant women attending antenatal clinics in Agona West Municipality. Nutritional and phytochemical analyses will determine the iron, folate, vitamin C, and antioxidant properties of turkey berry.

A turkey berry-based powdered food product will be developed as part of the study and evaluated for physicochemical properties and sensory acceptability among pregnant women and healthcare providers. The product will be formulated in powder form to enhance convenience, shelf stability, storage, and incorporation into meals similar to commercially available seasoning powders. Descriptive statistical analyses will be used to summarize findings.

Results and Discussion

The study is expected to demonstrate that turkey berry possesses significant nutritional potential relevant to haemoglobin improvement and maternal nutrition. However, behavioural barriers such as bitterness, limited convenience, and inadequate awareness may reduce regular consumption. The developed turkey berry-based powdered product is expected to improve accessibility, shelf stability, convenience, and sensory acceptability, thereby enhancing utilisation among pregnant women. These findings support the growing recognition of indigenous opportunity crops in strengthening sustainable and nutrient-sensitive food systems in Africa

Table 1. Expected outcomes of turkey berry utilisation for pregnancy anaemia prevention

Variable	Expected outcome
Knowledge of turkey berry benefits	Moderate awareness among pregnant women
Consumption practices	Inconsistent intake patterns
Nutritional composition	Presence of iron, folate, vitamin C, and antioxidants
Product development	Improved convenience and shelf stability
Sensory acceptability	Moderate to high acceptability
Perceived effectiveness	Positive perception regarding blood improvement

Conclusion

Turkey berry represents an important indigenous opportunity crop with potential to contribute to sustainable maternal nutrition interventions in Ghana. Integrating behavioural assessment with product development and sensory evaluation may enhance utilisation and improve pregnancy anaemia prevention strategies through culturally acceptable food-based approaches. The proposed powdered turkey berry formulation may further promote ease of use, dietary incorporation, and consumer acceptability among pregnant women.

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28. Diversity and Consumer Perception of Neglected and Underutilized Crops in the North West Region of Cameroon

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Introduction

In the North West Region of Cameroon, agricultural production is heavily dominated by a few staple crops such as rice, maize, beans, Irish potato, yams, and cassava (MINADER, 2020), leading to a decline in agrobiodiversity and increased vulnerability to climate change (Ebert, 2014).

Neglected and Underutilized Crops (NUS) are traditional crops that, despite their potential to enhance food security, nutrition, and environmental sustainability, remain underutilized in modern agriculture (Padulosi et al., 2013; Chivenge et al., 2014). Despite their nutritional, environmental, and cultural benefits, NUS like bambara groundnut remain underutilized, particularly in urban and global markets (Temegne et al. 2020) and their diversity in certain regions of Cameroon remain understudied. This study seeks to explore the diversity of NUS in Bamenda, and how consumer perception shapes the adoption and use of these crops. This would help shape strategies to enhance the visibility, accessibility, and cultural revaluation of NUS, thereby improving food security and sustainability in Bamenda.

Materials and Methods

The survey targeted farming communities across Bamenda's rural and peri-urban areas, particularly in Bamendankwe, Nkwen and Mankon.The study employed a mixed-methods approach involving field surveys and structured questionnaires. Following the framework suggested by Padulosi et al. (2013) for assessing underutilized species, data on crop diversity were collected through identification of scientific and common names. Consumer perception was evaluated using a Likert-scale focusing on awareness, challenges and cultural stigmas through straightforward interviews and focused group discussions. Data analysis utilized descriptive statistics to summarize crop diversity, identify trends in consumption and primary constraints.

Results and Discussion

The findings revealed a significant diversity of NUS in the Bamenda highlands (Table 1). Amongst consumers, knowledge and consumption of these crops remains significantly low. Among consumers, the study showed overall awareness of 33% of NUS and strong nutritional knowledge (78%), particularly among females (65%) and postgraduate-educated respondents (71%).

However, lower awareness was recorded among males (54%) and younger respondents. Further analysis showed that higher awareness correlates with increased consumption (95% of aware respondents consume NUCS vs. 77% of unaware, $r \approx 0.45$, $p < 0.01$). Respondents frequently identified sweet potatoes (78%), garden eggs (60%), guavas (55%), and bambara groundnuts (45%). Analysing consumer attitude towards NUS, the study showed that 80% of respondents consider NUS as nutritious, 70% find them tasty, and 85%

believe they are safe, while 65% recognize their cultural heritage. The key drivers to possible consumption of NUS included nutritional value (60%), taste (50%), affordability (45%), cultural reasons (30%), and environmental concerns (20%), while the primary barriers to consumption included lack of availability (55%), lack of preparation knowledge (40%), high price (30%), perceived low status (20%), and cultural beliefs (10%).

