OPPORTUNITY CROPS FOR SUSTAINABLE FOOD SYSTEMS

Crop profiles highlighting their potential to strengthen nutrition, resilience and livelihoods in African food systems

CROP TRUST

CONTACT
Global Crop Diversity Trust (Crop Trust)

Platz der Vereinten Nationen 7
53113 Bonn, Germany
General Contact: info@croptrust.org

Crop Trust publications:
publications@croptrust.org
www.croptrust.org

BASED ON REPORTS PREPARED BY
Michel Edmond Ghanem (Centre de coopération internationale en recherche agronomique - CIRAD), Gloria Otieno (Alliance of Bioversity International and CIAT), Priscila Marimo (Consultant).

EDITORIAL, COORDINATION AND PRODUCTION CONTRIBUTIONS
Janny van Beem, Nora Castañeda and Natalia Rodríguez, (Crop Trust); Paul Neate and Giovanna Chávez-Miguel (Editors).

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Introduction

Today's food systems rely heavily on a surprisingly small number of crops. Wheat, rice, maize and a handful of others dominate farms, markets and diets across much of the world. While these crops are essential, this dependence on a narrow range of species has reduced agricultural diversity and contributed to diets that are often less varied.

Farming systems in many regions are becoming increasingly vulnerable to drought, pests and diseases. Meanwhile, many locally adapted crops that have been grown by communities for generations remain absent from agricultural research, policy and investment.

These lesser-known species – often referred to as neglected and underutilized species (NUS), or "opportunity crops" – include cereals, legumes, fruits, vegetables and tree crops that continue to play important roles in local food systems despite receiving relatively little attention. Many of these crops are well adapted to harsh conditions and can thrive in areas where more widely cultivated crops struggle. Others are important because of their nutritional value, role in traditional cuisines or their cultural heritage within local communities. Across many parts of Africa, they remain part of everyday life. They are sold in local markets, cultivated in gardens, cooked in traditional dishes and exchanged through informal seed systems.

This publication presents 15 opportunity crop profiles from across West and East Africa, selected through stakeholder consultations held in Benin, Ghana, Tanzania and Uganda as part of the BOLDER initiative. More than 250 farmers, genebank experts, researchers, government representatives, civil society organizations and private-sector actors participated in the process. The consultations revealed both regional diversity and shared priorities.

Stakeholders in Tanzania selected finger millet, Bambara groundnut, moringa, sweetpotato and jute mallow. In Uganda, participants prioritized jackfruit, pearl millet, pumpkin, cowpea and amaranth. In Benin, the selected crops were fonio, jute mallow, miracle berry and Bambara groundnut, while stakeholders in Ghana prioritized turkey berry, baobab, sesame and amaranth.

Each crop profile explores the crop's history, biology, nutritional characteristics, production systems, cultivation status, processing challenges and market opportunities. Expanding their use will require greater investment in research, seed systems, processing infrastructure and public awareness. It will also require recognizing the value of the knowledge and practices that have kept these crops in use for generations.

Amaranth in opportunity crop demonstration field at WorldVeg. Arusha, Tanzania.
Photo: Michael Major / Crop Trust

AMARANTH

Amaranthus spp.

Opportunities for strengthening seed and vegetable production in Ghana

History of Domestication

Amaranth is an ancient crop believed to have originated in Central and South America, where it was cultivated by the Aztecs, Mayans and Incas more than 6,000 years ago (Riggins and Mumm, 2021). It served as a staple food in pre-Columbian civilizations, especially in Mexico and the Andean region. Today, amaranth is cultivated worldwide, primarily in tropical and subtropical regions of the Americas, as well as in certain parts of Asia and Africa. In Ghana, the crop is known as aleefu and is commonly found across the savannah, deciduous, and forest agroecological zones (Dari, Nenguwo, and Afari-Sefa, 2015).

Taxonomy and Biology

Amaranth is an ancient crop that belongs to the family Amaranthaceae, which also includes quinoa, spinach and beets, plants broadly adapted to diverse and often dry environments. The genus *Amaranthus* L. comprises roughly 70 species found worldwide, encompassing cultivated grain and leaf types as well as numerous wild and weedy forms, most of which are native to the Americas (Riggins and Mumm, 2021). The crop is used as a leafy vegetable, food grain, forage, and ornamental plant, and are valued for their high nutritional properties (Ulbricht *et al*., 2009; Maurya and Arya, 2018). The most commonly grown species for edible seeds and leaves are *Amaranthus cruentus* L., *A. hypochondriacus* L., and *A. caudatus* L., while *A. tricolor* L. and *A. blitum* L. are widely consumed as leafy vegetables, particularly in Africa and Asia (Aderibigbe *et al*., 2022; Riggins and Mumm, 2021). Amaranth species display considerable morphological diversity, showing variation in growth form, plant height, number of inflorescences, seed color, protein content, and seed yield (Assad *et al*., 2017). The crop thrives across a wide range of environmental conditions, owing to advantageous agronomic traits that include fast growth rates, efficient C4 photosynthesis, and high tolerance to drought, heat and salinity (Riggins and Mumm, 2021). It matures early and demonstrates resilience against pests, including birds, rodents and termites, as well as diseases and drought. Its adaptability to different soil types, pH levels, climates, rainfall patterns, and day lengths gives it significant potential to enhance food security and strengthen food system resilience across Africa in the context of climate change (Reta Alemayehu *et al*., 2015).

Importance, Sociocultural Aspects and Potential

Amaranth is widely recognized for its exceptional nutritional content. Both seeds and leaves are rich in essential micronutrients, including beta-carotene, iron, calcium, vitamin C, and folic acid (Chivenge *et al*., 2015; Mabhaudhi *et al*., 2019; Appiah-Kubi *et al*., 2022). As a gluten-free crop, amaranth is considered to have significantly higher nutritional value than other protein-rich foods such as milk and soybeans and has been used as a dietary supplement for HIV/AIDS patients in some African countries (Riggins and Mumm, 2021; Reta Alemayehu *et al*., 2015; Appiah-Kubi *et al*., 2022). Multiple species within the genus *Amaranthus*, including *A. spinosus* L., *A. viridis* L., and *A. cruentus* L., are also recognized for their ethnomedicinal applications, encompassing the treatment of constipation, fever, hemorrhage, anemia, renal disorders, and parasitic infections (Mensah *et al*., 2008; Koffuor *et al*., 2013; Appiah-Kubi *et al*., 2022).

Amaranth is one of the most commonly produced and consumed indigenous crops on the African continent (Aderibigbe *et al*., 2022). Often called a poor man's vegetable, the crop has been rediscovered as a promising food source due to its low production costs, high nutritional content and resilience to heat and drought (Bressani, 1988; Das, 2016). Despite its agronomic and nutritional promise, amaranth faces challenges rooted in consumer perception. A recent study in Ghana found that many farmers remain unaware of the edibility of amaranth grain, though 81% expressed interest in cultivating it in response to growing consumer demand (Darfour *et al*., 2024). Negative perceptions of traditional crops more broadly continue to limit uptake, alongside constraints related to irrigation access and market connectivity.

The promotion and improvement of amaranth production holds substantial potential for smallholder farmers in both rural and urban areas. Vegetable production is a profitable activity in Ghanaian cities and towns, contributing to food and nutrition security, improved livelihoods and increased farmer incomes (Owusu-Boateng and Amuzu, 2013; Hawkes and Ruel, 2006; Drechsel and Keraita, 2014). A Nigerian case study demonstrates that amaranth production remains highly profitable even during the dry season (Emokaro and Ekunwe, 2007). There has accordingly been a recent increase in the promotion and use of amaranth in Ghana (Darkwa and Darkwa, 2013; Appiah-Kubi *et al*., 2022), though challenges related to market access and consumer awareness persist.

Farmer Emeline Geremia Massawe with one of her Tricot plots of amaranth, in Kimashuku District, Kilimanjaro Region, Tanzania. Photo: Neil Palmer / Crop Trust

Neglect, Underutilization, Challenges

Even with their history of use, cultivated amaranths are often called ‘orphan crops’ (neglected and underutilized crops) due to the overall lack of research and limited breeding efforts compared to major crops (Riggins and Mumm, 2021). Production is typically small-scale and scattered, often maintained by traditional farming communities without strong policy support or extension services (FAO, 2013). Despite the high nutritional value of their protein-rich seeds and micronutrient-dense leaves, amaranths remain marginalized in commercial markets, where staple cereals dominate value chains (National Research Council, 1989). Low consumer awareness, variation in culinary traditions, and inconsistent produce supply further hinder its integration into mainstream food systems (FAO, 2018). Together, these challenges limit amaranth’s potential as a climate-resilient, nutrient-dense crop able to strengthen food and nutrition security in diverse regions.

Agronomic Issues

Despite its many advantages, amaranth production faces a number of agronomic constraints that limit its widespread adoption. Seed production is complicated by the plant’s tendency to cross-pollinate, requiring that different varieties be grown well apart from one another (Aderibigbe *et al*., 2022). Most smallholder farmers growing amaranths address this by saving seeds from their own harvest or obtaining seed from neighbors or local markets.

In certain environments, amaranth is also susceptible to pests, diseases, and heavy metal contamination. Common fungal diseases, include anthracnose, Fusarium wilt, damping-off caused by Pythium, Rhizoctonia, and Aphanomyces spp., and cankers caused by Phoma or Rhizoctonia (Stallknecht and Schulz-Schaeffer, 1993; Reta Alemayehu *et al*., 2015; Appiah-Kubi *et al*., 2022). Managing this crop can be labor-intensive and is often done manually across much of Africa (Aderibigbe *et al*., 2022).

Moreover, wastewater is frequently used to irrigate vegetables in urban areas such as Accra, Kumasi and Tamale in Ghana, as well as in other African cities (Akoto *et al*., 2015). In Ghana, about 17% of the country’s arable land is irrigated with wastewater, which accounts for roughly 34% of the crops consumed in urban regions (Appiah-Kubi *et al*., 2022). This practice raises health concerns because wastewater often contains harmful pollutants, including heavy metals like cadmium and lead. Appiah-Kubi *et al*. (2022) found that high contamination levels in wastewater and soil lowered leaf number, leaf size and chlorophyll content in amaranth during both dry and rainy seasons in Ghana.
They also suggested that using groundnut husk biochar to filter and treat wastewater can reduce the toxic effects of cadmium and lead. Biochar filtration has proven effective in decreasing heavy metal contamination in wastewater, leading to better growth and yields of amaranth (Nimatu, *et al*., 2023)

Conservation and Breeding

The long-term potential of amaranth as a food security crop depends on conserving its genetic diversity, both through formal genebanks and farmer-led systems. Several institutions maintain amaranth germplasm collections, including the USDA Agricultural Research Service, INIFAP in Mexico, ICAR-National Bureau of Plant Genetic Resources and the National Botanical Research Institute in India, FOFIFA in Madagascar and the World Vegetable Center in Taiwan (Riggins and Mumm, 2021; Anuradha *et al*., 2023). Alongside these formal efforts, farmer-based seed systems play a vital role in preserving local varieties, cultural knowledge, and heritage, accounting roughly for 80% of the total seed system for most staple crops in Ghana (Louwaars and de Boef, 2012). In Ghana, however, policy developments have increasingly undermined these systems: the Plant Variety Protection Bill restricted farmers from multiplying and distributing improved seeds, while the Plants and Fertilizer Act effectively criminalized informal seed exchange by requiring formal labelling and packaging (Vernooy *et al*., 2023).

In terms of seed breeding, research efforts in genetic improvement lag significantly behind those of major crops (Joshi *et al*., 2018). However, Anuradha *et al*. (2023) cite numerous studies classifying genetic diversity of amaranths, including both its morphological and genetic traits. They also review many studies on the breeding behavior of amaranths, especially in India and the U.S.

Amaranth seeds in the genebank at the World Vegetable Center, Cotonou, Benin. Photo: Neil Palmer/Crop Trust.

Processing and Value Chains

Transforming amaranth into marketable products involves both overcoming processing challenges and capitalizing on its diverse commercial applications. As a grain, amaranth contains antinutritional factors, i.e., tannins and phytic acid, that limit nutrient bioavailability, though methods such as defatting, blanching, germination, fermentation and autoclaving have proven effective in reducing them (Aderibigbe *et al*., 2022).

Amaranth has also found use in a range of food products, including breads, biscuits, weaning foods and brewing, as well as in livestock and poultry feed, though heat treatment is required to eliminate growth-inhibiting factors (Aderibigbe *et al*., 2022). Beyond food, amaranth oil is a promising source of squalene, an antioxidant used in cosmetics and as a vaccine adjuvant, with notably higher concentrations than olive oil, the current dominant source, making it commercially attractive if suitable extraction techniques can be scaled (Aderibigbe *et al*., 2022).

Market Access

While amaranth grain has gained increasing recognition as a “superfood” and seen growing demand in Europe and North America, its market remains underdeveloped across Africa, where consumer demand is still limited (Aderibigbe *et al*., 2022). Significant potential exists to develop domestic markets within Africa and forge connections to international ones, though realizing this will require establishing clear production standards, reliable sources of improved seed and access to advanced production technologies.

A chef at the kitchen of the World Vegetable Center in Arusha, Tanzania, with a bunch of amaranth ready for preparation.
Photo: Neil Palmer / Crop Trust.

Conclusion

The limited research on amaranth cultivation and use reflects a broader lack of awareness surrounding the crop. Consequently, several interconnected barriers have emerged, including the absence of improved varieties, challenging cultivation and processing conditions, limited market access and the stigma of amaranth being considered «food for the poor» (Darfour et al., 2024). However, evidence suggests that targeted interventions, such as varietal selection and optimizing seed planting rates, can meaningfully improve growth and yield (Sokoto and Johnbosco, 2017). Addressing these gaps through sustained research, extension efforts and awareness campaigns is essential to unlocking amaranth's potential as a driver of nutrition, food security and sustainable food systems in Ghana.

Tricot trials of amaranth. Photo: Neil Palmer / Crop Trust.

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Traditional deshelling of Bambara groundnut in Unyamikumbi, Singida, Tanzania.
Photo: Michael Major / Crop Trust

BAMBARA GROUNDNUT

Vigna spp.

Focus on Tanzania and Benin

History of Domestication

Bambara groundnut is believed to have originated in West Africa (Lyimo et al., 2004; Hillocks et al., 2012). However, the Southern and Eastern African region has been suggested as an alternative or possibly secondary center for the domestication, evolution, or diversification of the crop (Aliyu et al., 2016). The Bambara groundnut is now cultivated across sub-Saharan Africa, South and Southeast Asia and parts of South America. It is valued for its ability to thrive in poor soils and drought-prone environments. In Tanzania, it is grown by smallholder farmers, both as a subsistence food crop and an important source of dietary protein.

Taxonomy and Biology

Bambara groundnut belongs to the Fabaceae family (NRC, 2006; WFO, 2025. It is an annual creeping herbaceous legume that usually grows close to the ground, spreading or trailing along the surface (Heuzé *et al*., 2020). The plant has trifoliate leaves and produces light yellow or deep yellow flowers (NRC, 2006). Its seeds are contained within clustered pods that develop underground or near the soil surface, reaching depths of about 4 cm in the soil (Majola *et al*., 2021). The seeds are spherical and display various patterns and colors, including cream, yellow, brown, red, purple and black (NRC, 2006; Majola *et al*., 2021). Studies in Benin have shown significant morphological diversity across different agro-ecological zones, with cream-colored seeds being the most common (Kanninkpo *et al*., 2022). Genetic diversity analysis using Simple Sequence Repeat (SSR) markers revealed the greatest diversity in accessions from the West African and Cameroon/Nigeria regions (Somta *et al*., 2011).

Bambara groundnut thrives in tropical and subtropical regions, growing well at altitudes up to 1,500 m, although optimal growth occurs at lower altitudes. It grows best at temperatures of 30–35 °C for germination and 20–28 °C for growth, with an annual rainfall of 300–1,000 mm (Basu *et al*., 2007; Heuzé *et al*., 2020; Mudau *et al*., 2022). Bambara groundnut performs well in hot, dry soils, surpassing crops like sorghum, maize and groundnuts in tough conditions. Ideal soils are light, well-drained sandy loams with a pH of 5.0–6.5 (Basu *et al*., 2007; Heuzé *et al*., 2020; Majola *et al*., 2021; Mudau *et al*., 2022), but it can also tolerate well-drained, low-calcium soils (Heuzé *et al*., 2020). The crop is highly sensitive to excessive moisture, which can negatively impact its growth, yield and quality (Basu *et al*., 2007; Mudau *et al*., 2022).

Importance, Sociocultural Aspects and Potential

The Bambara groundnut is highly nutritious, providing important proteins, carbohydrates, vitamins and minerals for food and nutritional security in sub-Saharan Africa (Mohammed *et al*., 2016; Majola *et al*., 2021). Due to its balanced macronutrient composition of approximately 64.4% carbohydrates, 23.6% protein, 6.5% fat, and 5.5% fiber, some describe it as a “complete food” (Tan *et al*., 2020; Mohammed *et al*., 2023). It is also rich in minerals, such as potassium, magnesium, iron and zinc, as well as in essential and nonessential amino acids. A literature review revealed that Bambara groundnuts have significantly higher mineral levels than mung beans and chickpeas (Halimi *et al*., 2019; Tan *et al*., 2020). Furthermore, the plant offers valuable phytochemical, nutritional, and antimicrobial properties in its seeds, leaves and roots (Ogbuagu *et al*., 2022). Nevertheless, the full medicinal and health potential of this underutilized crop requires further research.

Bambara groundnut nuts are eaten fresh, cooked, or roasted as snacks, crushed into flour, or incorporated into various dishes (Lyimo *et al*., 2004). In Tanzania, the crop holds cultural significance and is commonly used in traditional ceremonies. It is popular during Ramadan due to its softness when cooked and its easy digestibility (Boulay *et al*., 2020), and is typically eaten with tambi (a type of noodle) and andazi (local doughnuts) (Boulay *et al*., 2020).

The cultivation of Bambara groundnuts is primarily carried out by women in Benin and Tanzania, reflecting their deep integration into women-led subsistence farming systems (Massawe *et al*., 2003; Dansi *et al*., 2012; Karwani *et al*., 2017). The crop's resilience in dry areas makes it an important insurance crop for households facing climate variability (Lyimo *et al*., 2004; Boulay *et al*., 2020). Its ability to fix atmospheric nitrogen also contributes indirectly to healthier food environments by improving soil fertility and the nutritional quality of intercropped plants (Kishinevsky *et al*., 1996; Mohale *et al*., 2014).

Tanzanian farmers often sell surplus produce for additional income. Value-added opportunities include processing the nuts into flour and flour-based products (Olatunde *et al*., 2021), blended products (Honi, 2016; Honi *et al*., 2018), Bambara groundnut milk (Ntundu *et al*., 2006; Murevanhema and Jideani Victoria, 2013), animal feed (Bbebe, 2019), and canned products (Hillocks *et al*., 2012). creating seasonal market opportunities (Boulay *et al*., 2020).

It is estimated that approximately 420,000 hectares of Bambara groundnut were planted globally in 2023, yielding around 275,000 tonnes of seed, with 171,000 tonnes produced in West Africa (FAO, 2025). The global average yield of 596.6 kg/ha is significantly lower than the potential yield of 2,200 kg/ha recorded in southeastern Tanzania (Tenga, 2019), underscoring the need for increased investment in the crop.

Esther Yohana Majija uses traditional African vegetables in products she makes at her bakery, the Fortlene Bakery, in Babati, Tanzania. A team from BOLDER and World Vegetable Center visited her to see products made with Bambara groundnut. Photo: Michael Major / Crop Trust

Neglect, Underutilization, Challenges

Despite its numerous nutritional and agronomic benefits, Bambara groundnut remains underutilized across sub-Saharan Africa (Hillocks *et al*., 2012; Aliyu *et al*., 2016; Boulay *et al*., 2020). In Tanzania, some younger farmers perceive the crop as outdated, limiting intergenerational uptake (Karwani *et al*., 2017), while research indicates that only a small portion of cultivated land is dedicated to it, with most farmers growing it as a supplementary rather than a main crop (Boulay *et al*., 2020). The crop also contains antinutritional factors, including tannins, phytic acids, and trypsin inhibitors, that may reduce consumer demand, though soaking, cooking, dehulling, roasting and fermentation have all been shown to effectively reduce these compounds (Halimi *et al*., 2019; Adegunwa *et al*., 2014; Yahaya *et al*., 2022). Cultural beliefs further constrain production in some communities: in Mtwara district, beliefs about early planting delaying rainfall lead to late sowing and reduced yields, while other gender-related taboos influence field management practices in Kagera and Muleba districts (Boulay, 2017; Boulay *et al*., 2020; Karwani *et al*., 2017). Little research has been conducted on the crop in Tanzania, and the factors preventing farmers from increasing production remain poorly understood, limiting the effectiveness of breeding and extension efforts (Kundy *et al*., 2018; Boulay *et al*., 2020).