Table 1: Diversity of NUS in Bamenda

Crop (common name)	**Scientific name**
Green	Amaranthus caudatus viridis
Bambara groundnut	Vigna subterranea
Aerial Yam	Dioscorea bulbifera
Anchia	Solanum Macrocarpon
Sweet Potato	Ipomoea batatas
Millet/Guinea corn	Pennisetum glaucum
Garden eggs/African eggplant	Solanum aethiopicum
Bitterleaf	Vernonia amygdalina
Jama jama/African nightshade	Solanum scabrum
Fluted Pumpkin/Okonghobong	Telfairia occidentalis
Bread fruit	Artocarpus altilis
Tomatoe fruit/Tamarillo	Solanum betaceum
Sour sop	Annona muricata
Ibo coco/taro	Colocasia esculenta
Moringa	Moringa oleifera
Rambutan	Nephelium lappaceum
Guava	Psidium guajava
Cashew/African wallnut	Lovoa trichilioides
Bush Black/Black olive	Canarium schweinfurthii
African butter pear/Plums	Dacryodes edulis

Conclusion

This study identifies a diverse range of NUS, which are recognized for their nutritional benefits and cultural significance. However, there is low awareness of NUS coupled with limited availability, inadequate preparation knowledge, and a perceived low status among younger consumers, hindering their broader adoption. These findings emphasize the critical need for targeted interventions to overcome practical and perceptual barriers, ensuring NUS can fully contribute to food security, nutritional diversity, and environmental sustainability. It is recommended that policymakers incorporate NUS into national agriculture strategies, for greater integration of biodiversity into nutrition policies.

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29. Integrating Neglected and Underutilized Crop Species into Food Systems: Opportunities for Population Nutrition and Food Security

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Introduction

Nutritional security is threatened by a lack of dietary diversity, which presents a comparable image of the state of world nutrition (Matthews and Ghanem, 2020). Presently, three crops rice, wheat, and maize dominate global food systems and provide more than half of the world's daily energy requirements. Although the emphasis on high-yielding crops has led to impressive productivity gains, it has not always resulted in better food security or nutrition outcomes. In light of this, Neglected and Underutilized Crops Species (NUCs) have drawn interest as a potential solution to these problems. By 2050, there will be about 10 billion people on the planet, with a large portion of this increase expected to occur in sub-Saharan African nations like Nigeria, the Democratic Republic of the Congo, Ethiopia, Tanzania, and Uganda (United Nations Department of Economic and Social Affairs, Population Division, 2022). In these nations, children under five, women of reproductive age, and expectant and nursing mothers are particularly vulnerable to malnutrition and its detrimental effects on health and quality of life. In ensuring food security NUCs can solve the Sustainable Development Goals (SDGs) of the United Nations, SDG 2 (zero hunger) which seeks to address food security by 2030, while SDGs 3 (good health and wellbeing), 12 (responsible production and consumption), and 15 (life on land) contributing to an enabling environment (Baldermann et al., 2016; Li et al., 2020; Li and Siddique, 2020). Stressing to the point that NUCs foods are rich in nutrients Bruinsma, (2009); Tilman et al. (2011); Keyzer et al. (2005), stated that ignoring them would undermine their health advantages and achievement of SGDs.

They are essential in combating poverty and hunger, Poor and marginalized people will continue to have inadequate dietary diversity if Neglected and Underutilized Crops Species (NUCs) are not used (Kay et al., 2022). In order to close current food and nutritional gaps, nutrition must be given top priority in international discussions and action plans on climate change adaptation alternatives for developing nations that concentrate on agri-food systems (Hendre et al., 2019). Underutilized plants can be considered future horticultural assets to help countries ensure food and nutrition security as well as provide social, environmental, and recreational value because of their significant medicinal and nutritional value (Meena et al., 2022).

Materials and Methods

Study Area

The study area is Maiduguri Borno State, Nigeria. Maiduguri lies within the latitude coordinates of 11º.42'N to 12º 00' N and longitudes of 12º.54' to 13º 14'. Maiduguri is surrounded by Jere LGA on the Northern side, Konduga LGA on the Western, Southern, and South-Western sides while Mafa LGA on the North-Western side. The entire Maiduguri Metropolitan Council (MMC) area makes up the Maiduguri City Area. The geographical setting of Maiduguri lies within the semi-arid Northeast of Nigeria, where grass vegetation dominates, but drought-resistant plants like acacia trees and baobab are also prevalent, and shrub vegetation prevails in drier elevations. The site of Maiduguri was specifically chosen for the research based on the following factors: (1) high levels of malnutrition and food insecurity; (2) availability of traditional knowledge regarding NUCs in local communities; and (3) urgent need for resilient and nutrition-rich food sources in the semi-arid northeast.

Method of Data Collection

This study adopts a qualitative, exploratory, and descriptive research utilising both literature review and field-based data collection to provide a comprehensive understanding of Neglected and Underutilised Crops Species (NUCs). To enhance the credibility and validity of the findings, triangulation was employed through the use of multiple data collection methods. Primary data was collected through direct interactions with the traders who sells NUCs in Maiduguri Market. Interview were conducted and recorded to capture respondents' experiences, perspective and knowledge regarding production, marketing and utilisation of the crops. In addition, non-participants observation was used to examine market activities, the display and handling of NUCs. Furthermore, photographs of the NUCs and market activities were taken as part of the primary data.

Results and Discussion

Bambara Groundnut

The native African legume known as Bambara groundnut (Vigna subterranea) is commonly cultivated in semi-arid areas. In the northern region of Nigeria, the Hausa name is Gurjiya. Tan et al. (2020), highlighted the nutritious value of Bambara nut indicating that it has essential amino acids, and high-quality protein (usually 17–25%), they are especially beneficial in areas where protein-energy malnutrition is common. Bambara nuts include anti-nutritional factors (ANFs) like tannins, phytic acid, saponins, and enzyme inhibitors despite having a high protein and vitamin content.

Fig. 1: The researcher observing Bambara groundnut and other neglected and underutilised crops displayed by a vendor for sale in Maiduguri, Borno State.

A seller, while reflecting on the usefulness of Bambara groundnut, explained, "I don't only sell Bambara groundnut in one form in my business. I buy seeds from farmers, clean and sort them, then sell raw, roasted, or make flour for cooking. I also process it into local dishes and snacks to add more value and income. One of my popular products is Bambara groundnuts chips which many customers enjoy because it is tasty and easy to eat."

In Agreement with its nutritional value, Mayes et al. (2019) and Olayide et al. (2018), similarly denotes that cultivating this crop has provided assurance to farmers and consumers, considerably improving household nutrition and food security. In the context of a fast-escalating global food crisis, Tilman et al. (2011) predict a 100% - 110% increase in crop demand from 2005 to 2050.

Garden egg

Solanum Aethiopicum is called Dauta in Hausa. Garden egg is one of Nigeria's and West Africa's most significant vegetable crops. In addition to being the primary source of income for many rural households, crops are consumed daily by both rural and urban families.

Fig. 2: The researcher observed varieties of Neglected and Underutilised Crops (NUCs) namely; garden egg, mango and watermelon traded in Maiduguri, Borno State.

A participant reported; “I like garden egg because when I eat, it helps my digestion and brings down my blood pressure. I usually buy it and keep it for many days without it spoiling quickly. It is also easy to carry around and eat at any time of the day. Garden eggs help me feel full, so I don’t get hungry too often. When I eat garden egg, I feel strong. I enjoyed eating it fresh and sometimes I take it with groundnut paste, making it more delicious. Overall, to me garden egg is useful to me because it is very cheap.”

This above statement is in an agreement with the findings of Eletta et al. (2017), that garden egg has abundant protein, minerals, vitamins, carbohydrates, fats, crude fibre, and water compounds included in African eggplant are pertinent and quite beneficial for nutrient supplementation and health enhancement. In another development Ayodele (2018), concluded that garden Egg fruit is distinguished by its high fibre content and comparatively low calorie and protein content. These characteristics are thought to be very important in reducing excess body fat. With only 25 calories and 4 grams of dietary fibre per 100 grams, garden-fresh raw eggs are an excellent nutritional choice for anyone trying to lose weight.