Agronomic Issues

In Tanzania, farmers in Mtwara district have reported abandoning Bambara groundnut primarily due to high labor requirements, limited access to seeds, and pest and disease pressure, while barriers to first-time cultivation include lack of training, preference for other crops, unfavorable weather, low marketability and cultural beliefs (Boulay *et al*., 2020). In Kagera district, low yields have been attributed to the absence of improved seeds, Fusarium wilt and social and structural inequalities that limit women's access to improved technologies and management practices (Karwani *et al*., 2017). In Benin, the main biotic constraints are insect pests, which can cause total crop loss, and damping-off disease caused by *Sclerotium rolfsii*, while the primary abiotic constraints are poor soils, irregular rainfall and drought (Loko *et al*., 2013; Gbaguidi *et al*., 2015a; Bossou *et al*., 2022). Weed infestation, lack of certified seeds and low yields are additional challenges reported in Benin (Gbaguidi *et al*., 2015a; 2015b). Limited support from extension services further constrains farmers' ability to adopt improved practices (Karwani *et al*., 2017).

Conservation and Breeding

Genesys holds a total of 4,105 accessions of *Vigna subterranea*, with nearly half (2,004) maintained by the genebank at the International Institute of Tropical Agriculture (IITA) in Nigeria (Genesys, 2025). The National Plant Genetic Resources Center in Tanzania holds 284 accessions, while the Unité de Génétique, Biotechnologie et Science des Semences at the Université d'Abomey Calavi in Benin holds 85 accessions. Breeding efforts face several challenges, including limited data on genetic diversity and insufficient representation of different varieties in research (Aliyu *et al*., 2016). Although characterization studies have been conducted on Tanzanian varieties (Collinson *et al*., 2000; Ntundu *et al*., 2004; 2006; Kundy *et al*., 2018; Gao *et al*., 2023), the available data remain insufficient to support robust breeding programs, and weak value chains restrict effective feedback to breeders (Aliyu *et al*., 2014). Six varieties have been released in Tanzania, four in 2013 through a McKnight Foundation-funded project and two in 2018, but information on their adoption remains limited, and farmers in Kagera district reported having never accessed new varieties (Chancellor and Chilombo, 2016; Karwani *et al*., 2017). Exploring the crop's broader genetic diversity and developing structured breeding programs could lead to significant improvements in yield, climate resilience and nutritional quality (Temegne *et al*., 2018; Muhammad *et al*., 2020).

Bambara groundnut accessions at the National Plant Genetic Resources Centre hosted by the Tanzania Plant Health and Pesticides Authority (TPHPA) in Arusha, Tanzania. Photo: Michael Major / Crop Trust

Processing and Value Chains

Value chains for Bambara groundnut are weak and fragmented, making investments in the value chain difficult. Additionally, long cooking times may discourage consumption (Hillocks *et al*., 2012). Another challenge is that Bambara groundnut does not dehull easily, which could discourage value chain actors (Hillocks *et al*., 2012). There is limited information on processing and related value chains. While there is potential in the value addition market, more research is needed to better understand consumer preferences for these products.

Market Access

Bambara groundnut faces several challenges in marketing and market development, including slow market growth, difficulty entering international markets despite existing demand and a lack of trade information to guide marketing strategies (Hillocks *et al*., 2012). Local markets are generally limited and underdeveloped due to a preference for other more commercially viable legumes (Boulay *et al*., 2020). Furthermore, the absence of strong value chains from farm to consumer, including inadequate market and product development, further hampers sales and market growth for Bambara groundnut (Hillocks *et al*., 2012; Chancellor and Chilombo, 2016). Potential buyers in parts of Tanzania report that farmers are unable to meet the demand for guaranteed quantities (Chancellor and Chilombo, 2016). There are also reported gender imbalances that may disadvantage women—marketing of Bambara groundnut appears to be dominated by men, yet women provide most of the labor (Karwani *et al*., 2017).

Musa Msafiri, a wholesaler in Singida, showing Bambara groundnut.
Photo: Michael Major / Crop Trust

Conclusion

Bambara groundnut remains significantly underutilized despite its considerable nutritional, agronomic and economic potential. Key barriers include long cooking times, antinutritional components, limited investment in research, weak value chains and underdeveloped markets (Hillocks et al., 2012; Boulay et al., 2020; Tan et al., 2020). Production is typically small-scale, reliant on manual labor and constrained by limited access to improved seeds, extension services and market information (Alhassan and Egbe, 2013).
Realizing the crop's full potential will require coordinated efforts to improve crop management, develop improved varieties adapted to climate change, enhance value addition and expand market access (Majola et al., 2021). Greater investment in research, particularly on genetic diversity, innovative production techniques and biotic and abiotic stress management, alongside strengthened value chains and more equitable market participation, will be essential to elevating Bambara groundnut's role in food security and rural livelihoods in Tanzania and beyond (Ouoba et al., 2016; Chibarabada et al., 2017).

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Baobab fruits. Photo: Michael Major/Crop Trust

BAOBAB

Adansonia spp.

Revitalizing a Multifunctional Indigenous Tree for Sustainable Livelihoods in Ghana

History of Domestication

The baobab, a unique long-lived African tree, is believed to have originated in West Africa, from which it spread widely across the savannas of sub-Saharan Africa and Madagascar (Pock Tsy et al., 2009; Assogbadjo *et al*., 2021). It is now found throughout the drylands extending from Senegal to Sudan and from Ethiopia to Natal, reflecting its remarkable adaptability to arid and semi-arid environments (Leakey *et al*., 2022). Baobab is not a domesticated species and is predominantly harvested from the wild. Nevertheless, in some countries such as Niger, farmers actively manage its natural regeneration as part of agroforestry systems, representing an early stage in the transition toward domestication (Agúndez *et al*., 2020). Research efforts to support this process have explored various techniques, including seed treatment to enhance germination (Falemara *et al*., 2014) and grafting as a means of vegetative propagation (Anjarwalla *et al*. 2016; Jenya, Munthali and Mhango, 2018).

Taxonomy and Biology

The baobab is a deciduous tree in the subfamily Bombacoideae within the Malvaceae family (Kitony *et al*., 2024). It is drought-tolerant and can reach heights of up to 25 meters, with a trunk of as much as 10 meters in diameter (Leakey *et al*., 2022). Baobabs shed their leaves during the dry season to reduce water loss, and their massive trunks made of fibrous, spongy wood serve as water-storage organs capable of holding thousands of liters. Their flowers are large, showy and short-lived—opening at dusk and lasting only about 24 hours—and are primarily pollinated by fruit bats, with insects contributing in some regions. The resulting fruit forms a hard, woody pod containing a dry, nutrient-dense pulp rich in vitamin C, minerals, and fiber, surrounding many large seeds with tough coats and variable dormancy. Baobabs grow slowly but can reach exceptional size and age, with some individuals living for more than a thousand years, and they reproduce both sexually through seeds and vegetatively through resprouting, supporting their persistence in harsh environments (Wilkens and Lowe, 2008).

Importance, Sociocultural Aspects and Potential

The African baobab is a multipurpose tree native to the dry savanna of sub-Saharan Africa, where it plays an important role in securing the livelihoods of rural communities (Gebauer, El-Siddig and Ebert, 2002; Kamatou, Vermaak and Viljoen, 2011). All parts of the baobab tree, namely bark, flowers, fruits, leaves, roots, and seeds, are useful, with the fruit pulp, leaves, and seeds primarily valued for food, nutritional security, and their rich content of essential nutrients (Kaboré *et al*., 2011; Assogbadjo *et al*., 2008; 2021). The fruits, leaves and other parts are rich in vitamins, minerals, and bioactive compounds with documented health benefits (Namratha and Sahithi, 2015; Asogwa, Ibrahim, and Agbaka, 2021). Moreover, different parts of the Baobab have documented medicinal properties. The roots, bark, and leaf extracts demonstrate high antiviral and antimicrobial activities, and the bark contains an alkaloid called adansonin, which is effective against malaria and fever (Asogwa, Ibrahim, and Agbaka, 2021). Moreover, in Ghana, the baobab bark is commonly used to treat fever (Shukla *et al*., 2001). The fruit pulp also serves as a functional food that can help naturally address and prevent hyperlipidemia-related health issues by enhancing the activity of antioxidant enzymes (Asogwa, Ibrahim, and Agbaka, 2021).

In West Africa, the Baobab occupies a prominent place in the social, cultural, and economic fabric of many communities. More than 300 uses of baobab have been documented among 11 ethnic groups, reflecting its remarkable multifunctionality (Buchmann *et al*., 2010; Assogbadjo *et al*., 2021). Beyond its practical applications, the tree is deeply embedded in cultural identity and local belief systems (Buchmann *et al*., 2010). In Ghana, baobab products include food items, local beer, jam and juice, and many rural households depend on their sale to supplement farm income, particularly during the dry season (Kende-Robb, 2003; Akonga, 2024). In Ghana, the tree holds additional historical significance linked to the slave trade, as a notable specimen is located at the site of the Saakpuli Slave Market (Okoro, 2002). This cultural and historical embeddedness underscores the diversity of roles that baobab plays in supporting livelihoods and identity throughout Africa.

At the same time, baobab holds considerable potential as a cash crop in West Africa. In Ghana, it complements cocoa production systems and contributes to livelihood diversification (Egbadzor, Akuaku, and Aidoo, 2023). Research conducted in the Nabdam District of the Upper East Region highlights significant opportunities to increase household income through improved processing and market integration, recommending targeted skills training and seed capital to support marginalized groups in expanding their participation (Akonga, 2024). Efforts to commercialize baobab have also extended to international markets. Notably, the South African trade organization PhytoTrade lobbied for the approval of baobab fruit as a novel food in the European Union, which was granted in 2008, thereby opening the European market to African exports of dried baobab pulp (European Union, 2008; Buchmann *et al*., 2010). However, scholars caution that export-oriented commercialization must be carefully managed to avoid undermining local access and livelihoods (Buchmann *et al*., 2010). Although existing studies have examined aspects of baobab commercialization (Malabadi *et al*., 2021; Sylvanus *et al*., 2021), substantial untapped potential remains in Ghana, and further research is needed to assess its contribution to climate change adaptation (Akonga, 2024).

Baobab fruit at ICRAF genabank. Photo: Michael Major/Crop Trust

Neglect, Underutilization, Challenges

Baobab's contribution to food and nutrition security remains limited by low consumption, constrained production and insufficient investment in research and development for its domestication and improvement. These factors impede access, supply, use and long-term sustainability. Raising awareness of baobab's nutritional benefits and promoting technological progress, including tree improvement, climate-smart production systems, food product development and gender-responsive technologies, are essential steps toward addressing these constraints. A dedicated national research agenda that recognizes the role of orphan species in nutrition would help boost investment in the crop. Practical experiences from Cameroon offer valuable models that could be adapted to promote wider cultivation and consumption. Additional research into the impact of baobab production on climate change adaptation in Ghana is also needed (Akonga, 2024).

Agronomic Issues

Challenges to domestication include difficulties with seed germination and the long juvenile period of baobab. The seed coat of baobab is tough, causing mechanical dormancy, which must be broken before the seed can germinate (Egbadzor, 2020). One method is to treat the seed with sulfuric acid, which breaks dormancy and leads to early and uniform germination of seeds (Niang *et al*., 2015). However, the germination challenge makes it difficult to reliably produce seedlings.

Beyond seed dormancy, the lengthy juvenile period of the tree is a major limitation to its cultivation. However, Egbadzor and Akuwaku (2022) found that baobab can start fruiting within two years with proper agronomic practices like grafting, which could encourage farmers to grow it in Ghana. Although this was based on a single tree, reliably achieving this could motivate farmers who are discouraged by the plant's long maturity period to begin cultivating baobab. Exploring grafting techniques to reduce the juvenile phase would be beneficial.

Conservation and Breeding

One reason for the underutilization of baobab is its wild, undomesticated state. The tree naturally grows across Ghana, especially in the savannahs and drier regions. Research has mainly focused on understanding its diversity, germination and growth patterns to support domestication (Egbadzor, 2020). Jensen *et al*. (2011) describe efforts by a group of scientists working on baobab domestication in 2005 and mention plans to develop a domestication strategy in Burkina Faso, Mali and Niger. However, there is currently no active interest or ongoing work toward domesticating the plant.

Egbadzor (2020) identified high variability in baobab morphology in the Volta Region of Ghana (Adaklu District and Ho and Hohoe Municipalities), which could help in selecting plants for domestication. They also suggested that traits like the taste of baobab fruit pulp be included in future characterization efforts (Egbadzor, 2020).

ICRAF genebank, Nairobi. Agnes Were, Laboratory Assistant, performing seed extraction from baobab fruits. Photo: Michael Major/Crop Trust

Processing and Value Chains

Baobab fruits are processed into various food and non-food products, such as fruit juice, ice pops, sweets and cosmetics in Malawi (Darr *et al*., 2020). However, studies in Kenya found that processing is generally informal and small-scale, mainly limited to making sweets from the pulp and seeds (Mwangi, Kunyanga, and Onyango, 2023). Similarly, research in Malawi showed that out of 100 baobab processors surveyed, 97 were sole proprietors, two were cooperatives, and one was a limited liability company. Additionally, 94 were not officially registered businesses (Gangata *et al*., 2024). This largely reflects the lack of research and innovation in developing improved processing techniques (Omotayo and Aremu, 2020). Markets are typically local and informal.

Baobab in the Tanzania central market. Photo: Michael Major/Crop Trust

Market Access

Darr *et al*. (2020) observed increased interest in wild foods, including baobab products, among wealthier segments of the population in Malawi. This trend has also been seen in other parts of Africa (Schlesinger, Drescher, and Shackleton, 2015). However, Saeed *et al*. (2023) point out that there are few studies on the marketing of baobab fruit pulp, especially regarding consumer behavior, attitudes, and beliefs about it. Therefore, while opportunities for baobab product producers are growing, particularly in export markets to Europe and North America (Darr *et al*., 2020), wild foods are still poorly integrated into formal markets, which limits access. This is mainly due to supply variability, both in amount and seasonality, and inconsistent quality of wild-sourced foods and products. Additionally, increasing wild harvesting for market purposes could threaten the natural regeneration of the trees as fruit collection expands (Darr *et al*., 2020).

Conclusion

Baobab has many uses in the dry savannah of West Africa and other regions of the continent. Efforts are necessary to address key issues, including assessing and conserving existing diversity, tackling agronomic challenges such as poor germination and a long juvenile period, and improving processing technologies to boost market potential both locally and internationally.

The seeds of the baobab are covered with a whitish-pink, dry, acidic pulp that is high in Vitamin C and makes a nice juice. Agnes Were, a laboratory assistant at ICRAF genebank in Nairobi displays an open baobab fruit. The seeds are soaked in water to remove the pulp. Photo: Michael Major/Crop Trust

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Seeds tested in farmer's fields at Igbo-Ora, Oyo State, Nigeria.
Photo: Georgina Smith / Crop Trust

COWPEA

Vigna spp.

Unlocking Nutritional and Economic Potential for Smallholder Farmers in Uganda

History of Domestication

Cowpea is believed to be native to West Africa, specifically Nigeria, where it has been cultivated for thousands of years (Herniter, Muñoz Amatriaín and Close, 2020). The crop was likely introduced to Uganda by traders and farmers in the late 19th century, where it became an essential part of local diets and farming systems (Okello, Obote and Ezra, 2017). Today, the northern and eastern regions of Uganda are considered secondary centers of genetic diversity of cowpeas (Edema, Adipala and Florini, 1997).

Taxonomy and Biology

Cowpea belongs to the family Fabaceae and is an annual, warm-season herbaceous legume that exhibits significant morphological variability (Carvalho *et al*., 2017). Plants can grow either upright, reaching up to 2 meters in height, or as spreading climbers extending up to 80 cm (Heuzé *et al*., 2015). Leaves consist of three oval leaflets, and flowers, which grow in clusters, can be purple, pink, white, blue, or yellow. The seeds are globe-shaped or kidney-shaped, with smooth or wrinkled surfaces measuring 5–12 mm, and vary widely in color from white, cream, yellow, red, brown, and black, with some being speckled or blotched (NRC, 2006). Seeds are contained in long, smooth, cylindrical pods, each holding 8-20 seeds (NRC, 2006; Heuzé *et al*., 2015).

Cowpea takes anywhere from 60-240 days to mature, depending on the cultivar and climate (NRC, 2006). The crop thrives in well-drained sandy loam to clay loam soils that promote healthy rooting, with a pH range of 6–7(NaSARRI, n.d.). Its broad morphological diversity and wide maturity range reflect the crop's adaptability to varied environments, which has contributed to its widespread cultivation across tropical and subtropical regions.

Importance, Sociocultural Aspects and Potential

Cowpea plays an important role in food and nutritional security in Uganda, providing an accessible source of protein, vitamins, and essential minerals such as calcium, iron, and phosphorus (Nabirye *et al*., 2003). These nutrients are particularly vital for rural households that rely heavily on starchy staples such as millet, sorghum, maize, and cassava (Ddungu *et al*., 2015) Cowpea is also notably rich in folic acid and vitamin B, both critical during pregnancy for preventing neural tube defects. Accordingly, interest in nutritionally enhanced varieties is growing among consumers. For example, a study in Northern Uganda found that consumers were willing to pay more for biofortified cowpeas enriched with iodine (Olum *et al*., 2021).

Cowpea can be consumed in a variety of forms, including fresh and dried leaves, immature pods, fresh mature seeds, and dried seeds that can be stored, cooked whole, or ground into flour for use in local recipes (NaSARRI, n.d.). Tender leaves can be harvested regularly from four weeks after planting and every two weeks until flowering, providing an important dietary supplement that helps families bridge the gap between cereal harvests (Okonya *et al*., 2009). The leaves and stems also produce high-quality hay for animal feed, and the crop enhances soil fertility through nitrogen fixation, erosion prevention, and green manure provision (NaSARRI, n.d.).

Research in the Kumi and Soroti districts of Uganda highlights the crop's significant sociocultural importance: cowpea is served during key social occasions such as funerals and child naming ceremonies and is offered to visitors as a mark of hospitality (Mundua, 2010). In the Acholi region, cultural beliefs promote cowpea consumption during pregnancy, as it is associated with the birth of a healthy child. Among the Thur/Labwor ethnic group in Karamoja, infants under six months are given ngor (cowpea leaves) during naming ceremonies (Muggaga *et al*., 2017). However, in Bukenye district, eating the leaves is thought to cause the baby's death (Tugume *et al*., 2024).

Cowpea was traditionally grown almost exclusively as a subsistence food crop in Uganda. However, following the decline of cotton as the main cash crop in Northern Uganda and the expansion of external markets, approximately 50% of farmers in the region shifted to growing cowpea as a cash crop (Ddungu *et al*., 2015). Both grain and leaves are now grown commercially in some regions (Ayaa, Alumai, and Dranzoa, 2018; Lamwaka, 2018). As part of government input subsidy programs, the National Agricultural Advisory Services (NAADS) distributed 30,845 kg of cowpea seed in the Karamoja region during 2022–23 (Tihanyi *et al*., 2024). In 2022, approximately 13,260 tonnes were produced from 28,994 hectares, with an average grain yield of 457 kg per hectare (FAO, 2025). This figure is significantly below the potential yield of up to 3,000 kg per hectare (Ayaa, Alumai, and Dranzoa, 2018), indicating substantial room for productivity improvement.

A dark-seeded cowpea landrace at a seed fair in Bhanda, Zimbabwe.
Photo: Michael Major / Crop Trust

Neglect, Underutilization, Challenges

Despite its nutritional and agronomic value, cowpea remains significantly underutilized in Uganda, held back by a combination of structural, cultural, and research-related constraints. Average yields are low, ranging from 200 to 400 kg/ha against a potential of 3 t/ha (Ayaa, Alumai and Dranzoa, 2018). Limited research on production methods, processing, and post-harvest handling has reinforced its perception as a backyard crop cultivated primarily by women, reducing its visibility and investment appeal (Ayaa, Alumai and Dranzoa, 2018). Cultural perceptions and dietary preferences further constrain consumption, particularly in areas where other staples dominate local food systems (NRC, 2006). Together, these factors limit cowpea's potential to contribute more meaningfully to climate-resilient agriculture, nutrition security, and livelihood diversification across Uganda and the broader sub-Saharan Africa region.

Agronomic Issues

Although on-station trials report yields of 1.5-3 t/ha, farm-level yields of less than 0.5 t/ha are linked to various constraints, including low-yielding local varieties, pests, poor agronomic practices, land shortages, seed scarcity, drought, and poor soil (Okonya *et al*., 2009; Okello, Obote, and Ezra, 2017). Furthermore, cowpea scab disease is making a comeback in Uganda. Only one of the five improved cowpea cultivars is moderately resistant, and it is not widely available to farmers (Afutu, 2017; Alipa, 2023).