A farmer who is also a trader lamented on the problems faced; “the problem we are experiencing in the farm is that insects do feed on the fruits damaging them and reducing their quality.”

This is in line with Kekenou et al. (2025), who discovered that insects like the variegated grasshopper have been observed to eat on crops, especially garden eggs, where it can result in 25–80% yield loss. Dent (2003), states that sucking insects, such as aphids, absorb plant sap by using their mouthparts to pierce and probe plant tissue until they locate a phloem artery from which they extract the sap causing injury to the crops.

Conclusion

The integration of Neglected and Underutilised Crops Species (NUCs) into mainstream food systems presents a transformative yet largely underutilised opportunity to address global malnutrition, food insecurity and the loss agro biodiversity. As this analysis has shown NUCs offer a compelling dual solution, they are nutrition dense crops capable of filling critical micronutrient gaps in populations reliant on staple monocultures and they possess inherent climate resilience including tolerance to drought, poor soils and temperature extremes that makes them indispensable for stabilising food production under worsening environmental stresses. The destruction of pests highlights the importance of promoting Integrated Pest Management (IPM) techniques in NUCs by using sustainable methods like field observation, biological control, and the use of resistant crops. By elevating these crops from the margins to the mainstream, policymakers, researchers and practitioners can advance multiple Sustainable Development Goals, particularly Zero Hunger (SDG 2), Good Health (SDG 3) and Climate Action (SDG 13). The challenge is no longer one of awareness but of committed cross sectorial implementation.

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30. Physicochemical and Mineral Profile of Cochlospermum spp. Root Powder: A Neglected and Underutilized Species in the Sudanian Zone of Benin

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Abstract

The root powder of Cochlospermum spp. represents a key traditional food ingredient broadly incorporated into the diet of communities residing in the Sudanian zone of Benin. The present study characterized the physicochemical and mineral composition of this neglected plant food across the three phytodistricts of the Sudanian zone. Twelve processors per phytodistrict were monitored to document processing practices, and samples were subsequently collected for quantification of eight minerals—(Ca), magnesium (Mg), sodium (Na), phosphorus (P), iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn). Statistical analyses revealed that concentrations of Fe, Zn, Cu, Mg, Mn, and Na did not differ significantly among phytodistricts, whereas Ca and P contents varied significantly. Particularly elevated levels were recorded for iron (54.1±21.5 mg/100g dry weight) and calcium (ranging from 573.7±98 to 802.5±49.9 mg/100g dry weight across the Atacora Chain and Northern Borgou phytodistricts). These findings indicate that Cochlospermum spp. root powder holds nutritional potential for helping to address iron and calcium deficiencies in local communities.

Key words: Cochlospermum spp., mineral deficiencies, root, plant food, nutrition

1. Introduction

Accelerating population growth, combined with the progressive depletion of natural ecosystems, intensifies pressure on food supply systems and underscores the urgency of identifying alternative nutritional resources (Mawunu et al. 2020). Wild plant species constitute an underexplored yet substantial reservoir for this purpose; globally, an estimated one billion people predominantly in low-income countries incorporate edible wild plants into their diets (Khan et al. 2016). In Benin, such species remain integral to the food security and livelihoods of a broad cross-section of rural and urban households (Avocèvou-Ayisso et al. 2009). Among these, Cochlospermum spp. have attracted growing scientific attention on account of their dual roles in food and medicine (Achigan-Dako et al. 2010; Favi et al. 2020). Within rural Beninese communities, these plants serve multiple functions by supporting nutrition, healthcare, and economic well-being (Favi et al. 2021). An ethnobotanical survey in the Sudanian zone of Benin documented thirteen distinct culinary applications of Cochlospermum spp. root powder, with incorporation into diverse sauces emerging as the predominant use (Affonfere et al. 2024). Notwithstanding this wide use, rigorous data on the mineral composition of this plant food remain scarce. The present study therefore aimed to characterize the physicochemical properties and mineral profile of Cochlospermum spp. root powder across the phytodistricts of the Sudanian zone of Benin.

2. Materials and Methods

2.1. Study Area

This investigation was carried out in the Sudanian climatic zone of northern Benin, a country situated in West Africa at latitudes 6°10'N to 12°30'N and longitudes 1'E to 3°40'E, with a total surface area of 114,746 km² (Gandji et al. 2018). The Sudanian zone (9°45'–12°N), which constitutes the natural habitat of Cochlospermum spp. (Akoègninou, Van der Burg, and Van der Maesen 2006), occupies the northern region of the country (Assogbadjo et al. 2005). Based on meso-scale assessments integrating vegetation cover, soil types, and climatic parameters, this zone has been subdivided into three phytodistricts: Northern Borgou, Atacora Chain, and Mékrou-Pendjari (Adomou 2005).

2.2. Sampling of Informants for Survey

Three municipalities were selected per phytodistrict based on documented Cochlospermum spp. use. Within each municipality, two villages were further identified. Table 1 lists the municipalities chosen in each of the three phytodistricts. To document Cochlospermum spp. root powder (CRP) processing, four processors per municipality (equating to two per village) were randomly recruited, yielding a total sample of 36 participants.

Table 1. Selected municipalities in each of the three phytodistricts

Phytodistricts	Selected municipalities	Selected municipalities	Main Staples food	Major soil type	Major plant formation
Atacora chain	Atacora chain	Natitingou	maize, sorghum, millet, cassava and yam	Poorly evolved & mineral soils	Riparian forest, dry forest, and woodland
Atacora chain	Atacora chain	Kérou	maize, sorghum, millet, cassava and yam	Poorly evolved & mineral soils	Riparian forest, dry forest, and woodland
Atacora chain	Atacora chain	Toucoutouna	maize, sorghum, millet, cassava and yam	Poorly evolved & mineral soils	Riparian forest, dry forest, and woodland
Mékrou-Pendjari	Mékrou-Pendjari	Malanville	maize, sorghum, millet, cassava and yam	Ferruginous soils with concretions sedimentary rocks	Trees, shrubs and grass savannahs, dry forest and riparian forest
Mékrou-Pendjari	Mékrou-Pendjari	Banikoara	maize, sorghum, millet, cassava and yam	Ferruginous soils with concretions sedimentary rocks	Trees, shrubs and grass savannahs, dry forest and riparian forest
Mékrou-Pendjari	Mékrou-Pendjari	Tanguiéta	maize, sorghum, millet, cassava and yam	Ferruginous soils with concretions sedimentary rocks	Trees, shrubs and grass savannahs, dry forest and riparian forest
North Borgou	North Borgou	Kouandé	maize, sorghum, millet, cassava and yam	Ferruginous soils on crystalline rocks	Dry forest, woodland and riparian forest
North Borgou	North Borgou	Kalalé	maize, sorghum, millet, cassava	Ferruginous soils on crystalline	Dry forest, woodland and

Phytodistricts	Selected municipalities	Selected municipalities	Main Staples food	Major soil type	Major plant formation
			and yam	rocks	riparian forest
North Borgou	North Borgou	Ségbana	maize, sorghum, millet, cassava and yam	Ferruginous soils on crystalline rocks	Dry forest, woodland and riparian forest

Source: (Adomou 2005; Amoussa Hounkpatin 2011; Mitchikpe et al. 2001)

2.3. Data Collection and Food Material Sampling for Laboratory Analyses

During the processing follow-up, the weight of material at each production step and the duration of each unit operation were systematically recorded, enabling the construction of a standardized flow chart for Cochlospermum spp. root processing. A 100 g sample was collected from each processor, sealed in laminate packaging, and transported to the laboratory for subsequent physicochemical and mineral analyses.

2.4. Laboratory Analyses

All CRP samples were characterized for dry matter content, total ash, pH, color, and mineral concentrations. All determinations were performed in triplicate, with the exception of mineral analyses, which were conducted in duplicate.

Dry matter and ash content: Moisture content was determined gravimetrically following AOAC (1993) guidelines. Briefly, 5 g of sample were weighed into a previously tared crucible and oven-dried at 105°C for 72 hours. Total ash content was obtained by dry-ashing the sample in a muffle furnace at 550°C for 8 hours, as per AOAC (1993).

pH and color: Sample pH was recorded using an Eutech instruments pH 510 metre (EAS, 2000). Colorimetric parameters—lightness (L*), redness (a*), yellowness (b*), and total colour difference (ΔE)—were quantified with a Chromameter CR-410 (Konica Minolta Optics, INC, Osaka, Japan) in accordance with the CIELAB (1976) colour system.

Minerals: Concentrations of Ca, Mg, Na, P, Fe, Zn, Cu, and Mn were determined by flame atomic absorption spectrometry following the reference method of Pinta (1975).