Several studies have focused on cowpea diseases in Uganda (Iceduna, 1993; Edema, Adipala and Florini, 1997; Adipala *et al*., 1999; Mbeyagala *et al*., 2014; Afutu *et al*., 2016; Afutu, 2017; Alipa, 2023; Nantale *et al*., 2023a, 2023b), but research on other aspects remains limited. For instance, fewer studies examine consumer preferences (Mundua, 2010; Orawu, Obuo and Omadi, 2013; Kyebalyenda *et al*., 2022), marketing issues (Emaju, 2000; Okello, Obote and Ezra, 2017), and the adoption rates of released varieties.

Conservation and Breeding

Limited investment in breeding programs and the absence of improved varieties contribute to low productivity, with many farmers relying on traditional landraces that are vulnerable to pests and diseases (Alipa, 2023). Although the Uganda National Genebank holds 34 cowpea accessions, all of which are landraces (Genesys, 2025), efforts to collect and conserve cowpea germplasm also remain insufficient, hampering the development of varieties suited to local conditions (Alipa, 2023).

Some institutional efforts are underway to address these gaps. The National Semi-Arid Resources Research Institute (NaSARRI) has established a cowpea breeding program, collecting landraces from across the country and sourcing additional lines from the International Institute for Tropical Agriculture (IITA) in Nigeria (NaSARRI, n.d.; Ddamulira *et al*., 2017). This work has resulted in the release of 11 varieties to date, five in 2013 and six in 2016 (NaSARRI, n.d.; NaSARRI, 2017), though no studies were found assessing their adoption rates.

The Makerere University Regional Centre for Crop Improvement (MaRCCI) has also released cowpea varieties through its breeding program, five of which have been commercialized (SECOW 1WT, SECOW 2W, NAROCOW 3, NAROCOW 4, and NAROCOW 5) and are now sold by 12 seed companies across Uganda (NARO, 2023). As of 2019, Uganda produced 1.7 tonnes of cowpea quality declared seed (Longley *et al*., 2021).

Staff at the National Plant Genetic Resources Centre (NPGRC) of the Zambia Agriculture Research Institute (ZARI) check cowpea growing in the NPGRC field genebank at ZARI's Mt Makulu Central Research Station, Lusaka. Photo: Neil Palmer/ Crop Trust.

Processing and Value Chains

Value addition for cowpea is minimal, mainly involving sorting and grading, with most sold as whole grain or occasionally as split grain (Ddungu *et al*., 2015; Okello *et al*., 2015). While trade has mostly been limited to local markets, a growing regional market is developing in South Sudan and Kenya (Ddungu *et al*., 2015). Traditionally, sun drying is used to preserve leaves, but modern methods such as solar drying, freeze drying, convection oven drying, and refractance window drying have potential, especially for commercialization (Kaaya, n.d.). A major post-harvest challenge is pest infestation during storage (Nampala *et al*., 2018).

Market Access

Cowpea programs in Uganda have largely focused on increasing productivity, with limited documentation on market evaluation for improved varieties (Alipa, 2023). Marketing challenges remain widespread, including limited market access, low market integration, price fluctuations, and poor information flows (Okello, Obote and Ezra, 2017). Emaju (2000) identified persistent structural issues facing cowpea traders, including high transportation costs, poor storage conditions, seasonal demand fluctuations, inefficient distribution channels, limited financing, and inadequate infrastructure. These problems largely persist today. Consequently, cowpea marketing is largely confined to local markets and farm gates due to poor road infrastructure, which restricts farmers' access to urban markets (Ddungu *et al*., 2015).

Emaju (2000) identified a range of persistent structural issues facing cowpea traders, namely high transportation costs, poor storage conditions, seasonal demand fluctuations, inefficient distribution channels, limited financing, and inadequate infrastructure. As a result, cowpea marketing remains largely confined to local markets and farm gates, with farmers' access to urban markets constrained by poor road infrastructure (Ddungu *et al*., 2015). Nevertheless, there is notable interregional trade, with Ugandan cowpeas regularly reaching Kenyan markets as a profitable export commodity (Ddungu *et al*., 2015).

Cowpea pods at a germplasm user evaluation group at Mwachilele Camp, Rufunsa District, Zambia. Part of the Seeds For Resilience project. Photo: Neil Palmer/ Crop Trust.

Conclusion

Cowpea holds considerable potential to strengthen food and nutrition security and contribute to economic growth in Uganda, yet its widespread adoption remains constrained by low yields, inadequate processing infrastructure, and limited market access. Realizing this potential will require targeted investment in production methods, agronomic practices, and breeding research, alongside improved germplasm conservation. Given their potential to support household livelihoods, increase smallholder income, and advance national food security goals, greater efforts to promote the adoption of cowpeas are crucial. Raising awareness of the nutritional and commercial value of cowpeas while recognizing their dual purpose as a food and feed crop could encourage broader adoption.

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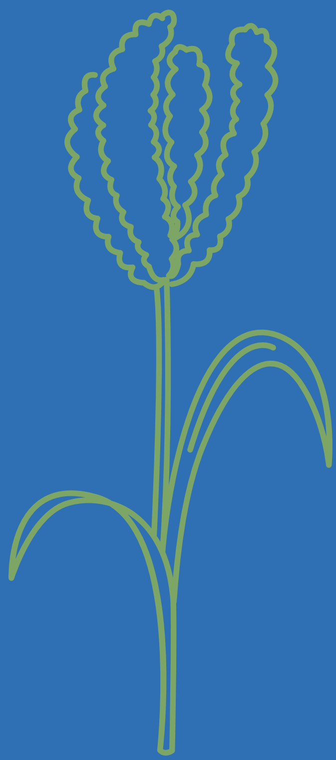
Finger millet in opportunity crop demonstration plot in western Kenya.
Photo: Michael Major/Crop Trust

FINGER MILLET

Eleusine spp.

Realizing the potential of an underutilized crop for nutrition and livelihoods in Tanzania



History of Domestication

Finger millet is believed to have been domesticated in East Africa, with evidence indicating its cultivation dates back more than 5,000 years (Msuya, 2005; Sood, Babu, and Joshi, 2022; Wright and Devos, 2024). It later spread to India and parts of Southeast Asia around 3,000 years ago, where finger millet is still widely cultivated today and remains an essential part of agricultural and cultural landscapes.

Taxonomy and Biology

Finger millet is classified in the family Poaceae and is classified as an annual cereal crop (Chandra *et al*., 2016; Swamy, 2023; WFO, 2024). The crop shows considerable genetic diversity, with variation in plant height, spike number, grain color, and maturity period across cultivars. It typically grows up to 170 cm tall and is characterized by 4–19 spikes (the “fingers”) at the top of the stem, each consisting of up to 70 alternate spikelets containing 4–7 seeds that can grow up to 170 cm tall (Heuzé and Tran, 2015). The grains are small, measuring 1–2 mm in diameter, and range in color from white and cream to light brown, dark brown, or reddish brown (FAO and ICRISAT, 1996).

Finger millet thrives in hot climates with optimal temperatures of 18–27 °C, though it can tolerate cooler conditions, and grows at altitudes between 500 and 2,400 meters (Infonet Biovision, n.d.). It requires 500–1,000 mm of well-distributed rainfall during the growing season. While adaptable to a range of soil types, it performs best on reddish-brown lateritic soils with good drainage, high water-holding capacity, and elevated levels of iron and aluminum (Infonet Biovision, n.d.). Notably, finger millet is more tolerant of waterlogging than most other cereal crops, further extending its adaptability across diverse farming environments (Infonet Biovision, n.d.; Swamy, 2023).

Importance, Sociocultural Aspects and Potential

Finger millet plays a key role in meeting the dietary needs of rural households in Tanzania (Msuya, 2005; Mgonja *et al*., 2007). It is a nutrient-dense cereal rich in essential micronutrients such as zinc, iron, and particularly calcium, containing about 350 mg per 100 g, approximately three times more than milk and sufficient to provide up to one-third of the recommended daily intake (Shobana *et al*., 2013; Orr *et al*., 2016). Finger millet contains relatively high levels of protein and essential amino acids, contributing to the prevention of protein malnutrition and related conditions, such as kwashiorkor. Due to this nutritional profile, finger millet is widely valued as a food for nursing mothers, children, infants, the sick, and the elderly (Kisandu *et al*., 2005; Orr *et al*., 2016). Its gluten-free nature further enhances its dietary relevance, making it suitable for individuals with gluten intolerance and certain digestive disorders (Asharani, Jayadeep and Malleshi, 2010; Gabaza *et al*., 2018; Negi, 2022).

In Tanzania, finger millet is widely grown as a traditional staple using predominantly local farming methods (Msuya, 2005; Msuya, 2006a). It is mainly produced in the Southern Highlands, particularly in Mbeya, Iringa, Ruvuma, and Rukwa, which together account for over half of national production (Msuya, 2006a). Other important producing regions include Mara, Kigoma, Kilimanjaro, Singida, and Dodoma. The crop’s tolerance to drought, poor soils, and harsh climatic conditions makes it a reliable food source in marginal environments and has increased its importance in drought-prone districts (Ojulong *et al*., 2017; URT, 2021).

Finger millet is versatile and can be processed into a wide range of products, including fermented drinks, other beverages, flour, and various food preparations (Schipmann-Schwarze *et al*., 2015; Kasule *et al*., 2023). In Tanzania, processing is traditionally carried out at the household level, often using locally adapted methods. The crop is widely used to prepare traditional beverages such as kimpumu in the Southern Highlands and mbege in northern regions. It is also utilized for malt production in the commercial brewing industry. In areas such as Sumbawanga and Mbozi, finger millet is a key ingredient in stiff porridge, which constitutes a dietary staple. Its small grain size contributes to a long shelf life and resistance to storage pests, reducing post-harvest losses (Msuya, 2005).

Finger millet holds cultural significance in various Tanzanian communities and is closely linked to local dietary traditions. In many areas, it is considered a woman's crop, with women playing a central role in cultivation and processing (Ojulong *et al*., 2017). Cultural beliefs also shape consumption patterns. In some communities in Singida, Arusha, and Dar es Salaam, new and lactating mothers are encouraged to consume soft, nutrient-rich porridge (uji wa lishe) but avoid stiff millet porridge, which is believed to cause stomach ulcers or reduce breast milk production (TFNC, 2023).

Growing urbanization and health-conscious consumption trends are increasing demand for nutritious crops, including finger millet (Schipmann-Schwarze *et al*., 2015; Orr *et al*., 2016). Its suitability for low-input systems makes it attractive for domestic and regional markets. Furthermore, the crop's gluten-free trait is generating further opportunities in high-value domestic and international markets. Accordingly, studies indicate that, by the early 2000's, finger millet was increasingly being cultivated as a cash crop in Tanzania (Kisandu *et al*., 2005; Msuya, 2006a). In 2019/20, the National Sample Census of Agriculture recorded 31,468 ha under cultivation and 32,950 t of production, with Rukwa leading in output and Mwanza achieving the highest yield of 1.8 t/ha, which is still below the 4–5 t/ha obtained in on-station trials (URT, 2021). Nonetheless, further research is needed to verify this trend.

Overall, the crop's low production costs have the potential to increase household incomes and reduce poverty among smallholder farmers (Kisandu *et al*., 2005; Mgonja *et al*., 2007; Msokwa, 2024). By lowering production costs and reducing produce losses, these traits directly translate into higher household incomes and broader poverty alleviation in rural areas (Msokwa, 2024). Together, these market and agronomic advantages highlight the substantial economic potential of finger millet for enhancing the livelihoods of farmers in Tanzania.

Neglect, Underutilization, Challenges

Finger millet remains neglected and underutilized in Tanzania due to various socio-economic and market factors. Despite its nutritional advantages, it encounters low market demand, limited processing infrastructure, and low consumer awareness (Kasule *et al*., 2023; Wright and Devos, 2024). Issues in grain processing, changing taste preferences, and insufficient research and policy support hinder its production and use (Elorm, 2023). As a result, farmers often prefer other crops, like maize and rice, which have more developed value chains and higher market demand (Ojulong *et al*., 2017; Negi, 2022; Wright and Devos, 2024), causing a decline in production as farmers and consumers shift to these alternatives.

Agronomic Issues

Finger millet has been overlooked by farmers in Tanzania, and declining production and yields may be due to low input use, pests and diseases, and limited access to improved varieties (Ojulong *et al*., 2017). Many farmers rely on their own saved seed or seed from neighbors and fellow farmers (Msuya, 2006b; Marimo *et al*., 2021). However, the structure, functioning, and role of these seed systems remain insufficiently documented, underscoring the need for further research to better understand seed access, diversity, and innovation pathways in Tanzania.

Finger millet growing on the ICBA campus in Dubai
Photo: Petra Pajdakovic/Crop Trust

Conservation and Breeding

Despite its nutritional and agronomic potential, finger millet faces significant challenges in conservation and breeding that have limited its wider adoption. Investment in research and development for new finger millet varieties remains low, which has significantly hindered its progress (Msuya, 2005; Kasule *et al*., 2023). One major challenge is its inbreeding nature, which makes crossbreeding efforts more difficult and reduces genetic diversity (Kisandu *et al*., 2005; Wright and Devos, 2024). These breeding challenges have slowed the development of improved varieties that could better adapt to changing environmental conditions and increase yields. This may have contributed to the continued marginalization of finger millet, keeping it classified as an underutilized crop despite its potential to improve food security, especially in the context of climate change. Addressing these breeding obstacles and boosting investment in research would allow finger millet to better realize its potential to strengthen food systems in Tanzania.

To date, the National Plant Genetic Resources Centre in Tanzania has 407 finger millet accessions, including 357 landraces (Genesys, 2025). The Tanzania Agricultural Research Institute (TARI) also holds some accessions, although data on the numbers are pending.

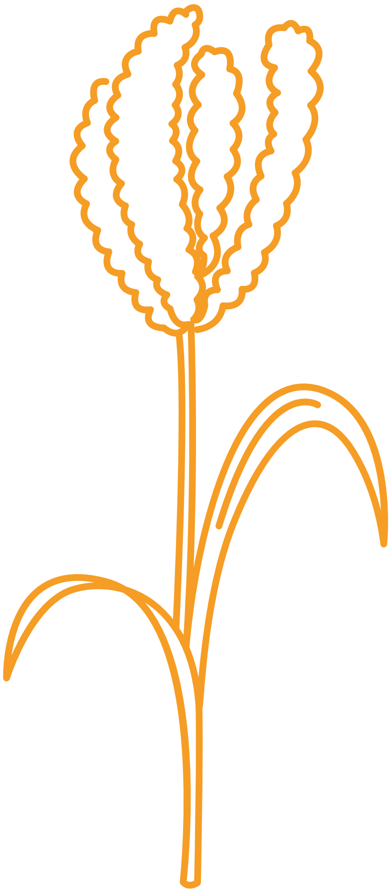
Three improved finger millet varieties have been released in Tanzania: one by TARI in 2020 and two by TARI Uyole in 2012. TARI Uyole has developed nine additional new varieties, which are awaiting registration for national distribution to farmers (Msokwa, 2024).

Despite ongoing efforts, the adoption of new varieties by farmers remains low, perhaps due to their limited involvement in developing and evaluating these varieties (Ojulong *et al*., 2017). This highlights the importance of participatory research approaches to promote greater acceptance and impact of new agricultural technologies (Mgonja *et al*., 2007; Ojulong *et al*., 2017). Participatory varietal selection for some released varieties showed that trait preferences differ between women and men: women favor risk-avoiding traits such as short duration, drought tolerance, compact heads, and disease resistance, while men prioritize market-related traits, including high yield, brown color, and larger heads (Ojulong *et al*., 2017).

Display stand of the Genetic Resources and Biotechnology Institute (GRBI) at the Good Seed & Food Festival, Harare. Photo: Michael Major / Crop Trust

Processing and Value Chains

Processors find finger millet less attractive than other cereals because of the labor-intensive nature of post-harvest handling (Msokwa, 2024; Wright and Devos, 2024). In Tanzania, processors also encounter challenges such as poor-quality grain from farmers, seasonal fluctuations in availability and price, and a lack of processing equipment (Schipmann-Schwarze *et al*., 2015).



Finger millet ugali Tanzania. Photo: Michael Major / Crop Trust

Market Access

While finger millet holds considerable market potential both locally and internationally, this demand remains largely unrealized due to underdeveloped market infrastructure. Processors face challenges including high advertising costs, expensive packaging, and poorly developed supply chains, all of which erode profit margins (Schipmann-Schwarze *et al*., 2015). Strengthening market linkages and reducing these structural costs is key to translating finger millet’s latent demand into viable commercial opportunities.

Conclusion

Finger millet offers a valuable opportunity for enhancing food security and economic resilience in Tanzania, owing to its nutritional value and ability to thrive in challenging environments. Despite its potential, the crop is still underused because of limited research, processing facilities, and market development, highlighting the need for focused efforts to promote its cultivation and consumption.

Finger millet crop in Matungu Sub-County of Kakamega County. Photo: Michael Major/Crop Trust

Mary Kwena with a handful of her recent finger millet harvest.
Matungu Sub-County of Kakamega County. Photo: Michael Major/Crop Trust

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Fonio plant in Benin. Photo: Mike Major / Crop Trust

FONIO

Digitaria spp.

Revitalizing an Ancient Grain for Nutrition and Resilience in Benin

History of Domestication

Native to West Africa, fonio (*Digitaria exilis* Stapf and *Digitaria iburua* Stapf) is considered the oldest cereal cultivated on the continent. It was first cultivated by Mande-speaking farming populations in West Africa (Vodouhe et al., 2003). Fonio is cultivated from Senegal to Lake Chad, with the Republic of Guinea being the world's largest producer. In this region, fonio is a staple food in the mountainous areas of Fouta Djalon (Cruz and Béavogui, 2011). Today, it is also found in Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, and Togo (Cruz and Béavogui, 2011; Barnaud et al., 2023).

Taxonomy and Biology

Fonio belongs to the family Poaceae and is a small annual herbaceous plant. There are two cultivated species, namely white fonio (*Digitaria exilis*), which is the more widely grown and commercially significant, and black fonio (*Digitaria iburua*), which is cultivated more locally in parts of Nigeria and Niger (Vodouhe *et al*., 2003; Barnaud *et al*., 2023). Fonio grows to a height of 30–80 cm, with a thin cylindrical hollow stem of less than 1 mm in diameter. Each plant produces 2–6 or more tillers, and the inflorescence typically consists of 2–3 racemes bearing spikelets in pairs for early varieties or 3–4 for newer varieties, each containing a sterile and a fertile flower that produces the fonio grain (Abrouk *et al*., 2020; Cruz and Béavogui, 2011). The grain is a caryopsis encased in its glumes and is exceptionally small, with a 1,000-seed weight of only 0.5 g, compared to 20 g for rice and 40 g for wheat (Cruz and Béavogui, 2011).

Fonio is cultivated across West Africa under a tropical climate characterized by a distinct dry season, average temperatures of 25–30°C, and annual rainfall of 600–1,200 mm. In Guinea, it is also grown in mountainous regions above 1,000 m altitude, where rainfall is considerably higher (1,500–2,000 mm) and temperatures notably cooler (15–25°C) (Vodouhe *et al*., 2007; Cruz and Béavogui, 2011; Abrouk *et al*., 2020). The crop exhibits high diversity among local varieties, which differ in plant color, growth habit, grain color and size, and length of the vegetative cycle (Vodouhe and Achigan Dako, 2006; Vodouhe *et al*., 2007; Diallo *et al*., 2008). Fonio grows best in light, well-drained soils and does not perform well in heavy or clayey soils (Gigou *et al*., 2009). , traditional land preparation involves shallow hoeing or plowing to a depth of approximately 10 cm (Gigou *et al*., 2009; Adoukonou-Sagbadja *et al*., 2006; Ballogou *et al*., 2014). Maturity ranges from 70–90 days for extra-early varieties to more than 130 days for late varieties (Vodouhe *et al*., 2007; Gigou *et al*., 2009). Research conducted in Mali has shown that fonio is a photoperiodic cereal, capable of regulating the duration of its vegetative phases according to the earliness of the sowing date (CIRAD, 2019).

Importance, Sociocultural Aspects and Potential

Fonio is a nutritionally rich cereal that offers a distinctive profile of macronutrients, micronutrients, and bioactive compounds that set it apart from other staple grains. Its biochemical composition of carbohydrates, lipids, and proteins generally resembles that of other cereals (Cruz, 2004; Fliedel *et al*., 2004), yet it is notably high in methionine and cystine, two essential sulfur-containing amino acids absent in wheat, rice, corn, and sorghum, as well as other amino acids including leucine, phenylalanine, tyrosine, and valine (Fliedel *et al*., 2004). Fonio is especially rich in iron, calcium, phosphorus, magnesium, and zinc, and is a notable source of thiamine, essential for energy metabolism and the proper function of the nervous and cardiovascular systems (Cruz and Béavogui, 2016), as well as riboflavin, which supports healthy skin, vision, and nervous system function (Jideani and Jideani, 2011). Being gluten-free, high in dietary fiber, and with a relatively low glycemic index (approximately 66 compared to 95 for rice), fonio is particularly well suited for children, the elderly, and pregnant women, as well as for individuals who are overweight or managing metabolic conditions such as diabetes (Traore *et al*., 2009; Adoukonou-Sagbadja *et al*., 2006; Besançon, 2000). In some areas of Africa, such as Togo, fonio is traditionally used to prevent blood clotting after childbirth and to boost milk production in nursing mothers, reflecting its recognized therapeutic value in local health practices.

Fonio is a highly valued culinary staple for many rural families in West Africa, most commonly enjoyed as couscous or porridge, but also used in salads, cakes, fritters, bread, and dumplings. Fonio products range from paddy and husked fonio to blanched, precooked, toasted, and flour-based forms (Cruz and Béavogui, 2011). Fonio grain and straw are also used as animal feed: the chopped straw stored after harvesting serves as fodder during the hot, dry season and has been shown to have a digestibility of 51%, with mineral nitrogen concentrations higher than those of maize, sorghum, and millet (Göhl, 1981).

Furthermore, the crop holds considerable sociocultural importance across West Africa. Traditionally in Burkina Faso, Mali, Senegal, and Togo, it was reserved for chiefs and royalty and is commonly consumed during Ramadan and at celebrations such as weddings and christenings. In the past, fonio was grown primarily for home consumption, but it is increasingly becoming a cash crop due to its higher market price relative to other crops in the region. Women play a central role in the post-harvest processing and commercialization of fonio at urban markets. Traditionally, they prepare the grain for storage and consumption by blanching it, which entails removing the inner husk and germ, leaving behind a bran-free kernel of fonio. More recently, women's groups have begun establishing small enterprises that sell pre-processed, packaged fonio, reflecting a broader shift toward organized, commercialized value chains (Kaczmarek *et al*., 2023).

Due to its growing popularity among urban consumers in major African cities, as well as to advances in mechanizing of post-harvest operations, countries such as Guinea, Mali, and Senegal have seen the emergence of small businesses processing and selling fonio in urban and export markets. In fact, fonio has reached the European and North American markets, primarily through fair trade and exotic food channels, where it is sold pre-cooked. Acknowledging its market potential, the European Commission funded a project in 2006 to enhance the quality and competitiveness of fonio in West Africa. CIRAD coordinated this project in collaboration with national research institutes in Mali and Guinea, including the Institut de recherche agronomique de Guinée.

Neglect, Underutilization, Challenges

Although fonio is suited to low-rainfall environments, achieving optimal yields requires timely sowing, careful weeding, and improved water management, with diseases, insects, birds, and rodents presenting additional hazards. Harvesting and post-harvest processing are highly labor-intensive and largely manual, often discouraging farmers from expanding fonio cultivation, despite recent advances in mechanization and post-harvest technology that could help address this constraint. Furthermore, one of the main barriers for developing a formal seed system for fonio is farmers' dependence on landrace seeds purchased at local markets, combined with minimal input use and significant weed and water management pressures (Vodouhe *et al*., 2003). Conservation efforts remain limited, with major gaps in both in situ and ex situ collections, no significant breeding programs owing to the crop's small floral structures, and an increasing need for regional collaboration and organized germplasm sharing (Barnaud *et al*., 2023).

Agronomic Issues

Farmers purchase fonio seeds from local markets, selecting them based on germination quality, health status, and the absence of mold, with almost all seeds being landraces and no seed treatment typically applied. There is no formal seed system for fonio. The crop is usually grown without chemical fertilizers, and organic alternatives such as manure, plant by-products, green manures, and leguminous crops are recommended. Although its seeds germinate quickly, the crop is sensitive to weed competition due to its short stature and limited soil cover, requiring one to three weeding operations per season.

Progress has been made in developing better fonio cultivation methods, including determining optimal planting times, soil types, sowing densities, and fertilizer rates (Gigou *et al*., 2009; Gueye *et al*., 2015; Ndor and Dauda, 2016). Effective water management is vital in traditional rainfed fonio farming, particularly given the increasing frequency and intensity of droughts. Recommended practices include early sowing, use of early-maturing cultivars, mulching, reduced tillage, and adjusted plant populations in arid areas. Although fonio has low susceptibility to disease, it remains vulnerable to fungal infections, with seed quality, soil conditions, and weather all influencing infection levels. Treating seeds with natural fungicides such as ash and plant extracts, including neem and castor leaves, can slow the development of seed-borne fungal diseases.

Fonio harvest at the farm of Mathias N'tcha-N'tcha, a retired pastor who planted his first crop of fonio based on recollections of his father. Photo: Michael Major / Crop Trust

Conservation and Breeding

Realizing the full potential of fonio requires strengthening both in situ and ex situ conservation efforts. Fonio's genetic diversity and the associated traditional knowledge about its cultivation and use are threatened in several producing countries, including Benin (Dansi, Adoukonou-Sagbadja, and Vodouhe, 2010; Sekloka *et al*., 2015) and Togo (Adoukonou-Sagbadja *et al*., 2006). Current collections are limited, and Guinea and Nigeria, the two main fonio producers, lack significant landrace collections. The largest collection is held by the Institut de Recherche pour le Développement in Montpellier, France, with over 2,500 accessions of D. exilis, though no collections of wild relatives exist beyond herbarium specimens (Burgarella *et al*., 2019; Pironon *et al*., 2019). On-farm conservation initiatives are also crucial, as fonio cultivation is becoming scarcer in many regions where unique genetic diversity exists (Diop *et al*., 2018). Fonio is not listed in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture, making careful management of germplasm exchange essential to ensure fair benefit sharing with custodian communities. No hybridization-based breeding program has been undertaken due to the difficulties involved in manipulating the crop's extremely small floral organs, and current research has mainly focused on evaluating local diversity. Regional collaboration among producing countries and support for the African Fonio Research Network (AFoReN), launched by CIRAD and the Institut de Recherche pour le Développement, are essential steps forward.

Jodelle W. J. Fafolahan (Genebank assistant, In charge of Characterization and Conservation) uses a seed analyser. Photo: Michael Major / Crop Trust

Processing and Value Chains

Fonio is harvested by hand as soon as the grain ripens, typically early in the morning after the dew has evaporated, using a knife or sickle to cut stalks a few centimeters above the ground (Barnaud *et al*., 2023). Grain yields generally range from 200 kg per hectare on marginal land to over 600 kg per hectare with good management (Vodouhe *et al*., 2007; Cruz and Béavogui, 2011).

Increasingly, farmers have stopped growing fonio due to the time and labor demands of harvesting and post-harvest tasks, with harvesting typically requiring 20–30 person-days per hectare (Barnaud *et al*., 2023). To cut labor costs, farmers can mechanize harvesting and other post-harvest activities. Mechanization, however, faces obstacles such as lodging of fonio plants during harvest and farmers' limited financial resources (Adoukonou-Sagbadja *et al*., 2006; Ballogou *et al*., 2014; Blench, 2016; Diop *et al*., 2018). After the harvest, fonio is threshed and dehulled before storage. Dehulling remains largely manual, involving repeated pounding in a pestle and mortar followed by winnowing, a slow process usually carried out by women (Barnaud *et al*., 2023). The grain is then stored as sheaves, paddy, hulled, or blanched grains in granaries, silos, or sacks, to match the immediate needs of the farmer's family. To reduce grain losses, farmers could improve their post-harvest practices by harvesting at the right time, properly drying the grain, and employing improved post-harvest methods. Establishing improved processing facilities could also substantially increase the crop's economic value, and some progress in this regard has already been made in post-harvest technologies (CIRAD, 2019).

Market Access

In 2012, fonio production was approximately 600,000 tonnes (FAO, 2024), enough to feed several million people during the toughest months. By 2019, production rose to nearly 700,000 tonnes, cultivated on close to 920,000 acres with an average yield of 760 kg per acre (FAO, 2024). Fonio exports are still very small compared to national output, as the fonio sector mainly aims to meet local demand. However, there is strong potential for growth in export markets, including in Europe and the United States. Guinea already exports approximately 5,000 tonnes of shelled fonio annually to Mali and also supplies Senegal and Côte d'Ivoire (Nitidae and LuxDev, 2018). Guinean fonio commands premium prices due to its recognized quality: whiter, more uniform, and with fewer contaminants than fonio from other areas. In some parts of West Africa, farmers are beginning to shift toward exotic crops with stronger urban market demand, a trend that could discourage fonio cultivation if not counteracted through improved market linkages, price stability, and greater consumer awareness of fonio's nutritional value.

Conclusion

Fonio has significant potential as a nutritious, culturally important, and commercially promising crop. Nonetheless, this potential remains constrained by labor-intensive production and post-harvest systems, limited investment in research and breeding, gaps in germplasm conservation, and underdeveloped market linkages. Addressing these challenges requires increased funding for agronomic research and processing technologies, strengthened regional collaboration on germplasm exchange and conservation, and targeted efforts by multiple stakeholders to develop formal seed systems and value chains. Specific interventions could focus on:
(1) creating unified strategies, such as multi-environment phenotyping and on-farm conservation monitoring;
(2) fostering strong leadership to coordinate various initiatives throughout West Africa;
(3) maintaining long-term collaborative projects among countries; and
(4) educating a new generation of researchers and stakeholders (Barnaud et al., 2023).
Finally, raising awareness of fonio's nutritional and commercial value, among both producers and consumers, remains essential to unlock its full contribution to food security and rural livelihoods across West Africa.

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Jackfruit fruits hanging from tree. Kawanda, Uganda. Photo: Natalia Rodriguez / Crop Trust

JACKFRUIT

Artocarpus spp.

Bridging Conservation Gaps and Value Chain Development in Uganda

History of Domestication

Jackfruit (*Artocarpus heterophyllus*) is believed to originate from western India and widely distributed throughout tropical regions, particularly in South and Southeast Asia, in Brazil, the Caribbean, and Africa (Sidhu, 2012; Ismail, Akhtar and Lazarte, 2023; Khan et al., 2023). In Uganda, where it is locally known as ffenensi or ffene, the crop was probably introduced in the 1890s by Asian indentured workers who came to build the Uganda railway (Nakintu et al., 2020).

Taxonomy and Biology

Jackfruit belongs to the Moraceae family (WFO, 2024). It is a medium-sized evergreen tree commonly cultivated in tropical regions, typically reaching heights of 8–25 meters (Nakintu *et al*., 2019). The tree is monoecious, meaning it bears both male and female flowers on the same plant (Ranasinghe *et al*., 2019). It produces the largest tree-borne fruit in the world, which can weigh up to 50 kg, and yields can reach up to 80 tonnes per hectare (Morton, 2013; Balamaze, Muyonga, and Byaruhanga, 2019). The tree produces fruit year-round, with a peak in production in December and January (Nakintu *et al*., 2019). The fruit's color is determined by its pulp, which can be white, orange, or yellow (Balamaze, Muyonga, and Byaruhanga, 2019).

Jackfruit is adaptable to a range of soil types, including sandy soils, but performs best in well-drained, nutrient-rich soils with a pH of 5.0–7.5 (Infonet Biovision, n.d.; Bakewell-Stone, 2022). Its tolerance of diverse growing conditions, combined with its exceptionally high fruit yield and year-round production, makes it one of the most productive and economically valuable tree crops cultivated in tropical regions.

Importance, Sociocultural Aspects and Potential

Known as the largest fruit in the world and widely described as a "superfood," jackfruit plays an important role in food and nutrition security in Uganda. It is valued in part for its large size, which allows a single fruit to feed many people (Ranasinghe *et al*., 2019; Jagdale *et al*., 2021; Nakintu *et al*., 2020). Jackfruit is also rich in carbohydrates, vitamins, and macronutrients, particularly magnesium and calcium, making it a valuable dietary component (Nantongo *et al*., 2022b). Moreover, research has documented that jackfruit possesses anticancer, anti-HIV, anti-inflammatory, antimicrobial, and antifungal properties, and has been found effective in addressing anemia, asthma, ulcers, indigestion, dermatitis, diarrhea, cough, and high blood pressure, among other conditions (Ranasinghe *et al*., 2019; Jagdale *et al*., 2021; Gwokyalya *et al*., 2024).

In Uganda, the fruit is most commonly eaten fresh, while the seeds are consumed boiled or roasted. The fruit is also used as animal feed and processed into wine, and the wood is utilized as timber (Balamaze, Muyonga and Byaruhanga, 2019; Katongole, 2023). Value-added products with a longer shelf life include ripe fruit segments in sugar syrup, sweetened pulp, sun-dried ripe bulbs, and blanched, dehydrated unripe mature bulbs (ACSA, 2019). Nevertheless, value addition and commercial utilization of jackfruit in Uganda remain limited, and the value chains for many potential products are not yet fully developed (Khan *et al*., 2023).

Jackfruit is common across all regions of Uganda, with the Central region considered the center of diversity for the crop (Nakintu *et al*., 2023).

Historically, the Buganda Kingdom in Central Uganda encouraged planting jackfruit trees as a reliable food source for communities (Searle, 2023). In some regions, cultural norms discourage the sale of jackfruit, as doing so is believed to bring bad luck, given that the fruit is seen as a communal resource that should always be available to share with neighbors (Searle, 2023; Versi, 2023). Cultural beliefs in Buyende district associate jackfruit consumption during pregnancy with complications at childbirth or excessive drooling in newborns (Tugume *et al*., 2024). In the Western region, a region hosting high jackfruit diversity, historical myths that jackfruit can kill livestock have contributed to lower production (Nakintu *et al*., 2019; 2020).

The rising global demand for plant-based products makes jackfruit a viable meat alternative, owing to its meat-like texture and ability to absorb flavors, particularly in international export markets (Khan *et al*., 2023). Deliberate efforts to expand production through orchards have been documented, though their scale remains limited (Nantongo *et al*., 2022a; Balamaze, Muyonga, and Byaruhanga, 2019). With further development of its value chains, jackfruit in Uganda has the potential to stimulate economic growth beyond smallholder farming, generating opportunities in processing, packaging, and export industries (US Business News, 2024).

Neglect, Underutilization, Challenges

Nantongo *et al*. (2022b) note that jackfruit is underutilized in Uganda, with gaps in production and marketing that likely affect income and nutrition, mainly due to a lack of awareness of its nutritional value and variation within the species that may prevent access to suitable varieties. In jackfruit, apparent variability among plants expected to be clonal usually results not from genetic instability but from seedling substitution or contamination, weak nursery traceability systems, rootstock effects on scion performance, and strong environment × management influences on tree growth and fruit expression.

Agronomic Issues

Jackfruit trees take a long time to start producing fruit, which can be a disincentive for cultivation. However, innovative grafting techniques can shorten the time to fruiting (Ndyomugyenyi, Okot and Mutetikka, 2014). They are also restricted to warm, humid climates with minimum temperatures of 16-22°C and average temperatures of 25-30°C, with rainfall evenly spread throughout the year (Bakewell-Stone, 2022).

Khan *et al*. (2021) report a wide range of pests and diseases affecting jackfruit worldwide. This includes over 250 insect pest species, eight mites, and seven nematodes. The most serious diseases they list are Rhizopus rot (Rhizopus artocarpi) and leaf spot (Phomopsis artocarpina, Pestalotia quepini, Colletotrichum lagenarium, Septoria artocarpi). The tree is also vulnerable to bacterial dieback caused by Erwinia carotovora, blossom rot caused by Rhizopus stolonifer, and pink disease caused by Corticium salmonicolor (Bakewell-Stone, 2022).

Conservation and Breeding

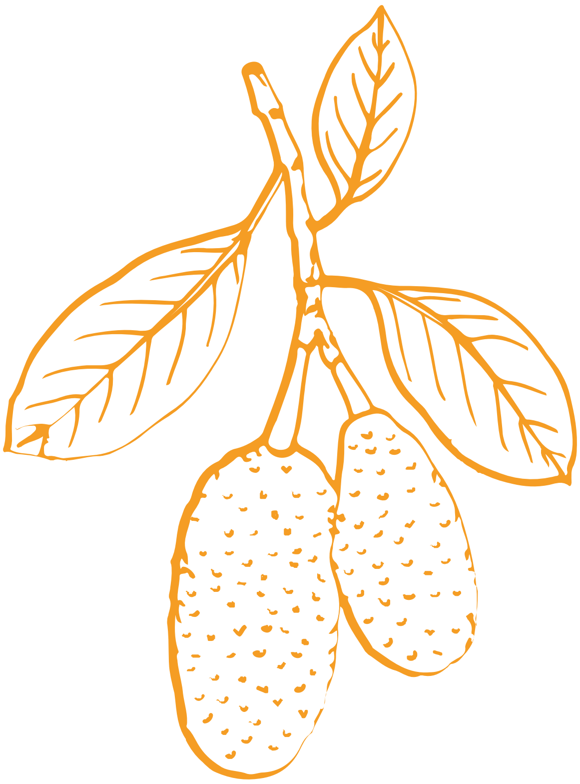
Limited research and insufficient investment in jackfruit breeding programs impede the development of improved varieties. Challenges in jackfruit breeding include a long juvenile phase that delays fruit production and recalcitrant seeds that do not store well (Ramachandra *et al*., 2022). High genetic variation among clones is an issue because seed-derived plants are highly variable in fruit size, bulb quality, yield, and bearing age. However, recent progress has been made in developing superior clones or cultivars in countries such as Australia, Bangladesh, India, Malaysia, Myanmar, the Philippines, Sri Lanka, and Vietnam (Mitra, 2020). While some recent studies have characterized jackfruit varieties in different regions of Uganda (Ojwang *et al*., 2017; Ojwang *et al*., 2018; Nakintu *et al*., 2019; Nakintu *et al*., 2020; Nakintu *et al*., 2023; Gwokyalya *et al*., 2024), more research is still needed in this area.

Farmers maintain diverse jackfruit landraces in their fields, thus preserving genetic diversity, but deforestation and the replacement of jackfruit trees with other crops threaten this in situ/on farm conservation (Nakintu *et al*., 2020). The National Forestry Resources Research Institute (NaFORRI) in Uganda has 217 landraces in its collection. Evidence indicates that farmers have been selecting against jackfruit varieties with less desirable traits by cutting them for timber and fuel, which could lead to genetic loss (Nakintu *et al*., 2020; Nakintu *et al*., 2023). This highlights the need to conserve these varieties, which will need to be done in vitro and/or in field genebanks.

Jackfruit at the Kawanda market, Uganda. Photo: Natalia Rodriguez / Crop Trust

Processing and Value Chains

The limited processing infrastructure for jackfruit restricts its marketability. As a result, farmers often lack access to value chains that could help them benefit from their efforts. Jackfruit is usually grown as a subsistence crop with only a small percentage processed: a study in Mityana, Kayunga, Kamuli, Luuka, and Jinja in Uganda, found that just 1% of harvested jackfruits are processed, while 80% are eaten fresh or used as animal feed (6%) (Balamaze, Muyonga and Byaruhanga, 2019).



Market Access

Current production in Uganda is not sufficient to meet the growing demand for domestic use, export, and industry (Balamaze, Muyonga and Byaruhanga, 2019). Fragmented supply chains and disorganization hinder farmers from selling their produce profitably (Balamaze, Muyonga and Byaruhanga, 2019). Some isolated efforts aim to address this, such as the work of Zahra Food Industries Ltd (Searle, 2023).

Conclusion

Jackfruit has significant potential to improve food and nutrition security and boost the economy in Uganda, but it faces challenges that limit its widespread use. Production is mostly subsistence, with unorganized and small-scale methods restricting its growth (Balamaze, Muyonga and Byaruhanga, 2019). Little is known about the genetic diversity of jackfruit in Uganda (Nakintu et al., 2020). Farmers also lack information and access to high quality germplasm (Gwokyalya et al., 2024). To enhance farmers' livelihoods and attract interest from current and future stakeholders in the value chain, it is crucial to improve production methods and quality through proper, organized agronomic practices (Balamaze, Muyonga and Byaruhanga, 2019). Additional research characterizing jackfruit varieties to determine their potential for industrial and commercial application is also necessary (Nakintu et al., 2019).

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Jute mallow in Benin. Photo: Michael Major / Crop Trust.

JUTE MALLOW

Corchorus spp.

Unlocking the Nutritional and Economic Potential of an Underutilized Crop in Tanzania and Benin

History of Domestication

Jute mallow is a widely consumed leafy vegetable across Africa and Asia. Africa is considered the primary center of origin, while the Indo-Burmese region serves as the secondary center of diversity (Fondio et al., 2024). The crop is considered to be in the early stages of domestication, as it still grows predominantly in the wild with little systematic breeding or selection (Nyadanu et al., 2017). In Tanzania, it is regarded as semi-domesticated, as cultivation practices remain informal and inconsistent across regions. In some areas it is still viewed as a wild plant, and this absence of intentional cultivation makes it less appealing for inclusion in agricultural development programs, limiting its potential despite its nutritional and economic value (Ngomuo et al., 2017a; Ngomuo et al., 2017b).

Taxonomy and Biology

Jute mallow is classified in the family Malvaceae (RBG Kew, 2024). The genus *Corchorus* includes 50-60 species distributed across tropical, subtropical, and warm-temperate regions of the world (Benor *et al*., 2012). In West Africa, six species of Corchorus are primarily grown, with C. olitorius being the most widely cultivated (Oyekale, Olorode, and Oyekale, 2017). Jute mallow plants exhibit much morphological diversity, with different cultivars displaying various agronomic traits and phytochemical profiles (Adebo *et al*., 2015; Adjatin *et al*., 2018).