2.5. Determination of the Contribution of CRP to the Minerals Harmonized Average Requirements for Children Aged 6–59 Months

The capacity of a 10 g (dry weight) daily serving of CRP to satisfy the mineral Harmonized Average Requirements (H-ARs) for children aged 6–59 months was assessed using Equation 1. This reference dose of 10g was selected on the basis of evidence that 10 g/day of food supplements such as moringa leaf powder is well tolerated by children below five years of age (Houndji et al. 2013). The H-ARs published by Allen, Carriquiry, and Murphy (2020), which are derived from guidelines issued by the Institute of Medicine (IOM) and the European Food Safety Authority (EFSA), served as the nutritional benchmarks. Since no H-AR exists for sodium, Na was excluded from this assessment. Where inter-phytodistrict differences were non-significant for a given mineral, the pooled mean concentration was applied; where significant variation was detected, the range (minimum to maximum value) was used in the calculation.

Cover rate (%) = [Mineral content in 10g dry weight of CRP / Harmonized Average Requirement for Mineral] × 100 (Equation 1)

2.6. Statistical Data Analysis

Physicochemical and mineral data were expressed as mean ± standard deviation. One-way analyses of variance (ANOVA) were performed to assess whether CRP composition differed significantly across phytodistricts; the significance threshold was set at $\alpha = 0.05$. When a significant effect was detected ($p < 0.05$), pairwise comparisons among phytodistricts were carried out using Tukey's post-hoc test. For parameters with no significant inter-phytodistrict variation, the overall mean value was computed and reported.

3. Results

3.1. Processing Diagram of Cochlospermum spp. Root

The production of Cochlospermum spp. root powder hinges on two principal unit operations: pounding and solar drying (Figure 1). Once the plant has been uprooted from its wild habitat, processors manually strip the outer bark from the fresh root. The peeled root is then pounded using a mortar and pestle, spread for sun drying, and, once sufficiently dry, subjected to a second round of pounding followed by sieving to obtain the finished powder. On average, 1,500 g of fresh root yielded 242.7±62.6 g of powder, corresponding to a conversion efficiency of 16.9±6.7% (Figure 1).

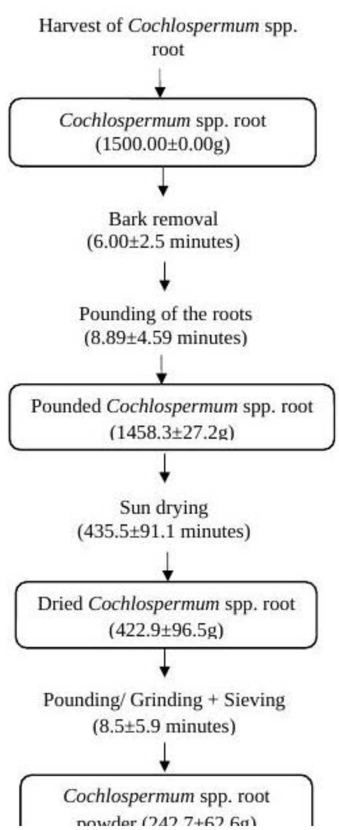

Figure 2. Flow chart diagram of Cochlospermum spp. root processing

3.2. Physicochemical Composition of Cochlospermum spp. Root Powder

Table 2 reports the physicochemical characteristics of CRP across phytodistricts. Of the seven parameters evaluated, only dry matter content and ash content exhibited statistically significant inter-phytodistrict variation ($p < 0.05$). Ash concentrations were comparably elevated in samples from Mékrou-Pendjari (8.1±1.5 g/100g) and Northern Borgou (8.0±0.9 g/100g), both significantly exceeding the value recorded for Atacora Chain (5.1±0.2 g/100g). Conversely, the highest dry matter values were found in CRP from Atacora Chain (95.6±0.4%) and Northern Borgou (94.9±1.1%), while samples from Mékrou-Pendjari displayed the lowest dry matter content (93.6±1.0 g/100g).