Jute mallow is an annual, woody herb with long, narrow leaves that typically grows to heights of 0.5 to 1.2 meters, although it can reach up to 2.5 meters (Ngomuo *et al*., 2017a; Infonet-Biovision, 2024). Stem color ranges from green to deep red (Ngomuo *et al*., 2017a). Varieties differ in leaf size, shape, and color (Bayi, Ngah, and Meguen, 2020; Infonet-Biovision, 2024). The plant produces yellow, hermaphrodite flowers, and cylindrical fruits containing angular gray-black seeds (Infonet-Biovision, 2024).

Importance, Sociocultural Aspects and Potential

Jute mallow is one of the most nutritious traditional leafy vegetables consumed across Africa (Nyadanu and Lowor, 2014; Ngomuo *et al*., 2017a). It is rich in essential nutrients including carotenoids, protein, vitamins A, C, K, and B9, and minerals such as iron, calcium, and magnesium (Steyn *et al*., 2001; Dansi *et al*., 2008; Ngomuo *et al*., 2017a; 2017b). The leaves contain an average of 4.8 g protein, 259 mg calcium, 4.5 mg iron, and 105 mg ascorbic acid per 100 g (Harborne, Baxter, and Moss, 1999; Grubben and Denton, 2004). Studies comparing traditional vegetables found that jute mallow had the highest beta-carotene content among amaranth, black nightshade, and jute mallow, a nutrient important for vision and immune function (Mwaisenye, 2016; Traoré, 2017). The plant also contains a variety of phytochemicals with antioxidant and anti-inflammatory properties (Adjatin *et al*., 2018; Abdel-Razek *et al*., 2022; Biswas *et al*., 2022). A summary of the nutritional composition of both raw and cooked jute mallow is provided by Infonet-Biovision (2024). Moreover, Corchorus species are widely used in treating various diseases and possess broad antibacterial properties (Zakaria *et al*., 2006; Fagbohoun and Ibrahim, 2011; Soro *et al*., 2012; Ngomuo *et al*., 2017a). In Tanzania, an infusion from the leaves is used to treat constipation (Fondio *et al*., 2024), as well as abdominal pain, menstrual pain, pregnancy-related pain, and gonorrhea (Weinberger and Msuya, 2004). Its diverse ethnomedicinal applications reflect a deep-rooted traditional knowledge of its therapeutic value across rural communities.

Jute mallow plays a vital role in local food culture and socio-economic systems across Africa (Zannou, Struik, and Richards, 2013), with uses spanning food, medicine, and cosmetics (Akouehou *et al*., 2014; Ndiaye *et al*., 2022). The main use of jute mallow is as a leafy vegetable (Dansi *et al*., 2008; Benor *et al*., 2010). The leaves, either fresh or dried, are commonly cooked into a thick, viscous soup or added to stews, providing a rich source of vitamins and minerals (Branda *et al*., 2004). Farmers particularly value the crop for its food security benefits and resilience. It is a reliable nutritional resource during droughts due to its long shelf life. When properly processed, it can be dried and stored in bulk during the rainy season for use in the dry season (Chipungahelo, 2015).

In Tanzania, it is locally known as mlenda and communly found in the Singida, Dodoma, and Morogoro regions (Makauki, 2020). In Benin, it is cultivated across all agro-ecological zones and is among the most consumed vegetables across various sociolinguistic groups (Dansi *et al*., 2008; Adjatin *et al*., 2017). Some jute varieties also have potential for fiber production, although such varieties are more common in Asia (Grubben and Denton, 2004). Women are typically responsible for preserving and storing jute mallow, reflecting their central role in managing this crop within household food systems (Mwaisenye, 2016).

Owing to its nutritional, medicinal, and value-added benefits, jute mallow has considerable economic and market potential, able to attract a range of stakeholders (Akouehou *et al*., 2014). In Benin, intercropping jute mallow increases productivity per unit area, helps manage pests, lowers input costs, and enhances nitrogen cycling. These improvements enhance farm profitability (Makauki, 2020). The crop's adaptability and relatively low maintenance requirements make it an attractive option for smallholder farmers. However, further investment in processing and market development could substantially increase its commercial potential.

A farmer checks tricot trials of jute mallow at a village in Bonou, south-eastern Benin. Pic by Neil Palmer for the Crop Trust. tricot trials of jute mallow at a village in Bonou, south-eastern Benin. Photo: Neil Palmer/ Crop Trust.

Neglect, Underutilization, Challenges

Farmers in Tanzania tend to overlook traditional vegetables like jute mallow in favor of cereal crops (Makauki, 2020). In Benin, its production is limited by several biotic and abiotic challenges, including low yields and a lack of quality seeds (Adjatin *et al*., 2017). Limited seed availability constrains wider cultivation in Tanzania (Chipungahelo, 2015). Zhang *et al*. (2019) highlight that few new varieties exist and demand for them is low, pointing to a need for targeted marketing strategies and stakeholder engagement. Although seed supply channels in Tanzania involve both informal farmer recycling and formal distribution through agro-dealers and NGOs, including seed kits distributed by the World Vegetable Center since the early 2000s, project participants have reported challenges in recycling seeds. Challenges relate to poor performance of recycled seeds in colder regions, as well as reduced germination rates and longer harvesting periods (Wanyama *et al*., 2023). Cultural beliefs also play a role in some regions. For instance, in some communities in Singida and Mkalama, jute mallow is believed to lack sufficient nutrients for children, limiting household uptake (TFNC, 2023). Ineffective knowledge-sharing among farmers, youth, and extension services further constrains production. Farmers exchange traditional knowledge informally; however, the exchange of information on nutritional benefits, production and processing techniques remains limited (Chipungahelo, 2015). Moreover, young people have a limited understanding of traditional vegetables, creating a generational gap in knowledge and interest. The loss of indigenous knowledge, shifting food habits, climate change, and the spread of exotic vegetables are identified as key threats to the diversity of traditional crops, including jute mallow (Keller, Mndiga, and Maass, 2005). The creation of a dedicated knowledge-sharing platform could offer opportunities to spread best practices, nutritional information, and health benefits of traditional vegetables (Chipungahelo, 2015).

Agronomic Issues

Traditional farming systems in Benin rely primarily on natural soil fertility, using low quantities of fertilizers (Ayodélé, Omotoso, and Akinrinsola, 2006). This residual fertility is insufficient to meet the nutrient needs of jute mallow, which responds well to fertilization, particularly nitrogen (Ogunrinde and Fasinmirin, 2011). In Tanzania, farmers often practice minimal management in areas where jute mallow is grown, leading to underuse of both land and crop potential (Makauki, 2020; Chipungahelo, 2015). The slow growth of jute mallow at higher altitudes in the Mbeya Rural and Kilolo districts of Tanzania also presents an additional agronomic challenge (Lukumay *et al*., 2017).

Integrating jute mallow into existing farming systems through intercropping with cereals such as sorghum and maize is recommended as a way to maximize land use, boost yields, and increase farmers' income and food security in West African contexts (Makauki, 2020). Organic manure, such as municipal waste compost and cow dung, represents a viable alternative to chemical fertilizers and has been shown to improve agricultural productivity (Tovihoudji *et al*., 2015). Although diseases do not appear to significantly impact jute mallow production, the crop is especially vulnerable to nematode attacks, particularly eelworms, and intercropping with amaranth has been suggested as a means of reducing this problem (Infonet-Biovision, 2024).

Conservation and Breeding

Corchorus olitorius is known for its extensive intraspecific diversity, as demonstrated by morphological studies conducted in Nigeria, Senegal, and Pakistan (Akoègninou, van der Burg, and van der Maesen, 2006; Denton and Nwangburuka, 2012; Mbaye *et al*., 2001; Islam *et al*., 2002; Benor *et al*., 2012). The largest germplasm collection is held by the Unité de Génétique, Biotechnologie et Science des Semences at the Université d'Abomey Calavi in Benin, with 1,566 accessions, followed by the World Vegetable Center in Taiwan with 304 accessions and the Plant Genetic Resources Research Institute in Ghana with 126 accessions (Genesys, 2025). A collection also exists at the ECHO East Africa community seedbank (Kasubi and Juma, 2019). The presence of duplicates within germplasm collections remains an issue that needs to be resolved (Adoukonou-Sagbadja *et al*., 2006; Dansi *et al*., 2009; 2013). There is no formal national jute mallow breeding program, and jute mallow cultivated in Tanzania has a narrow genetic base and remains underresearched, limiting its resilience and potential (Ngomuo *et al*., 2017c). While several characterization studies have been conducted on morphological, genetic, agronomic, and nutritional traits (Ngomuo *et al*., 2017a; 2017b; 2017c; Makauki, 2020; Mwaisenye, 2016; Lyimo, Temu, and Mugula, 2003), further research is needed to fully understand diversity across regions and to develop varieties with improved drought tolerance, pest resistance, and leaf yield, the latter being particularly challenging due to its inverse relationship with seed yield (Ngomuo *et al*., 2017b; Ngomuo *et al*., 2017c; Zhang *et al*., 2019). Participatory assessments and the inclusion of all stakeholders throughout the breeding process are therefore essential to ensure that improved varieties match local tastes and gain consumer acceptance (Wanyama *et al*., 2023).

Jute mallow seeds in the genebank at the World Vegetable Center, Cotonou, Benin.
Photo: Neil Palmer/ Crop Trust.

Processing and Value Chains

Post-harvest processing of jute mallow remains a significant challenge. Factors that hinder the effective drying of leaves, including dust, rainfall, insects, pests, and mold, can compromise the nutritional quality of dried leaves and pose health risks after consumption (Mwaisenye, 2016). Establishing dedicated processing facilities would improve product quality, reduce post-harvest losses, and substantially increase the crop's economic value. Greater investment in processing infrastructure and value chain development is therefore essential to translate the crop's nutritional and commercial potential into tangible benefits for farmers and consumers alike.

Jute mallow leaves being prepared for use in the popular Beninese dish, crin-crin, or Ninnouwi (Corète Potagère). Prized for their sliminess, the leaves are pounded and whisked into a green soup, which provides the base of the dish. Photo: Neil Palmer/ Crop Trust.

Market Access

In some areas of Tanzania, farmers tend to prioritize exotic vegetables such as Chinese cabbage, spinach, and carrots over native species like jute mallow, driven by higher urban demand and better income prospects in formal markets (Keller, Mndiga, and Maass, 2005; Keding *et al*., 2007). This trend might discourage the cultivation of indigenous vegetables. However, research suggests that indigenous vegetables can in fact be more profitable, as they allow multiple harvests and have lower production costs (Molina *et al*., 2020). Broader structural constraints, including information gaps, fluctuating prices, poor food safety standards, and weak infrastructure, continue to limit the consumption and market integration of jute mallow and other vegetables (Molina *et al*., 2020). Addressing these barriers through improved market linkages, consumer awareness campaigns, and better post-harvest infrastructure is essential to expanding the crop's commercial reach.

Conclusion

Jute mallow has significant potential as a nutritious food, medicinal plant, and income-generating crop, yet this potential remains constrained by inadequate production support, inefficient land use, limited market opportunities, and insufficient investment in research and crop development. The loss of traditional knowledge surrounding its cultivation, processing, and nutritional value, combined with ineffective knowledge-sharing across generations, poses an additional threat to its long-term sustainability. Unlocking the full potential of jute mallow will require increased research efforts, awareness-raising campaigns, and targeted investment in farmer training, capacity building, financial support, and access to high-quality seeds (Karanja et al., 2012).

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Staff at the genebank of the University of Abomey-Calavi (CalaviGen) in Cotonou, Benin, check the ripening pods of miracle berry fruits. Photo: Neil Palmer/Crop Trust.

MIRACLE BERRY

Synsepalum spp.

From Functional Fruit to Market Opportunity in Benin

History of Domestication

Miracle berry is a semi-domesticated species indigenous to Central and West Africa (Achigan-Dako et al., 2015). In Benin, it is commonly found in home gardens and wild fields. Farmers sow seeds obtained from neighbors without clear selection criteria, but select seedlings beneath mother trees based on their vigor (Tchokponhoué et al. 2021). An ongoing breeding initiative involving partners from Benin, Ghana, Nigeria, and Togo is currently underway with the aim of developing improved cultivars (Tchokponhoué et al., 2023).

Taxonomy and Biology

Miracle berry (*Synsepalum dulcificum*) belongs to the Sapotaceae family and is an evergreen shrub reaching 2–5 m in height (Jeremiah, Ilesanmi and Ige, 2015; Adeyi *et al*., 2022). It has a bushy growth habit with a dense canopy, making it suitable for cultivation across different agro-ecological zones. The leaves are simple, alternate, and elliptical (5–10 cm long), with a glossy green appearance that also gives the plant ornamental value (Tchokponhoué *et al*., 2020). Its small, white to yellowish, often fragrant flowers grow in clusters and are hermaphroditic, allowing primarily self-pollination, although cross-pollination can occur (Tchokponhoué *et al*., 2021).

The fruit is an oval berry (2–3 cm long) that turns from green to bright red upon ripening. Each berry contains a single seed surrounded by a thin pulp layer rich in miraculin, the glycoprotein responsible for the fruit's unique taste-modifying effect (Wagner *et al*., 2023; López *et al*., 2020). The pulp is also high in antioxidants, phenolic compounds, and flavonoids, contributing to its recognized health benefits (Wagner *et al*., 2023). By temporarily altering sour taste perception to sweetness, miraculin has attracted growing interest in food science and dietary management (López *et al*., 2020).

The species produces recalcitrant seeds that cannot withstand drying or sub-zero storage, complicating conventional genebank conservation and propagation efforts (Tchokponhoué *et al*., 2019). It exhibits notable phenotypic plasticity, with growth influenced by light and nutrient availability (Tchokponhoué, N'Danikou and Achigan-Dako, 2019). Although slow-growing, the plant performs best under moderate shade and adequate moisture (Tchokponhoué *et al*., 2019). In Benin, it occurs naturally in gallery forests and fallows and is widely cultivated in home gardens, backyards, and farms, particularly in the south where climatic conditions are favorable (Tchokponhoué *et al*., 2021). Management practices such as weeding, fertilization, and pruning can further enhance growth and yield.

Importance, Sociocultural Aspects and Potential

Miracle berry has attracted increasing attention for its notable nutritional and health-promoting properties. The fruit is rich in essential amino acids and vitamins, and contains particularly high levels of vitamin E, exceeding those found in many common fruits such as blueberries and raspberries (Njoku *et al*., 2015). In addition, the pulp exhibits strong antioxidant properties due to its high content of phenolic compounds and flavonoids (Du *et al*., 2014; Awotedu *et al*., 2021). A notable property of this substance is its ability to enhance the sweetness of sour foods, a property that could have specific applications in the dietary management of individuals with conditions such as diabetes, who need to limit their sugar intake (Akinmoladun *et* *al*., 2020; Yang *et al*., 2022). These nutritional characteristics are highly relevant for public health, as they may contribute to the prevention of chronic diseases, including diabetes and cardiovascular conditions (Akinmoladun *et al*., 2020; Onuminya *et al*., 2023). In addition, miracle berry is recognized for its multifaceted pharmacological properties. Research indicates that fruit extracts exhibit antimicrobial and anticancerogenic properties, making the plant a promising candidate for the development of natural cancer treatments (Shi *et al*., 2016; Afzal *et al*., 2021). The plant has also been traditionally used to treat diabetes, cough, and hyperuricemia, and ethnomedicinal practices involving miracle berry reflect a deep understanding of its therapeutic potential (Obafemi *et al*., 2017; Assogba *et al*., 2017; Busari *et al*., 2022).

Miracle berry is widely found in home gardens and wild fields in West Africa, particularly in Benin, reflecting its deep integration into local agroecological systems (Achigan-Dako *et al*., 2015). Farmers sow seeds obtained from neighbors without formal selection criteria, instead selecting seedlings beneath mother trees based on vigor, a practice that embodies traditional knowledge and community seed-sharing networks (Tchokponhoué *et al*., 2021). The fruit is eaten fresh and is commonly used in local cooking, boosting the flavor of traditional dishes and drinks (Tchokponhoué *et al*., 2021). This integration into the local diet contributes to dietary diversity and provides an additional source of nutrition for communities in Benin (Fandohan *et al*., 2017; Tchokponhoué *et al*., 2021). An ongoing breeding initiative involving partners from Benin, Ghana, Nigeria, and Togo is currently underway with the aim of developing improved cultivars with strong commercial potential (Tchokponhoué *et al*., 2023).

The economic potential of miracle berry is highlighted by its growing popularity in both local and international markets, where it is sold for its unique taste-modifying properties and health benefits (Fandohan *et al*., 2017). Its relatively low maintenance requirements make it an attractive choice for smallholder farmers, and growing and harvesting the crop provides income for farmers and traders involved in its production and sale (Tchokponhoué *et al*., 2021; Onuminya *et al*., 2023). As interest in natural, functional foods grows globally, miracle berry presents a significant commercial opportunity for West African farmers.

Staff at the genebank of the University of Abomey-Calavi (CalaviGen) in Cotonou, Benin, check the ripening pods of the so-called "magic" or "miracle" fruit Synsepalum dulcificum. Photo: Neil Palmer/Crop Trust.

Neglect, Underutilization, Challenges

Miracle berry remains an underutilized crop largely because of its cultivation and post-harvest challenges. The fruits are highly perishable, and the plant requires specific soil and climatic conditions (Tchokponhoué *et al*., 2021). Despite its unique taste-modifying compound, miraculin, commercial development has been limited by regulatory uncertainties in key markets, including restrictions on its use as a food additive in the United States since the 1970s (Kurihara, 1992). The species has received relatively little research investment, resulting in gaps in agronomic knowledge, improved varieties, and scalable production systems (Tchokponhoué *et al*., 2019). Moreover, value-chain development is still nascent, with few processing technologies or market channels available to reduce perishability and expand consumer access.

Agronomic Issues

Management practices for miracle berry vary across ecological zones in Benin, with men being the primary cultivators (Tchokponhoué *et al*., 2021). Soil physicochemical properties, especially phosphorus, potassium, and cation exchange capacity, significantly influence the plant's rhizosphere bacterial communities (Adigoun *et al*., 2024). To boost production, daily watering and balanced fertilization (1.5 g each of nitrogen, phosphorus, and potassium per seedling) can speed up growth and reproductive maturity, reducing the juvenile period from over 36 months to about 23 months (Tchokponhoué *et al*., 2020).

Conservation and Breeding

Despite the many benefits of miracle berry, Synsepalum dulcificum faces significant challenges in conservation and sustainable use. The species is currently listed as vulnerable by the International Union for Conservation of Nature (IUCN), primarily due to habitat loss and overexploitation (Fandohan *et al*., 2017). This underscores the urgent need for targeted conservation efforts to ensure the long-term sustainability of the crop. Key traits sought by farmers and consumers, including large fruit size, early fruiting, and high miraculin content, guide selection priorities, and an ongoing breeding initiative involving partners from Benin, Ghana, Nigeria, and Togo is currently underway to develop improved cultivars (Tchokponhoué *et al*., 2021). Educational initiatives focused on raising awareness of the ecological and economic importance of S. dulcificum can play a key role in promoting its preservation and wider cultivation (Djagoun *et al*., 2010; Tchokponhoué *et al*., 2021).

Processing and Value Chains

Most miracle berry processing currently occurs on a small scale, carried out primarily by farmers themselves, with women playing a central role in these activities (Tchokponhoué *et al*., 2021). On the other hand, industrial-scale processing methods include maceration of the fruits, cold-pressing to extract the juice, extraction of chemical constituents using pressurized liquids, and freeze-drying the pulp to preserve its taste-modifying properties (DMB, n.d.; Mosquera *et al*., 2025). A major challenge across all scales of processing is the extremely short shelf life of fresh fruit, which is only 2–3 days, significantly limiting market reach and value chain development (Fadeyibi, Lamidi, and Ademola, 2021). Options for engaging the private sector to produce miracle berry on an industrial scale have been discussed for both Ghana and Benin, though these remain largely unexplored (Tchokponhoué *et al*., 2021). Investing in processing infrastructure and cold chain development would be essential to overcome the perishability constraint and unlock the crop's broader commercial potential.

Market Access

Tchokponhoué *et al*. (2021) noted that the production of miracle berries is more market-oriented in Ghana than in Benin, although only 5% of farmers in Ghana have commercial plantations of miracle berries. Tchokponhoué *et al*. (2023) found that 63.2% of miracle berry fruits harvested in southern Nigeria were consumed by the harvesting household, with 21.3% sold and 15.5% given as gifts. Among those selling the fruits, 94.3% sold them at local markets, while the rest had access to international markets, including exporting fresh fruit to the USA. Only a small amount of the fruit was processed into powder or juice and sold in Lagos. DMB (Dried Miracle Berry) is "the only ingredient with miraculin that has the Novel Food authorization in European Union" (EFSA *et al*., 2021). However, as of September 2022, purified miraculin had not been certified "Generally Recognized as Safe" by the Food and Drug Administration in the USA (Demesyeux, Brym, and Chambers, 2022).

Miracle berry growing at the genebank of the University of Abomey-Calavi in Cotonou, Benin. Photo: Neil Palmer/Crop Trust.

Conclusion

Despite its nutritional and medicinal benefits, S. dulcificum faces challenges, including habitat loss and the need for sustainable management practices to ensure its ongoing availability. Conservation efforts are essential to preserve the biodiversity of this species and to support the livelihoods of those who rely on it for food and income (Tchokponhoué et al., 2021; Dansi et al., 2012). Additional efforts are also necessary to develop local and export markets for the crop.

Staff at the genebank of the University of Abomey-Calavi (CalaviGen) in Cotonou, Benin, check the ripening pods of miracle berry. Photo: Neil Palmer/Crop Trust.

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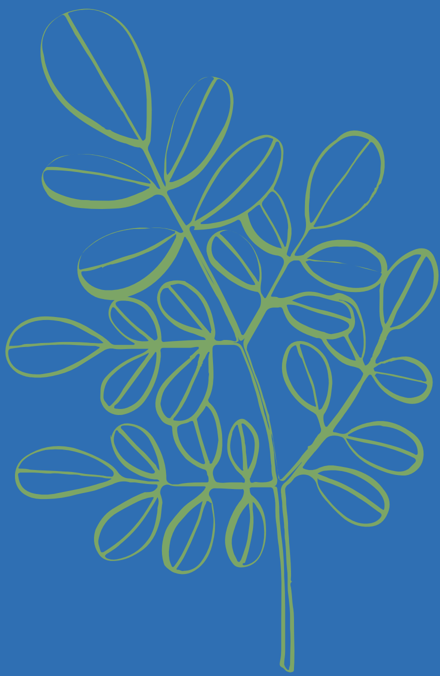
Moringa, Natitingou, Benin. Photo: Mike major / Crop Trust

MORINGA

Moringa spp.

Harnessing the Potential of
a Multipurpose Tree for Food Security
and Rural Livelihoods in Tanzania



History of Domestication

Moringa, also known as the “miracle tree”, “drumstick tree,” or “horseradish tree”, is indigenous to the foothills of the Himalayas on the Indian subcontinent (Bk and Patel, 2017). It has been introduced and is now naturalized in various tropical and subtropical regions around the world, including Africa (Paliwal, Sharma, and Pracheta, 2011). It was likely brought to Tanzania by Indian and Arab traders (Creighton, 2002). Today, moringa is widely cultivated across the country and has become increasingly recognized for its nutritional, medicinal, and economic value among Tanzanian farming communities.

Taxonomy and Biology

Moringa belongs to the family Moringaceae (Trigo *et al*., 2021; WFO, 2025). It is a fast-growing, medium-sized tree reaching heights of up to 10 meters, with a straight trunk up to 30 cm in diameter covered in whitish or gray bark (NRC, 2006). The flowers are insect-pollinated, and the fruits are dark green, tri-lobed pods - commonly known as drumsticks - growing up to 120 cm in length (NRC, 2006). Each pod contains 12–35 seeds with lightly woody shells and three papery wings when mature (NRC, 2006). Moringa can flower and produce pods year-round, with some varieties capable of fruiting within three months of planting (NRC, 2006). A single tree can yield up to 25,000 seeds annually (Trigo *et al*., 2021).

Moringa is highly adaptable and grows well across a variety of soils and climatic conditions. The tree reaches its maximum productive potential at altitudes below 600 m and in well-drained sandy or sandy loam soils, with a recommended soil pH range of 4.9–9 (Radovich, 2011). It is particularly suited to warm, semi-arid tropics with annual rainfall of 250–3,000 mm (NRC, 2006). Its optimal temperature range is 25–35 °C, and it can endure brief periods of up to 48 °C (Trigo *et al*., 2021). Its exceptional drought tolerance and ability to withstand high temperatures and light frosts further contribute to its widespread cultivation across tropical and subtropical regions.

Importance, Sociocultural Aspects and Potential

Moringa is a nutritionally exceptional multipurpose tree with wide adaptability and ability to withstand harsh conditions, making it a dependable source of food and nutrition security for communities across Tanzania (Hella and Omari, 2012; Mashamaite, Ramatsitsi, and Manyevere, 2024). Almost all of its parts having recognized uses, namely its seeds, leaves, flowers, pods, bark, and roots. The leaves are particularly rich in protein, essential minerals such as calcium and potassium, vitamins A, C, and E, beta-carotene, and antioxidant compounds (Bk and Patel, 2017; Ndhlala and Tshabalala, 2023). Moringa leaves are eaten fresh, dried, or cooked and incorporated into a variety of local dishes, while the pods are consumed in some regions (Creighton, 2002; Hella and Omari, 2012). They also contain compounds that can be used as nutritional supplements and to extend the shelf life of various food products (Trigo, Castelló, and Ortolá, 2023). Oil and fuel can also be extracted from the plant (Hella and Omari, 2012). Detailed nutrient profiles of the different plant parts are provided by Godinez-Oviedo, Guemes-Vera, and Acevedo-Sandoval (2016) and Zarina *et al*. (2024). Different parts of the moringa tree also have documented medicinal properties for a wide range of ailments (Gandji *et al*., 2018; Zarina *et al*., 2024). Furthermore, anecdotal evidence indicates that traditional healers in Tanzania have long used moringa leaves, leaf powder, bark, and roots in herbal treatments, a practice passed down across generations (Creighton, 2002). Research conducted has further explored its medicinal applications (Lunyera *et al*., 2016; Begum *et al*., 2021; Peter *et al*., 2021).

As global demand for natural, nutritious, and sustainably produced food products continues to grow, moringa presents a significant economic opportunity for Tanzania. Different parts of the tree can be used to produce a wide range of products for both domestic and international markets, and the development of processing facilities could substantially increase its commercial value while generating employment in both urban and rural communities. A range of value-added products exists already in the Tanzanian market for nutritional, medicinal, and cosmetic uses, including soap, oils, and dried powdered seeds (Farm Africa, 2020). Moringa's potential in food fortification and supplementation has also been studied (Bisanz *et al*., 2015; Hekmat *et al*., 2015; Alphonce *et al*., 2019; 2021; Shija *et al*., 2019), and shows further potential in animal feed (Sarwatt, Kapange, and Kakengi, 2002; Ndemanisho *et al*., 2006; Mmanda *et al*., 2020), vegetable oil production (Kibazohi and Sangwan, 2011), and water purification (Marobhe and Sabai, 2021). Moreover, the crop has been recommended for home garden seed kits used in humanitarian aid programs as a tool for income generation (Chadha and Olouch, 2007). Furthermore, recent initiatives, including projects launched by youth groups and women's platforms focused on moringa value addition across East Africa, reflect growing recognition of the crop's economic potential in the region (Farm Africa, 2020).

Moringa at the Seed Fair of Chimukoko Community Seed Bank.
Photo: Michael Major/Crop Trust

Neglect, Underutilization, Challenges

Despite the many benefits of moringa, it remains underresearched in Tanzania. Hella and Omari (2012) noted that the potential of moringa in Tanzania was limited by a lack of documentation on best production practices, as well as the absence of policy and advocacy for the crop; these issues remain relevant.

There are few studies focusing on moringa in Tanzania; research that aims to understand social, cultural, economic aspects, and the preferences of value chain actors is especially scarce. Exceptions include: Hella and Omari (2012), who documented good agricultural practices for moringa; Farm Africa (2020), which offered some insights into youth-led initiatives in the moringa value chain; Farm Africa and SUGECO (2019), which provided a guide for moringa production in Tanzania; and Balama *et al*. (2023), who carried out a social network analysis of stakeholders in the moringa value chain. Nevertheless, the overall gap in knowledge limits the potential to optimize cultivation, use, and benefits of moringa in the country.

Agronomic Issues

A lack of knowledge about best practices was identified as a major problem hindering improved moringa production in Zimbabwe (Mudyiwa *et al*., 2013) and Bangladesh (Rahman *et al*., 2024). Mudyiwa *et al*. (2013) contrast this with intensive production methods in West Africa, including Niger and northern Nigeria, involving high-density small-plot plantations and agroforestry systems. However, El Bilali *et al*. (2024) note growing research interest in moringa across Africa, particularly on agronomic issues.

Pests, diseases, and parasitic plants are reported as major obstacles to moringa production in southern Ethiopia and Kenya (Kumssa *et al*., 2017). However, Gatan (2020) and others mention that moringa is fairly disease-tolerant and claim that diseases do not significantly impact production.

Conservation and Breeding

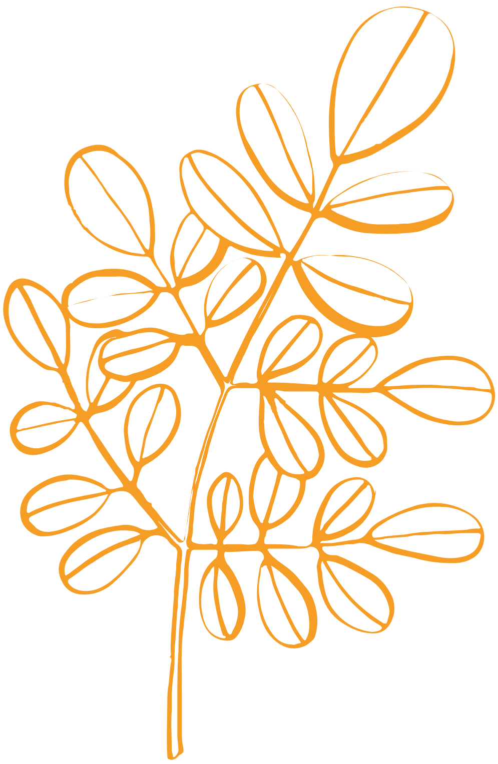
The genebank at the World Vegetable Centre in Arusha holds 40 landrace accessions of moringa, with 29 originating from Tanzania. Currently, there is no known breeding program for moringa in Tanzania. Only a few studies have characterized the varieties in the country (e.g., Munyanziza and Sarwatt, 2003; Kakengi *et al*., 2007; Mgendi, Manoko, and Nyomora, 2010; Edward *et al*., 2012; Edward *et al*., 2014). Characterizing the existing diversity and establishing a genebank are vital steps for conserving the genetic resources of moringa in Tanzania. The collection could be managed by the National Plant Genetic Resources Centre or the Tanzania Agricultural Research Institute – Tumbi (Tabora), which focus on agroforestry. These efforts are essential for initiating a breeding program to improve agricultural productivity and help conserve this valuable resource (Leone *et al*., 2015).

ICRAF Genebank, Nairobi. Ludy Keino, Laboratory Technician, performing germination planting of moringa on sand. Photo: Michael Major/Crop Trust

Processing and Value Chains

Moringa is currently produced on a very small scale, with only a few companies involved in exporting. Although published research and data are limited, gray literature and company websites offer some useful information; see, for example, Tanner (2010), Farm Africa (2020), Al-Mauly (2023), Matha Exports International (n.d.), and Symfonio (n.d.). The moringa value chain in Tanzania faces challenges such as unreliable markets, lack of credit facilities, outdated equipment, limited and costly packaging materials, and a lack of interest from government institutions (Farm Africa, 2020). The absence of connections among value chain actors impedes timely access to information, transparency, and fair pricing.

Germination planting of moringa tree on sand.
Photo: Michael Major/Crop Trust



Market Access

Introducing new products from moringa into existing markets is challenging and requires a thorough understanding of competition. Hella and Omari (2012) suggest that it is important to implement good agricultural practices, develop specialized products, form production clusters, and ensure products meet regulatory guidelines to improve the commercial development of moringa in Tanzania. Recent regional programs exist supporting the processing and commercialization of an increasing variety of value-added products, such as powders, oils, and soaps, which are available in Tanzanian markets.

Seed Fair at Chimukoko Community Seed Bank. Photo: Michael Major/Crop Trust

Conclusion

Moringa is a highly versatile tree whose nutrient-rich leaves, seeds, pods, and other parts provide food, medicinal, and economic benefits. It grows well across diverse and harsh environments in Tanzania. Its leaves and pods are widely consumed. Research supports its use in food fortification, medicine, animal feed, and water purification. Rising global demand for natural and nutritious products makes moringa a promising crop for income generation, employment, and value-added initiatives. Despite these advantages, moringa remains neglected in Tanzania, with limited documentation, weak policy support, and few studies that address the social, cultural, and economic aspects of its value chain. Agronomic challenges include gaps in knowledge about efficient production practices, pests and diseases in some regions, and the need for more research. However, interest in the crop is increasing across Africa. Conservation efforts are still minimal, with no breeding program in Tanzania. This highlights the need for characterization, genebank development, and improved coordination to strengthen value chains, market access, and overall crop development.

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Farmer visit to Malunga in the Matabeleland South province in southwestern Zimbabwe.
Photo: Michael Major/Crop Trust

PEARL MILLET

Cenchrus spp.

Enhancing Resilience, Nutrition, and Markets in Uganda

History of Domestication

Pearl millet is believed to have originated in the Sahel region of West Africa, where it was first domesticated approximately 4,000 to 5,000 years ago, making it one of the oldest cultivated cereals in the world (Jiménez-Arteaga et al. 2025). The crop ranks sixth among cereals worldwide in terms of global production and overall importance as a staple cereal crop, following wheat, rice, maize, barley, and sorghum (Satyavathi et al., 2021). Pearl millet thrives in hot, arid, and semi-arid climates and is primarily cultivated in regions with low, erratic rainfall. In Uganda, it is thought to have been introduced from Sudan around 3,000 BCE, where it was initially cultivated by pastoral communities in the north of the country (Kasule et al., 2024).

Taxonomy and Biology

Pearl millet is an annual grass (Kasule *et al*., 2024) with plants reaching heights of up to 4 meters (FAO, 1995). It thrives in warm conditions and is a short-day plant, requiring long nights to flower (Mamo, Singh, and Mahama, 2023). Although pearl millet spikelets are capable of self-pollination, their protogynous flowering habit favors cross-pollination (Lubadde, 2014).

The grains are small, about 3 to 4 mm long, oval-shaped, and come in various colors, including white, pale yellow, brown, gray, slate blue, and purple (FAO, 1995). They are also lightweight, with 1,000 seeds weighing approximately 8 grams (FAO, 1995). Pearl millet can grow well in different soils, such as sandy, acidic, and less fertile soils (Mamo, Singh, and Mahama, 2023). Its optimal soil pH is 6–7, though it may grow in soils with a pH as high as 8 (Jennings, Vendramini, and Blount, 2020).

Importance, Sociocultural Aspects and Potential

Pearl millet is a rich source of protein and essential minerals, particularly iron and zinc, making it an important dietary crop for food and nutrition security in Uganda (Satyavathi *et al*., 2021). Its high nutritional content is especially significant for communities in arid and semi-arid regions that face persistent food insecurity (Lubadde *et al*., 2015; Kasule *et al*., 2024). Moreover, the crop's high content of iron and zinc gives it particular relevance for addressing micronutrient deficiencies common in nutritionally vulnerable populations across northern and eastern Uganda. Its gluten-free nature also makes it a suitable dietary option for individuals with gluten intolerance, adding to its broader health value (Satyavathi *et al*., 2021).

Pearl millet is mainly cultivated in Uganda's arid and semi-arid regions, including the Northern and Eastern regions (Lubadde *et al*., 2015). The crop is well suited to these environments, tolerating heat, drought, and soil salinity while remaining less susceptible to pests and diseases than most other cereals grown under similar conditions. Nevertheless, these challenging agroecological conditions contribute to persistently low yields and severe food insecurity (Lubadde *et al*., 2015; Kanfany *et al*., 2020; Dube *et al*., 2021; Kasule *et al*., 2024).

Traditionally, women have been the primary managers of pearl millet (Lubadde *et al*., 2015). While men are responsible for land preparation and planting, women handle weeding, harvesting, and threshing. Children help by scaring away birds (Lubadde *et al*., 2016). Beyond its role as a staple food crop for family farmers, pearl millet provides broader agronomic and ecological benefits. Incorporating pearl millet into crop rotations reduces nematode infestations in wheat and soybean systems, supporting ecological pest management (Assis, Freitas, and Mason, 2018). Additionally, Ugandan farmers in Kumi District (Eastern Region) cultivate pearl millet to control Striga and enhance honey production (Lubadde, 2014). Despite its importance as a food security crop, family farmers continue to use low-yielding local varieties, which constrains overall productivity (Lubadde *et al*., 2015; Kanfany *et al*., 2020; Kasule *et al*., 2024). Although improved varieties have been introduced, farmers continue to prefer local varieties. This preference is attributed to limited access to quality seed stock and a limited selection of available varieties, as well as the valued characteristics of local varieties, such as high tillering ability, early maturity, drought tolerance, and spikes that deter birds.

Pearl mill*et al*so holds considerable economic and market potential, particularly in the processing of flour and value-added products. Rai *et al*. (2008) argue that successful commercialization depends on targeting premium or niche markets that emphasize the crop's unique functional and nutritional properties. These include its use in malt for beverages, weaning foods, and glucose production. Beyond grain-based products, pearl millet stover further enhances its economic value, as it can be utilized for fodder, building materials, and fuel (Mason, Maman, and Palé, 2015; Daduwal, Bhardwaj, and Srivastava, 2024). Realizing this potential, however, requires greater investment in improved seed systems, agronomic practices, and stronger market linkages. Such measures could substantially increase yields and strengthen pearl millet's contribution to rural livelihoods and food security (Lubadde *et al*., 2015; Kanfany *et al*., 2020).

Evaluating the sugar content and feed value of pearl millet, Agricultural Plant Genetic Resources Conservation and Research Centre, Wad Medani, Sudan. Photo: Paul Neate/Crop Trust

Neglect, Underutilization, Challenges

Research on pearl millet in Uganda began in the 1950s but has stalled over the past five decades due to limited funding, armed conflict, and insufficient human and infrastructural capacity, resulting in losses in genetic diversity (Kasule *et al*., 2024). The crop remains largely overlooked by key stakeholders, and investment in research, development, and promotion continues to be insufficient (Lubadde, 2014; Lubadde *et al*., 2015; Dube *et al*., 2021). Farmers grow pearl mill*et al*most exclusively at the subsistence level, selling only surplus produce, which limits its integration into commercial markets and suppresses demand for improved inputs (Lubadde *et al*., 2015; Kanfany *et al*., 2020; Kasule *et al*., 2024). This limited investment leads to persistently low farm-level productivity, undermining the crop's potential as a food security crop. Increased research and development funding is therefore crucial to enhance its economic and nutritional contributions in Uganda (Lubadde *et al*., 2015; Perumal *et al*., 2024).

Agronomic Issues

Despite its resilience and nutritional value, pearl millet production in Uganda faces a range of systemic and practical challenges. According to Lubadde *et al*. (2015), the formal pearl millet seed system in Uganda is underdeveloped. Many farmers rely on landraces and have limited awareness of improved, higher-yielding varieties. Their study found that 48.7% of interviewed farmers purchased seed grain, while 47.1% used their own saved seed (Lubadde *et al*. 2015, pp.59-60). Production is further constrained by the crop's labor-intensive cultivation and recurrent bird pressure from species such as the Ethiopian red-billed quelea (*Quelea quelea ethiopica*) (Lubadde *et al*., 2015). Post-harvest processing presents an additional burden, particularly for women, who bear primary responsibility for food preparation at the household level (Dube *et al*., 2021).

Conservation and Breeding

Despite its notable advantages as a drought-tolerant crop, the potential of pearl millet remains largely unexplored in Uganda (Kasule *et al*., 2024). The Uganda National Gene Bank holds 219 pearl millet accessions, including 15 landraces, 177 breeding/research materials, and 27 wild populations (Genesys, 2025a). Additionally, the National Semi-Arid Resources Research Institute (NaSARRI) in Uganda has around 450 accessions, while the genebank of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India holds more than 30,000 accessions (Genesys, 2025b).

Over the years, ICRISAT has partnered with the National Agricultural Research Organization (NARO), Bioversity International (now the Alliance of Bioversity International and CIAT), the Rockefeller Foundation, and other institutions to collect germplasm from across Uganda (Kasule *et al*., 2024). However, some of the diversity at the Uganda National Gene Bank gathered through such initiatives has been lost in the past due to poor maintenance, highlighting the need for ongoing investments to ensure proper care of current accessions (Kasule *et al*., 2024). These collections are maintained to address production challenges and meet the specific needs of various growing regions, such as drought tolerance (Kasule *et al*., 2024). There is a breeding program at NaSARRI, but it requires additional resources.

Little research has been conducted on the crop in Uganda, and there remains a gap in investment to support the breeding of improved varieties (Lubadde *et al*., 2015; Kasule *et al*., 2024). Previous breeding programs were halted in the past due to limited funding and war. Two pearl millet varieties have been officially released in Uganda: ICMV 225 in 2012 and ICMV 221, which was introduced from ICRISAT (ICRISAT, n.d.; Bantilan and Deb, 2003), most likely in the 2000s. Seed companies FICA and Grow More Seeds are licensed to sell ICMV 225 seed (NARO, 2023). As of September 2023, three pearl millet varieties were in the breeding pipeline at NaSARRI (NewVision, 2023).