Table 2. Physicochemical composition of Cochlospermum spp. root powder according to phytodistricts

Samples	Dry matter (%)	Ash (%)	pH	L*	a*	b*	b*	ΔE
Mékrou-Pendjari	93.6±1.0a	8.1±1.5a	4.9±0.1a	69.8±2.0a	15.8±0.8a	15.8±0.8a	36.7±2.3a	25.9±2.1a
Atacora Chain	95.6±0.4b	5.1±0.2b	4.9±01a	71.9±2.2a	18.9±1.2a	18.9±1.2a	36.5±2.6a	26.8±3.0a
Northern Borgou	94.9±1.1ab	8.0±0.9a	4.9±0.0a	69.4±1.6a	18.5±4.2a	18.5±4.2a	34.3±2.4a	29.4±2.5a
Mean values	nd	nd	4.9±0.1	70.4±2.1	17.7±2.7	17.7±2.7	35.8±2.5	27.4±2.8
Significance levels	0.034	0.003	0.730	0.214	0.228	0.228	0.329	0.200

Note: For each physicochemical parameter, means (±SD) sharing the same superscript letter are not significantly different (p >.05); nd: Not determined.

3.3. Mineral Profile of Cochlospermum spp. Root Powder

Table 3 summarizes the mineral composition of CRP according phytodistrict. No statistically significant differences were detected across phytodistricts for Fe, Zn, Cu, Mg, Mn, or Na; pooled mean values were therefore computed, yielding 54.1±21.5 mg/100g dw for iron and 1.0±0.3 mg/100g dw for zinc. In contrast, Ca and P contents differed significantly among phytodistricts ($p < 0.05$). Calcium concentrations were comparable in samples from Mékrou-Pendjari (791.3±39.0 mg/100g dw) and Northern Borgou (802.5±49.9 mg/100g dw), and both were significantly higher than that of Atacora Chain (573.7±98.7 mg/100g dw). For phosphorus, Mékrou-Pendjari (72.2±23.1 mg/100g dw) and Atacora Chain (49.9±9.3 mg/100g dw) showed comparable levels, each significantly lower than Northern Borgou (216.9±43.7 mg/100g dw).

Table 3. Mineral profile (mg/100g dw) of Cochlospermum spp. root powder according to phytodistricts

Samples	Ca	Mg	Na	P	Fe	Zn	Cu	Cu	Mn
Mékrou Pendjari	791.3±39.0a	378.2±42.2a	54.3±26.3a	72.2±23.1a	56.1±19.0a	1.1±0.3a	1.1±0.3a	0.3±0.0a	7.8±6.2a
Atacora Chain	573.7±98.7b	289.2±96.9a	32.7±3.2a	49.9±9.3a	44.5±8.8a	0.9±0.2a	0.9±0.2a	0.3±0.0a	4.0±0.2a
Northern Borgou	802.5±49.9a	310.7±42.2a	29.2±3.8a	216.9±43.7b	61.6±32.4a	0.8±0.2a	0.8±0.2a	0.3±0.1a	2.2±0.9a
Mean values	nd	326.0±90.0	38.6±18.2	nd	54.1±21.5	1.0±0.3	1.0±0.3	0.3±0.0	4.7±4.1
Significance levels	0.002	0.380	0.093	<0.001	0.562	0.196	0.196	0.832	0.133

Note: For each mineral, means (±SD) sharing the same superscript letter are not significantly different ($p > .05$); nd: Not determined.

3.4. Contribution of 10g of CRP to the Minerals Harmonized Average Requirements for Children Aged 6–59 Months

A 10 g dw daily serving of CRP would supply 67.6% of the iron H-AR for children aged 6–12 months, and would exceed the iron H-AR by more than 100% for children aged 12–59 months (Table 4). Zinc coverage was modest across all age categories: 4.0%, 2.6%, and 2.1% for the 6–12 months, 12–36 months, and 36–59 months children, respectively. Calcium contributions ranged from 14.7 to 20.6% of H-ARs for the 12–36 months group, and from 8.4 to 11.8% for children aged 36–59 months. Copper coverage was minimal (<1% of H-ARs) across all age categories, reflecting the inherently low copper content of CRP.