Processing and Value Chains

Pearl millet contains antinutrients — including tannins, phytic acid, and polyphenols — that reduce digestibility, palatability, and nutrient bioavailability (Rai *et al*., 2008; Dube *et al*., 2021; Samtiya *et al*., 2021). Processing methods such as decortication, milling, roasting, soaking, fermentation, and malting have proven effective in reducing these antinutritional factors, enhancing digestibility, and extending the shelf life of processed products (Dube *et al*., 2021; Samtiya *et al*., 2021). At a larger scale, pearl millet can be used to produce confectionery and malt-based products (Satyavathi *et al*., 2021). However, the crop's small grain size makes post-harvest handling highly labor-intensive. In Uganda, harvesting and processing are mostly carried out by women using traditional methods, including cutting panicles with a knife, drying on mats, threshing by striking, and winnowing, which often discourages potential value chain actors who prefer cereals with more established and profitable value chains such as maize (Lubadde *et al*., 2015). Harvesting and processing machinery for pearl millet remains less advanced than for other cereals, with relevant research still at an early stage (Umakanth *et al*., 2024). Storage losses due to rodents, mold, insects, weevils, moths, and poultry further compound

Sscanning of pearl millet accessions at ICRISAT genebank.
Photo: Michael Major / Crop Trust

post-harvest challenges for Ugandan farmers (Lubadde, 2014). Addressing these constraints through investment in labor-saving mechanized tools, improved storage infrastructure, and value chain development will be essential to expanding pearl millet's commercial potential beyond subsistence production.

Market Access

The overall market is constrained by inconsistent produce supply and weak value chains, which decrease incentives for further investment in the crop (Kasule *et al*., 2024). Farmers also face other challenges, including insufficient government support, low produce prices, high market taxes, predatory middlemen, poor transportation infrastructure, long travel distances, and unfavorable road conditions (Lubadde *et al*., 2015).

Conclusion

Pearl millet shows great promise for improving food and nutrition security among marginalized groups in Uganda's arid and semi-arid regions. With adequate support for breeding improved varieties, heightened awareness of its nutritional virtues, and incentives for its cultivation aimed at attracting farmers, processors, and consumers, pearl millet has the potential to play a far more significant role in enhancing food security and livelihoods nationwide.

Farmer visit to Malunga in the Matabeleland South province in southwestern Zimbabwe.
Photo: Michael Major/Crop Trust

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The diversity of pumpkin and squash at Norwich meadows farm. Photo: Luis Salazar/Crop Trust

PUMPKIN

Cucurbita spp.

Paths Toward Sustainable Integration in Uganda's Food Systems

History of Domestication

Pumpkin (*Cucurbita* spp.) is believed to be indigenous to the Americas (Nakazibwe et al., 2019). From there, it spread globally and is now widely cultivated across tropical, subtropical, and temperate regions of Africa, Asia, Europe, and Oceania, making it one of the most versatile and broadly grown vegetable crops in the world. Over centuries of introduction and cultivation across Africa, it has become widely naturalized and is now regarded as an indigenous vegetable in many parts of the continent. In Uganda, pumpkin is deeply integrated into local farming systems and culinary traditions, with both its leaves and seeds widely consumed and valued for their nutritional properties.

Taxonomy and Biology

Pumpkin belongs to the family Cucurbitaceae and the genus *Cucurbita*, which also includes squashes, zucchinis, and gourds (Ruwanthika, Munasinghe, and Marapana, 2023; WFO, 2025). It is an annual vine with long, fast-growing stems that can exceed 10 meters, featuring monoecious flowers and short-lived perennial roots (Hosen *et al*., 2021). The plant produces large fleshy fruits that mature in approximately 3.5 months, with considerable variation in shape, size, and color across varieties (Hussain *et al*., 2022). The fruits are large berries that can be globose, ovoid, obovoid, cushion-shaped, or cylindrical, with smooth or grooved skin ranging from white and cream to green, and can weigh up to 50 kg when ripe (Infonet Biovision, n.d.; Himani Ruwanthika *et al*., 2023). The flesh, which constitutes approximately 70% of the fruit, ranges in color from pale yellow to crimson and encloses numerous large white seeds (Dhiman, Sharma, and Attri, 2009).

Pumpkin grows well in loamy, well-drained soils with high humus content and a pH range of 6.5–7.5 (Yadav *et al*., 2023). Waterlogged conditions must be avoided to prevent fruit and root rotting (Desai and Musmade, 1998). Its ability to grow across a wide range of tropical and subtropical environments, combined with its high yield potential, makes it a widely cultivated and economically important vegetable crop.

Importance, Sociocultural Aspects and Potential

The three pumpkin varieties most commonly grown in Uganda are C. moschata, C. maxima, and C. pepo. Pumpkins are rich in dietary fiber, protein, calcium, potassium, iron, and carotenoids with provitamin A activity (Nakazibwe *et al*., 2020). All parts of the pumpkin plant are edible. Leaves can be consumed fresh or dried, the pulp can be eaten raw or cooked, and the seeds can be processed into flour (Nakazibwe *et al*., 2019). Boiling and steaming, which are preferred cooking methods in the region, have been shown to retain high levels of provitamin A carotenoids and produce nutritious foods suitable for young children (Buzigi, Pillay, and Siwela, 2020a; 2020b). Pumpkin pulp is also widely used as a weaning food and complementary food for infants (Akwap, 2019). Additionally, the seeds and other plant parts are used for medicinal purposes throughout Uganda (Akwap, 2019; Nakazibwe *et al*., 2020; Otoo *et al*., 2021). Thus, pumpkin is highly valued as a food security crop and is consumed more frequently during periods of food scarcity. Its extended shelf life makes it a reliable dietary resource for rural households (Ondigi *et al*., 2008; Nakazibwe *et al*., 2019).

In Uganda, pumpkins are typically intercropped with sorghum, millet, matooke, maize, and beans, with production carried out primarily on a small scale for household use (Ondigi *et al*., 2008; Nakazibwe *et al*., 2019; EWS-KT, n.d.). Women play a central role in pumpkin cultivation and food preparation in Uganda, as in many indigenous vegetable systems, where they are typically the primary cultivators, foragers, and traders (Mshenga *et al*., 2016; Musoki, 2025). Various cultural beliefs surround pumpkin cultivation: for instance, in some communities, farmers believe that women who are menstruating should not enter the pumpkin garden, as this is thought to cause the fruits to rot (Nakazibwe *et al*., 2019).

Pumpkin has significant economic and market potential, including integration into regional East African markets (Dijkxhoorn *et al*., 2019). A variety of value-added products can be made from pumpkins, such as wine, butter, oil, and aphrodisiac preparations from the seeds (Medius *et al*., 2017; Josmak, n.d.). Nakazibwe *et al*. (2019) provide a comprehensive overview of methods for using pumpkin and potential opportunities for adding value. Despite several initiatives launched to promote the crop's economic potential, the full value of pumpkin remains unrealized due to underdeveloped value chains (Otoo, Kilama, and Odongo, 2021).

Traditionally, women have been the primary managers of pearl millet (Lubadde *et al*., 2015). While men are responsible for land preparation and planting, women handle weeding, harvesting, and threshing. Children help by scaring away birds (Lubadde *et al*., 2016). Beyond its role as a staple food crop for family farmers, pearl millet provides broader agronomic and ecological benefits.

The diversity of pumpkin and squash at Norwich meadows farm. Photo: Luis Salazar/Crop Trust

Neglect, Underutilization, Challenges

Despite its nutritional, medicinal, and economic benefits, pumpkin remains underutilized in Uganda (Otoo, Kilama and Odongo, 2021; Kasisa, 2022). Understanding the reasons for this is crucial to developing effective interventions. Research on pumpkin is limited, with Masika *et al*. (2022) highlighting a lack of documentation of production challenges, management practices, input sources, and farmer production strategies..

Agronomic Issues

Although pumpkin is relatively easy to grow, several challenges limit its widespread cultivation. Pumpkin plants are often grown on a small scale and intercropped with other crops or near household kitchen gardens, where they often grow from accidental seed drops on rubbish heaps (Masika *et al*., 2017). As a result, pumpkins often receive less attention and fewer resources, such as fertilizers and pest control measures, compared with other crops (EWS-KT, n.d.).

Commercial seeds are available on the market. For example, BRAC began commercial seed production for the 'Boromashi' variety around 2013/14 (Biswas, 2018). Further commercial seed providers in Uganda include Simlaw Seeds, East African Seed, Degro, East-West Seed, Top Harvest, Amazon Seeds, Africasia Seeds, Golden Bull (U) Ltd, and Rock Seeds (EWS-KT, n.d.). However, most farmers rely on their own saved seeds or seeds from neighbors and friends, re-using them year after year, with no official statistics on this practice (Masika *et al*., 2022). One study conducted in nine agro-ecological zones in Uganda found that 69.5% of pumpkin farmers used their own saved seeds, while 14.3% sourced seeds from agro-input shops (Masika *et al*., 2022).

Remaining challenges affecting pumpkin production in Uganda include pests and diseases, unpredictable weather patterns, price fluctuations, lack of extension support, high transportation costs due to the bulk of the fruits, and high labor costs (Nakazibwe *et al*., 2019; Masika *et al*., 2022; EWS-KT, n.d.). Furthermore, lacking technical knowledge among agro-input dealers limit the effectiveness of their training services for farmers, leading to misdiagnosis of diseases, misuse of agrochemicals, higher disease rates, pesticide resistance, and environmental pollution (EWS-KT, n.d.).

Conservation and Breeding

Pumpkin is not a priority crop for the National Agricultural Research Organization (NARO) in Uganda. As a result, efforts to conserve local pumpkin germplasm are insufficient, which risks genetic erosion (Nakazibwe *et al*., 2019). There is no formal breeding program dedicated to this crop. However, the Makerere University Regional Centre for Crop Improvement (MaRCCI) recently launched an initiative to improve various orphan crops, including pumpkins. MaRCCI currently has over 100 pumpkin landraces and farmer collections (personal communication, November 27, 2024) (Awori, Mubiru, & Otieno, 2024), and the Uganda National Genebank has 27 C. maxima accessions, all of which are landraces (Genesys, 2025a). The largest genebank collections of C. maxima listed in Genesys are held by Embrapa Hortaliças in Brazil (841 accessions) and the USDA-ARS Northeast Regional Plant Introduction Station at Cornell University, USA (839 accessions) (Genesys, 2025b).

A few studies have characterized pumpkin varieties in Uganda; see, for example, Kukeera *et al*. (2015); Nakazibwe, Eunice, and Kagoro (2020), and Kazibwe (2022). Nevertheless, further research is necessary to improve understanding of phenotypic and genetic diversity, physicochemical characteristics and the preferences of different value chain actors.

Pumpkin seeds on display at a seed fair organized by Lupane State University and held in Bhanda, near Lupane, Zimbabwe. Photo: Michael Major / Crop Trust

Processing and Value Chains

While some value-added pumpkin products are available in local supermarkets, such as porridges, flours, and snacks such as fried or roasted seeds mixed with groundnuts or sesame (Akwap, 2019; Nakazibwe *et al*., 2019), the broader processing sector and value chain remain underdeveloped across much of Uganda, with some regions more affected than others (Otoo, Kilama and Odongo, 2021). Initiatives such as those led by EWS-KT and Josmak illustrate the potential for pumpkin value addition to generate income and support women's empowerment, yet these remain isolated examples rather than the norm.

Market Access

Limited pumpkin production volumes and inconsistent yields hinder the development of a sustainable pumpkin market, as small volumes can't attract major buyers. The value chain is underdeveloped, making it essential to establish linkages between farmers and buyers and to share market information for better planning.

Pumpkin leaves at a market in Singida Tanzania. Photo: Mike Major/Crop Trust

The diversity of pumpkin and squash at Norwich meadows farm.
Photo: Luis Salazar/Crop Trust

Conclusion

Pumpkin holds significant potential to strengthen food security and generate economic opportunity in Uganda, yet its cultivation and commercialization remain constrained by challenges spanning agronomy, breeding, processing, and market access. Addressing these barriers is essential for maximizing the crop's benefits and ensuring its sustainable integration into food systems. Equally important is the need to document indigenous knowledge surrounding pumpkin production and use (Otoo, Kilama and Odongo, 2021). Overall, greater investment in research and commercialization is needed, particularly in underdeveloped opportunities, such as pumpkin seed oil extraction (Kukeera et al., 2015).

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Sesame in opportunity crop demonstration plot at WorldVeg.

SESAME

Sesamum spp.

Unlocking the Commercial and Nutritional Potential of an Underutilized Oilseed Crop in Ghana

History of Domestication

Sesame (*Sesamum* spp.) is considered to have been domesticated in South Asia, most likely on the Indian subcontinent. However, Africa represents the center of diversity for the genus Sesamum and has played an important role in the crop's subsequent diversification and spread (Bedigian and Harlan, 1986). Numerous wild relatives of sesame are found in Africa, which are of considerable importance as potential sources of disease resistance and genetic diversity for breeding programs, while fewer wild relatives are found in India (Desai, 2004; Sintim and Yeboah-Badu, 2010). The crop is now widely naturalized in tropical regions worldwide, including sub-Saharan Africa, South and Southeast Asia, China, Mexico, and parts of South America.

Taxonomy and Biology

Sesame is classified within the family Pedaliaceae, a group of mostly tropical flowering plants known for their mucilaginous seeds. It is widely grown for its high-oil seeds and is one of the oldest oilseed crops.

Sesame is an erect annual broadleaf plant, growing up to 2.5 meters tall (Sintim and Yeboah-Badu, 2010; Editors of the Encyclopaedia Britannica, 2025). It is self-pollinating and produces one flower at each leaf axil. The crop is quite drought-tolerant, requiring only 500–650 mm of rainfall (Boureima *et al*., 2011). The plant sheds its leaves once the seed capsule forms.

Importance, Sociocultural Aspects and Potential

Sesame is increasingly recognized not only as an oilseed crop but also as a nutritionally valuable and health-promoting food. The seeds contain approximately 50% oil by weight, more than double the oil content of soybeans, which is about 20%. The oil is rich in behenic acid, which is used in skincare and hair products (Ansah *et al*., 2015; Sintim and Yeboah-Badu, 2010). Additionally, sesame seeds exhibit considerable antioxidant activity and high nutritional value, further highlighting their potential as functional food products (Dravie *et al*., 2020). With the growing acceptance of traditional medicine in Ghana, sesame has also gained recognition for its therapeutic properties. Its antioxidant compounds are associated with protective effects against chronic diseases. Moreover, roasted white sesame seeds packaged in sachets are marketed as a health condiment (Sintim and Yeboah-Badu, 2010). Nevertheless, further targeted research is required to fully substantiate and realize the crop's health-promoting potential.

Globally, sesame is cultivated on all continents except Antarctica, primarily for its edible seeds and oil (Weiss, 2000; FAO, 2025). Across Africa, it is grown in most countries, including Ghana's neighboring states Burkina Faso, Côte d'Ivoire, and Togo, although production in Ghana itself remains limited and largely non-commercial (FAO, 2025). Cultivation is concentrated among smallholder farmers in northern Ghana, where sesame is mainly grown for subsistence and typically consumed roasted, both as leaves and seeds (Sintim and Yeboah-Badu, 2010). Awareness of its commercial and nutritional potential remains relatively low, and farmers generally allocate only small areas to oilseed crops. However, research indicates that sesame can be cultivated profitably in Ghana, with yields of up to 1,176 kg/ha achieved on sandy soils with adequate nutrient availability at 10–30 cm depth, which supports optimal plant density and growth (Sintim and Yeboah-Badu, 2010).

Sesame is particularly well suited to the dry conditions of the Sahel and could become an important cash crop for smallholder farmers in the region (Dossa *et al*., 2017a). The crop is drought-tolerant, can be grown without irrigation or fertilizer, and may be planted early or late in the growing season. Under favorable conditions, up to three harvests per year are possible, making sesame highly suitable for low-external-input farming systems (Ansah *et al*., 2015; Iowa State University, n.d.). In 2023, the leading global producers were Sudan, India, Myanmar, China, and Nigeria (FAO, 2025). Given its agronomic suitability and growing interest in its nutritional and antioxidant properties, commercial sesame production in Ghana holds considerable potential for expansion, particularly in the development of value-added products.

Sesame being sold in Central Market, Natitingou, Benin.

Neglect, Underutilization, Challenges

Sesame production in Ghana and other West African countries shows promise but faces significant structural obstacles. There is no organized or well-defined sesame research or production program, making sesame farming less appealing to investors and development actors, and leaving local farmers to rely largely on a trial-and-error approach (Sintim *et al*., 2014). This absence of institutional support limits access to improved varieties, agronomic guidance, and market linkages. The crop is currently grown mainly as a subsistence crop in northern Ghana, and without targeted investment in research, extension services, and value chain development, its potential as a commercial cash crop for smallholder farmers in the region is likely to remain unrealized (Sintim and Yeboah-Badu, 2010; Dossa *et al*., 2017a).

Agronomic Issues

Sesame production faces a range of agronomic challenges, primarily related to pests and diseases (Sintim *et al*., 2014; Teklu *et al*., 2021). A preliminary survey of arthropods associated with sesame in the transitional zone of Ghana identified a wide range of associated species, including chewers, suckers, pollinators, scavengers, and predators, highlighting the need for integrated pest management approaches tailored to the crop (Sintim *et al*., 2014). The absence of improved, high-yielding cultivars that resist seed shattering, combined with an unreliable seed supply, represents one of the most critical constraints on sesame production more broadly (Pham *et al*., 2010; Tiwari, Kumar, and Gontia, 2011).

Conservation and Breeding

Improving sesame productivity will require investment in cultivar development and germplasm evaluation. Efforts in Ghana have included the assessment of exotic cultivars selected for the Japanese market, as well as the evaluation of local genotypes using morphological and molecular markers to identify potential parental lines for high-yielding cultivar development (Ansah *et al*., 2015; Adu-Gyamfi, Prempeh, and Zakaria, 2019), though the extent to which these lines have been incorporated into active breeding programs remains unclear. Research in Ghana also suggests that breeders should prioritize earliness, as three crops per year could be achieved if early-maturing varieties with a 12-week maturity period are planted when the first rains fall in early March (Ansah *et al*., 2015). Assessing broader genetic diversity through structured breeding programs represents a further pathway to improving yields and expanding the crop's adaptability across Ghana's agro-ecological zones.

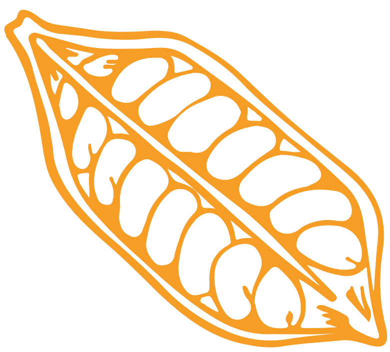
Sesame in opportunity crop demonstration plot at WorldVeg.

Processing and Value Chains

Sesame value chains in Africa typically involve multiple intermediaries, including producers, village traders, brokers, wholesalers, oil millers, exporters, retailers, and local consumers, and smallholder farmers often rely on these intermediaries because they sell in small quantities and lack access to efficient market information systems (Abebe, 2016; Gebremeskel *et al*., 2021; Wacal *et al*., 2021). Oil processing at the household level remains very limited, with most small-scale processing involving grinding seeds into paste, roasting, and mixing with honey and sugar to produce snack balls or pellets (Munyua, Orr, and Okwadi, 2013). Sesame exports from countries such as Uganda and those in the Sahel are predominantly in the form of raw seeds rather than processed oil, limiting the value captured along the chain (Munyua, Orr, and Okwadi, 2013; Dossa *et al*., 2017b). Sesame seed cake, a by-product of oil processing, has potential as a high-protein livestock feed additive and represents an underexplored avenue for value addition (Kabinda *et al*., 2022). Encouraging farmers to adopt inexpensive processing methods and promoting the development of cooperatives or farmers' organizations have been recommended as practical steps to advance sesame processing (Wacal *et al*., 2021).

Market Access

Marketing challenges persist across sesame-producing countries in Africa, with unreliable markets and price fluctuations reported in Senegal, Ethiopia, and Mali posing significant barriers to commercial development (Dossa *et al*., 2017a; 2017b; Teklu *et al*., 2021). Limited access to affordable credit constrains both farmers seeking to enter the sesame market and traders operating along the value chain (Munyua, Orr, and Okwadi, 2013; Wacal *et al*., 2021). In Ghana, the absence of an organized sesame production and research program further limits market development, leaving farmers without the institutional support needed to improve productivity, access buyers, or capture the growing domestic and export demand for sesame and its derivatives.



Conclusion

Sesame production in Ghana and West Africa more broadly shows considerable promise but remains constrained by the absence of organized research and production programs, leaving farmers to rely largely on trial-and-error approaches (Sintim et al., 2014). Major agronomic challenges include pests, diseases, seed shattering, and an unreliable supply of improved cultivars, although studies in Ghana have identified promising genetic lines for breeding and suggest that early-maturing varieties could enable up to three harvests per year under favorable rainfall conditions (Ansah et al., 2015; Adu-Gyamfi, Prempeh, and Zakaria, 2019). Value chain analyses across Ethiopia, Uganda, Senegal, and Mali highlight heavy dependence on intermediaries, minimal local oil processing, and a predominance of raw seed exports, pointing to significant untapped potential in processing and value addition (Abebe, 2016; Munyua, Orr, and Okwadi, 2013; Dossa et al., 2017b; Wacal et al., 2021). Across the region, unreliable markets, price fluctuations, and limited access to affordable credit for both farmers and traders remain persistent barriers to commercial development (Dossa et al., 2017a; Teklu et al., 2021). Addressing these structural constraints through targeted investment in research, breeding, processing infrastructure, and market linkages will be essential to realizing sesame's potential as a commercial crop for smallholder farmers in Ghana and beyond.

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Sweetpotato regeneration plot at NARI Aiyura, Papua New Guinea.
Photo: Mike Major / Crop Trust

SWEET POTATO

Ipomoea spp.

Leveraging a Versatile Root Crop for Food Security in Tanzania

History of Domestication

The sweetpotato (*Ipomoea* spp.) is believed to have originated in South and Central America, with domestication dating back at least 5,000 years (Mu and Li, 2019). Its global spread occurred first through interactions between ancient civilizations and later through European trade and colonialism (Barb, 2016). Today, sweetpotato is widely cultivated in tropical and warm temperate regions worldwide. In Tanzania, the main production areas are in the Lake Zone, Eastern Zone, and Southern Highlands (Mmasa and Msuya, 2012a; Adam, 2016). In 2023, Tanzania was the third largest producer of sweetpotato globally, after China and Malawi (FAO, 2025). According to the 2019/20 agriculture census report, 289,940 hectares of sweetpotatoes were planted in Tanzania, with smallholders cultivating 289,917 hectares and large-scale farms only 23 hectares (URT, 2021). Total production was 504,346 tonnes, with smallholders contributing 504,302 tonnes (99.9%) and large-scale farms 44 tonnes (0.01%), highlighting the vital role of smallholder farmers in food security.

Taxonomy and Biology

Sweetpotato is in the family Convolvulaceae (Bovell Benjamin, 2007). It is an herbaceous, dicotyledonous perennial vine (Behera *et al*., 2022). The plant's vines can grow up to 5 meters long and spread horizontally. Flowers can be white to lavender, while the leaves are primarily green with diverse purple markings, varying in shape and size, and arranged spirally on the stem (Behera *et al*., 2022; Truong *et al*., 2018). The sweetpotatoes are underground swollen storage roots, also sometimes referred to as tubers (Truong *et al*., 2018; Behera *et al*., 2022), measuring from a few centimeters to over 30 centimeters in length and weighing from 100 g to several kilograms each (Truong *et al*., 2018).

The tubers store nutrients for the plant's growth and development and come in diverse shapes, including ellipsoid, fusiform, or elongated forms. They also have a range of skin colors such as red, yellow, brown, white, and purple (Behera *et al*., 2022). Their flesh varies in color as well, including white, orange, purple, and yellow (Bovell Benjamin, 2007; Behera *et al*., 2022; Truong *et al*., 2018).

The sweetpotato grows best in well-drained loam, clay loam, or sandy loam soils with a clay subsoil (Behera *et al*., 2022) and a pH of 5.5-6.5. While it is drought-tolerant, the crop cannot grow in waterlogged conditions (Behera *et al*., 2022). It thrives in temperatures from 21-26 °C and needs plenty of sunlight (Behera *et al*., 2022).

The plant propagates through stem cuttings or sprouts from the storage roots (Truong *et al*., 2018). Although it is a perennial, sweetpotato is generally grown as an annual crop harvested after one growing season, typically 90–150 days after planting (Bovell Benjamin, 2007; Behera *et al*., 2022).

Importance, Sociocultural Aspects and Potential

Sweetpotato is a vital subsistence crop cultivated across nearly all agro-ecological zones of Tanzania. It ranks as the third most important root and tuber crop after cassava and white potato (Masumba *et al*., 2004; Kapinga and Carey, 2003; Adam, 2016). The crop is highly valued for its nutritional and health-promoting properties. Its roots are rich in starch and energy, and orange-fleshed varieties are particularly high in beta-carotene, which helps combat vitamin A deficiency (Mu and Li, 2019). In addition, sweetpotato roots contain substantial amounts of dietary fiber, vitamin B6, and potassium. Colored-flesh varieties are especially rich in bioactive compounds, contributing to a comprehensive nutrient profile in both raw and cooked forms (Cartabiano Leite, Porcu, and de Francisco, 2020). Bioactive compounds such as carotenoids and anthocyanins are associated with antioxidant, anti-inflammatory, and disease-preventive properties (Cartabiano Leite, Porcu, and de Francisco, 2020). Orange-fleshed varieties, in particular, are widely recognized for their role in addressing vitamin A deficiency, a major public health concern in Tanzania and across sub-Saharan Africa (Mu and Li, 2019).

In Tanzania, sweetpotato plays a crucial role in food security, particularly during famine periods, due to its drought tolerance and rapid development of storage roots (URT, 2021). Dried and stored products such as michembe (sliced and dried roots) and matobolwa (boiled, sliced, and dried roots) can be preserved for up to ten months and are especially important in arid regions during times of food scarcity (Mmasa and Msuya, 2012a; 2012b; Mlambiti and Mmasa, 2015). These products are processed and consumed in various forms to support both short- and long-term food security. Roots are commonly boiled for children or eaten for breakfast, while the leaves are blanched and used as a vegetable (Masumba *et al*., 2007; Stathers *et al*., 2013). In urban areas, roots are often deep-fried and sold as snacks (Adam, 2016). Additional products include cakes, chapattis, doughnuts, kaimati, flour for meal preparation, porridge, and crisps (Mmasa and Msuya, 2012a).

Although primarily cultivated for home consumption, sweetpotato is also grown for market in certain regions, particularly in the Eastern Zone (Masumba *et al*., 2004). The wide range of derived products, including dried goods, flours, snacks, and beverages, creates promising economic opportunities. Its short growing cycle makes the crop particularly suitable for areas with prolonged dry seasons, thereby supporting both household food security and income generation (Masumba *et al*., 2004; Kagimbo, Shimelis, and Sibiya, 2017). However, greater investment in processing infrastructure and stronger market linkages would be necessary to fully expand its commercial potential and enhance its contribution to rural livelihoods across Tanzania.

Farmer Anton Kua in the Asaro Valley at Meteiyufa village.

Neglect, Underutilization, Challenges

Sweetpotato production in Tanzania faces several challenges, including biotic and abiotic stresses and socioeconomic factors (Kagimbo, Shimelis, and Sibiya, 2018). Despite the high nutritional value of sweetpotato leaves, which are rich in vitamins A, C, and B-complex as well as antioxidants, they remain underutilized. They are often perceived as a food for the poor, which limits their acceptance in urban and higher-income markets (NRC, 2006; Woolfe, 1992). Limited nutrition education and promotion mean that many producers and consumers are unaware of their health benefits. Production systems typically prioritize roots over leaves, creating missed opportunities for dual-purpose varieties. Post-harvest handling and supply chains for fresh leaves are also weak, reducing their availability in local markets and limiting commercial integration. As a result, both sweetpotato roots and leaves remain undervalued dietary components despite their significant potential to improve nutrition outcomes and food system resilience (NRC, 2006).

Agronomic Issues

A chronic shortage of planting material is a major challenge for production in Tanzania (Mmasa and Msuya, 2012a; Tairo, Mneney, and Kullaya, 2008; Andersen, Gugerty, and Jones, 2019). Planting material is mostly obtained from local farming communities, with formal distribution channels being rare except during disaster relief efforts (Namanda, Gibson, and Sindi, 2011; McEwan *et al*., 2017). Most farmers grow landraces and have limited access to elite sweetpotato varieties (Mmasa and Msuya, 2012b; Ngailo *et al*., 2016a; Mmasa, 2023). Other significant challenges include lack of capital, unpredictable weather, and pest attacks (Hellen Keller International, 2012; Mmasa and Msuya, 2012a; Mmasa, 2023). Sweetpotato weevils and virus diseases pose major concerns (Ngailo *et al*., 2016b; Kagimbo, Shimelis, and Sibiya, 2018; Kagimbo, Shimelis, and Sibiya, 2020). Although earlier studies identified weevils as the primary constraint, recent assessments of their impact and farmers' perceptions are lacking (Kagimbo, Shimelis, and Sibiya, 2018). Traditional control methods like crop rotation and sanitation practices have limited success, highlighting the need for integrated pest management, including host resistance and chemical controls, although breeding for weevil resistance has not yet been explored in Tanzania (Kagimbo, Shimelis, and Sibiya, 2018).

Farmer inspecting her sweetpotato leaves in field near Mwanganjuki, Tanzania

Conservation and Breeding

The National Plant Genetic Resources Centre in Tanzania holds four sweetpotato accessions, all of which are landraces (Genesys, 2025). The Tanzania Agricultural Research Institute (TARI) also has some accessions, with data on the exact numbers pending. TARI has a sweetpotato breeding program focused on developing varieties with high yields, disease resistance, and high beta-carotene content (Tongoona *et al*., 2019). Previous efforts have concentrated on pest resistance, root yield, and adaptability to various environments (Masumba *et al*., 2004). The International Potato Center (CIP) and TARI have collaborated on research, resulting in the development of sweetpotato genotypes that have been tested in several zones, including Lake Zone, Eastern Zone, and Zanzibar (Hellen Keller International, 2012).

A technician examines a sweetpotato clone under conservation at WorldVeg, Arusha, Tanzania.

Genetic diversity studies of accessions at the Root/Tuber Crops Programme in Kibaha identified genotypes that could be used for breeding (Ngailo *et al*., 2016b). Ngailo *et al*., (2016a) identified genetically unrelated and complementary sweetpotato genotypes recommended for breeding. Participatory varietal evaluations showed that some genotypes were rejected by farmers because of low dry matter, inability to produce enough planting materials, especially during the dry season, and low yields (Ngailo *et al*., 2016a).

A total of 23 sweetpotato varieties have been released in Tanzania from 2000 to 2021, led by various research stations. Twenty-one orange-fleshed sweetpotato varieties introduced by CIP-Kenya in 2001 were evaluated in the coastal and Dar es Salaam regions, with farmers prioritizing root yield, marketability, drought tolerance, and resistance to pests and diseases (Masumba *et al*., 2004).

Despite ongoing efforts to develop improved cultivars, progress has been limited due to insufficient knowledge of the genetic diversity of local landraces, highlighting the need for more characterization studies (Tairo, Mneney and Kullaya, 2008). Although several studies have contributed to current characterization efforts (Tairo, Mneney and Kullaya, 2008; Elameen *et al*., 2008; Elameen *et al*., 2011; Gwandu *et al*., 2012; Ngailo *et al*., 2016a), there is a lack of comprehensive studies on the yield, dry matter content, and other traits of local and improved sweetpotato varieties in Tanzania (Ngailo *et al*., 2016b). Ngailo *et al*. (2016a) suggests that productivity could be enhanced by selecting locally adapted and farmer-preferred genotypes and targeted breeding.

Processing and Value Chains

Challenges in sweetpotato value chains in Tanzania include poor connectivity, lack of coordination, unregulated actors, and weak institutional frameworks among key actors (Mlambiti and Mmasa, 2015; Mmasa, 2023). Sweetpotatoes have a short shelf life, leading to post-harvest losses when there are no long-term storage facilities or processing options (Mlambiti and Mmasa, 2015). Losses are caused by pests such as sweetpotato weevils and poor handling during transportation (Andersen, Gugerty, and Jones, 2019). The sweetpotato value-addition sector in Tanzania faces constraints from inadequate value-addition, an informal market system, and limited support services, resulting in the sale of products in raw form and low returns for small-scale farmers (Mmasa, 2023).

Sale of sweetpotato leaves and other leafy vegetables at morning market in Singida, Tanzania.

Market Access

Sweetpotato is often viewed as a less important crop in Tanzania than maize, rice, and bananas, which limits its marketability in some areas. However, demand tends to rise significantly at certain times, such as during Ramadan (Adam, 2016). Marketing is primarily handled by small-scale traders, with farmers selling directly to consumers or through middlemen, village hawkers, or transporters who deliver products to retailers (Hellen Keller International, 2012; Mmasa and Msuya, 2012a; Mmasa and Msuya, 2012b; Mmasa, 2014). Small-scale farmers or middlemen also process sweetpotato into products like michembe and matobolwa for sale (Mmasa and Msuya, 2012b). Farmers often face exploitation by hawkers and middlemen (Mlambiti and Mmasa, 2015). Although sales of fresh sweetpotato roots have been increasing, especially in urban areas (Kapinga and Carey, 2003), the multiple layers of marketing decrease farmers' profit margins. Mmasa (2023) emphasizes the need to enhance market information services to provide adequate price information.

Conclusion

Sweetpotato production in Tanzania faces challenges from both biotic and abiotic stresses and ongoing perceptions, especially of its leaves, as "poor-person's food," which restricts its nutritional use in higher-income markets. Farmers experience chronic shortages of planting material, depend heavily on landraces, and have limited access to improved varieties, while pests like weevils and viral diseases continue to lower yields. Although national institutions such as TARI and international partners such as CIP have made progress in developing high-yielding, disease-resistant, and nutrient-rich cultivars, gaps still exist in understanding local genetic diversity and conducting comprehensive characterization studies. Value-chain issues—including weak coordination, poor handling, short shelf life, and limited processing capacity—hinder commercialization and cut profit margins for small-scale farmers. Market access is further restricted by informal trading systems, limited price information, and multiple intermediaries, leading to low returns despite rising urban demand for sweetpotato products. Its nutritional benefits, adaptability to various environments, and potential for genetic improvement, especially for dual-purpose use, make it a key focus for agricultural research and development in Tanzania and worldwide.

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Turkey berry plant. Photo: Natalia Rodriguez / Crop Trust.

TURKEY BERRY

Solanum spp.

Enhancing Nutrition and Livelihoods Through an Indigenous Crop in Ghana

History of Domestication

Turkey berry (*Solanum torvum*) is believed to have been domesticated in Mesoamerica, where wild populations range from Mexico through Central America. It then spread to the Caribbean, South America, Africa, and Asia through both pre-Columbian dispersal and later colonial exchanges (Morton, 1987). Although it is not classified as fully domesticated, it has been semi-domesticated and broadly incorporated into agroecosystems for food, medicine, and as a rootstock for grafting other Solanum species, especially eggplant (Bishnoi, 2019).

Taxonomy and Biology

Turkey berry belongs to the Solanaceae family, a large and diverse group of plants that includes tomatoes, eggplants, peppers, and many wild species. Its scientific name is *Solanum torvum*, placing it within the genus Solanum, one of the largest genera of flowering plants, known for species that have similar flowers, berry-like fruits, and often prickly stems and leaves (Aubriot & Knapp, 2022). Within Solanum, turkey berry is classified under the subgenus Leptostemonum, commonly called the "spiny solanums," which are characterized by stellate hairs and prickles (Bohs, 2005).

Turkey berry is a short (2–4 m), upright shrub found throughout tropical Africa, Asia, and South America at elevations up to 1,600 meters (Boonkerd, Ba Songkhla, and Thephuttee, 1993). It is widely used both as food and for its medicinal uses in folk medicine around the world. Turkey berry often grows along roadsides and in waste areas after soil disturbance and can develop into a large, thorny, dense thicket.

Importance, Sociocultural Aspects and Potential

Turkey berry is regarded as a nutritious, underutilized food with the potential to enhance dietary diversity and nutrition, especially among resource-constrained households (Asiedu-Darko, 2010; Ahenkan and Boon, 2011; Agbemafle *et al*., 2019; Darkwah *et al*., 2020). The fruit is rich in iron, calcium, and other essential minerals, supporting its traditional use in addressing nutritional deficiencies, particularly anemia (Asiedu-Darko, 2010; Akoto *et al*., 2015). A recent study conducted in Ghana demonstrated that consuming a turkey berry-fortified biscuit reduced the prevalence of anemia and improved cognitive performance among adolescent girls (Appiah *et al*., 2023), highlighting the crop's significant potential in nutrition interventions. Furthermore, the crop exhibits various pharmacological characteristics, including its antimicrobial, anti-inflammatory, and antioxidant properties (Yousaf, Wang, and Baydoun, 2013). Traditionally used in Ghanaian medicine, turkey berry extracts are reported to treat coughs, colds, and skin conditions (Chah, Muko, and Oboegbulem, 2000; Sundari, Rekha, and Parvath, 2013; Akoto *et al*., 2015). It is also reportedly used to treat snakebites, though more research is needed to validate this application (Harris, 1985).

In Ghana, turkey berry is known by different names among Akan communities: abedru or bedru among the Akyem, kantose among the Kwahu, and kwahu nsusua among the Ashanti (Essiedu, 1985; Asiedu-Darko, 2010). Although mostly consumed in rural communities, turkey berry is gradually gaining significance in peri-urban and urban areas of Ghana, reflecting a broader shift toward the recognition of indigenous vegetables (Asiedu-Darko, 2010).

This growing recognition in markets represents an emerging commercial opportunity (Asiedu-Darko, 2010). Its documented nutritional and medicinal properties position it well for value addition and product development, particularly in functional foods and natural health products. Greater investment in research, processing, and market development could unlock the crop's broader economic potential and support smallholder livelihoods across Ghana.

Agronomic Issues

Very little is known about the specific challenges of turkey berry production in Ghana. The plant is susceptible to anthracnose disease caused by *Colletotrichum acutatum*, which can cross-infect other solanaceous crops and represents a potential threat to integrated farming systems (Adongo *et al*., 2019). Post-harvest losses, a common problem in Solanaceae production across Africa, may similarly affect *S. torvum* cultivation, highlighting the need for improved harvesting and handling practices (Arah *et al*., 2015). The crop also remains largely absent from formal research programs in Ghana, limiting the development of improved varieties, agronomic guidance, and market support. Turkey berry has demonstrated potential as a rootstock for grafting eggplants and tomatoes, enhancing growth, yield, and resistance to Verticillium wilt (Bletsos, Thanassoulopoulos, and Roupakias, 2013). However, this application remains unexplored and unadopted in Ghana, signifying an untapped opportunity for the broader utilization of the crop.

Turkey berry plant. Photo: Natalia Rodriguez / Crop Trust.

Conservation and Breeding

Although there are numerous studies on the reproductive biology and breeding systems of turkey berry (e.g., Kumchai et al., 2013; Saha and Datta, 2016; Kumar et al., 2024; Zhang et al., 2024) and its use in crosses with domesticated eggplant (e.g., Afful et al., 2018), there appear to be limited conservation and breeding efforts specifically focused on the species. Genesys (2025) lists 143 accessions of *S. torvum*, mainly held at the World Vegetable Center in Taiwan (107 accessions) or at the Millennium Seed Bank at the Royal Botanic Gardens, Kew, UK (19 accessions).

Processing and Value Chains

Little information exists on the processing and value chains of turkey berry in Ghana or elsewhere. Green fruits are sold in markets in parts of Africa and South Asia (Areces-Berazain, 2024), and berries are traded in European markets under the name “pea eggplants” (Aubriot and Knapp, 2022). While numerous studies have examined the potential of *S. torvum* as a rootstock for eggplant and tomato cultivation (Arao *et al*., 2008; Petran and Hoover, 2014; Chandanshive *et al*., 2023), no studies on the commercial rootstock market were found. The significant gaps in knowledge around turkey berry’s value chains and processing potential represent both a research gap and an opportunity: greater investment in documenting existing trade flows, developing post-harvest technologies, and exploring value-added products could help unlock the crop’s broader commercial potential in Ghana and beyond.

Conclusion

Turkey berry plays a role in food security, nutrition, and health in Ghana, especially among low-income households, and is used in local dishes across Akan communities. It supplies minerals like iron and calcium, is used in traditional medicine, and shows promise in reducing anemia and enhancing cognitive function in adolescents. The plant also has antimicrobial, anti-inflammatory, and antioxidant qualities, though some traditional uses, such as treating snakebites, need scientific validation. Despite its significance, turkey berry remains overlooked and underused, with limited information on its cultivation challenges aside from its vulnerability to anthracnose disease and post-harvest losses. Although the species is valuable as a rootstock for eggplant and tomato, it is not used in this way in Ghana, and conservation and breeding activities are minimal, with most germplasm accessions stored outside the country (Ahenkan and Boon, 2011).

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CROP TRUST

THE GLOBAL CROP DIVERSITY TRUST
Platz der Vereinten Nationen 7
53113 Bonn
Germany

MEDIA CONTACT
media@croptrust.org

GENERAL CONTACT
info@croptrust.org