Table 4. Contribution (%) of 10g CRP to the minerals Harmonized Average Requirements for children

Minerals	Units	Age groups (months)	Age groups (months)	Age groups (months)
Minerals	Units	6 to 12	12 to 36	36 to 59
Calcium	H-ARs (mg/d)	NA	390.0	680.0
Calcium	Cover rate (%)	ND	14.7 to 20.6	8.4 to 11.8
Magnesium	H-ARs (mg/d)	NA	65.0	110.0
Magnesium	Cover rate (%)	ND	50.2	29.6
Phosphorus	H-ARs (mg/d)	NA	380.0	405.0
Phosphorus	Cover rate (%)	ND	1.3 to 5.7	1.2 to 5.4
Iron	H-ARs (mg/d)	8.0	5.0	5.0
Iron	Cover rate (%)	67.6	108.2	108.2
Zinc	H-ARs (mg/d)	2.4	3.6	4.6
Zinc	Cover rate (%)	4.0	2.6	2.1
Copper	H-ARs (μg/d)	NA	260	340
Copper	Cover rate (%)	ND	<1	<1
Manganese	H-ARs (mg/d)	NA	0.4	0.8
Manganese	Cover rate (%)	ND	116.9	58.4

NA: Not Available, ND: Not determined

4. Discussion

Inter-phytodistrict homogeneity was observed for the majority of minerals quantified (Fe, Zn, Cu, Mg, Mn, and Na) whereas Ca and P exhibited significant spatial variation. This pattern mirrors findings reported for other nutritionally valuable plants. Stevens, Ugese, and Baiyeri (2021) documented comparable uniformity across provenances for most minerals in Moringa oleifera in Nigeria, with calcium constituting the principal exception. Similarly, Assogbadjo et al. (2012) detected no statistically significant differences between climatic zones in Ca, Mg, and K concentrations in Adansonia digitata leaves, while iron showed significant variation.

The mean iron concentration of 54.1±21.5 mg/100g dw falls within the range previously reported for this species (26.8±2.7 mg/100g dw by Affonfere et al. (2021) and 70.1 mg/100g dw by Chadare et al. (2017)). Remarkably, this value closely approximates the iron content of moringa leaf powder (53.75±5.07 mg/100g dw) reported by Kayalto et al. (2013), suggesting that CRP could be promoted comparably to moringa leaf powder as a food fortificant for improving iron intake in populations where it is customarily consumed. Regarding calcium, the present study obtained values of 573.7±98 to 802.5±49.9 mg/100g dw, which are lower than the 1,061.3±11.5 mg/100g dw reported by Affonfere et al. (2021). These discrepancies are most likely attributable to genetic variation among Cochlospermum spp. accessions (Brisibe et al. 2009; Muthai et al. 2017) and to differences in soil physicochemical characteristics at the respective sampling sites (Assogbadjo et al. 2012). Future investigations should systematically explore the relationship between edaphic conditions and the biochemical and nutritional composition of CRP. The zinc concentration recorded in this study (0.9±0.0 mg/100g dw) was low and consistent with the value previously measured by Affonfere et al. (2021) (1.0±0.3 mg/100g dw), and remained below the zinc contents reported for Moringa oleifera leaf powder in several other studies (Adetola et al. 2019; Van der Merwe et al. 2019).

Although the theoretical iron coverage rates are promising exceeding 100% of H-ARs for children aged 12–59 months, these estimates represent upper-bound values that do not account for mineral bioavailability. In practice, effective absorption may be substantially lower; for instance, Ayosso (2016) estimated iron bioaccessibility at approximately 10% in Cochlospermum tinctorium root powder based on the [IP6]/[Fe] molar ratio. To maximize the dietary benefit of CRP despite this limitation, several strategies warrant consideration: increasing the daily intake of CRP beyond 10 g where tolerated, combining CRP with vitamin C-rich foods such as baobab fruit pulp to enhance iron uptake (Adetola et al. 2019; Drago 2017; Gabaza et al. 2018), and developing diversified food products in which CRP is an ingredient. Future research should also determine the upper acceptability levels of CRP in common food matrices such as porridges and sauces, and further elucidate the role of food combinations in meeting the full spectrum of nutrient requirements for vulnerable groups (Assogbadjo et al. 2012; Affonfere et al. 2021; Van der Merwe et al. 2019).

5. Conclusion

This study demonstrated that Cochlospermum spp. root powder is a mineral-dense food ingredient particularly rich in iron and calcium with the potential to contribute to the alleviation of micronutrient deficiencies. Mineral composition was broadly consistent across phytodistricts, with the exception of calcium and phosphorus. To translate these nutritional assets into measurable public health benefit, future research should quantify mineral bioavailability, determine anti-nutrient contents, and establish acceptable daily intake levels for diverse population groups.

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