A Review of Select Neglected and Underutilized Species (NUS) in Uganda

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The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT) delivers research-based solutions that address the global crises of malnutrition, climate change, biodiversity loss, and environmental degradation.

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The Building Opportunities for Lesser-known Diversity in Edible Resources project (BOLDER) Initiative is led by the Global Crop Diversity Trust (Crop Trust). The project aims to improve the utilization and value of opportunity crops also known as Neglected and Underutilized Species (NUS) in agri-food systems in East and West Africa. The project is presently being carried out in Benin, Ghana, Tanzania, and Uganda. BOLDER is a component of BOLD, a ten-year program run by the Global Crop Diversity Trust (Crop Trust) in partnership with national and international genebanks and research institutions. The project is funded by the Norwegian Agency for Development Cooperation (NORAD).

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ACRONYMS

ABC	Alliance of Bioversity International and CIAT
BOLD	Biodiversity for Opportunities, Livelihoods and Development
BOLDER	Building Opportunities for Lesser-known Diversity in Edible Resources
CGIAR	Consultative Group on International Agricultural Research Centers
CIAT	International Centre for Tropical Agriculture
CIFOR-ICRAF	The Center for International Forestry Research and World Agroforestry
CT	Crop Trust
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistics
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute for Tropical Agriculture
MARCCI	Makerere University Regional Centre for Crop Improvement
NAADS	National Agricultural Advisory Services
NaCRRI	National Crops Resources Research Institute
NaFORRI	National Agriculture, Forestry, and Research Institute
NAADS	National Agricultural Advisory Services
NARL	National Atmospheric Research Laboratory
NARO	National Agriculture Research Organization of Uganda
NaSSARRI	National Semi-Arid Research Institute
NGOs	Non-Governmental Organizations
NORAD	Norwegian Agency for Development
NUS	Neglected and Underutilized Species
PGRC	Plant Genetic Resource Centre
WP	Work Package
VEDCO	Volunteer Efforts for Development Concerns
UBOS	Uganda Bureau of Statistics
UNGB	Uganda National Gene Bank
WorldVeg	World Vegetable Center
ZARDI's	Zonal Agricultural Research Development Institutes

1. INTRODUCTION

The Global Crop Diversity Trust (Crop Trust), through the Building Opportunities for Lesser-known Diversity in Edible Resources project (BOLDER), aims to increase the use and value of opportunity crops also referred to as neglected and underutilized crops (NUS) in agri-food systems in West and East Africa. The project is funded by the Norwegian government through NORAD and is being conducted in Benin, Ghana, Tanzania and Uganda. BOLDER is part of Building Opportunities for Livelihoods and Development (BOLD), a larger initiative to strengthen food and nutrition security worldwide through the conservation and use of crop diversity in genebanks.

The Crop Trust in collaboration with the Alliance of Bioversity International and CIAT held a stakeholder workshop from 1-2 August in Kampala, Uganda to identify and prioritize five opportunity crops with potential benefits locally [1]. The BOLDER project will fund conservation and promotion for these crops. Workshop participants included representatives from civil society, private sector, government, and research institutions. The selected NUS were pearl millet, cowpea, pumpkin, jackfruit, and amaranth. This report provides a review of the five prioritized crops in the context of Uganda focusing on the following subtopics **for each crop**: (a) history of domestication, (b) crop's importance in terms of contribution to food security, social and cultural linkages, market potential and economic potential, (c) reasons for their neglect and underutilization including challenges related to agronomy, conservation, breeding and variety development, processing, value chains and marketing that make them less attractive to farmers, processors or the private sector.

2. JACKFRUIT

2.1. History of Domestication

Jackfruit (*Artocarpus heterophyllus)*, known as *Ffenensi* or *Ffene* in Uganda is believed to be native to western India [2–4]. It was likely introduced to Uganda in the 1890s by Asian settlers who came to build the Uganda railway [5]. While jackfruit is not widely cultivated commercially in Uganda, it is prevalent across all regions, with the Central region regarded as the center of jackfruit diversity [6]. Historically, the Buganda Kingdom in central Uganda and home to Uganda's largest ethnic group, has promoted the planting of jackfruit trees as a dependable food source for its people [7]. [8] notes that deliberate efforts have been made to enhance jackfruit production through orchards by transplanting already germinated seed. However there is no data on how widespread this practice is – in their study [9] did not find any farmers with an orchard. Jackfruit is mainly grown in Uganda's eastern, central, and western regions. Annually, approximately 0.3 million metric tons of fruit are produced per district in some of the regions with high production in Uganda specifically in the districts of Mityana, Kayunga, Kamuli, Luuka and Jinja [9]. Jackfruit production may be lower in the western region compared to other areas due to historical neglect of the crop, driven iStock/earleliason by myths that jackfruit can kill livestock - this concern is iStock particularly relevant in these cattle-keeping communities [10] but adoption has increased and recent research indicates that the west has high jackfruit diversity [5].

2.2. Taxonomy and Biology

The jackfruit tree belongs to the kingdom plantae, division Pteridobiotina, class Equisetopsida, order Rosales, family Moraceae, genus *Artocarpus* and species *Artocarpus Heterophyllus* [11]. It is an evergreen tree typically grown in tropical regions. The tree is medium-sized, averaging between 8 and 25 m in height [10]. It is a monoecious tree and both male and female flowers grow on the same tree [12]. It produces the largest tree-born fruit, that can weigh up to 50kg [13]. Jackfruit ripens throughout the year, with peak seasons in December and January [10].The fruit pulp can be white, orange or yellow [9]. While jackfruit can grow in sandy soil, it thrives in well-drained, nutrient-rich soil [14] with a pH 5-7.5 [15].

2.3. Importance, Sociocultural Aspects and Potential

Jackfruit is recognized as the largest fruit in the world [12] and is also labeled a "superfood" [16,17]. It plays a significant role in food and nutrition security in Uganda and is valued for its ability to feed many people due to its big size [5]. Farm households have at least two to seven jackfruit trees [9]. The fruit is rich in carbohydrates, vitamins, and macronutrients, especially magnesium and calcium, making it a valuable dietary component [18]. Research shows that jackfruit has anticancer, anti-HIV, anti-inflammatory, antimicrobial, antifungal properties and effective for treating anemia, asthma, ulcers, indigestion, dermatitis, diarrhea, cough and high blood pressure among others [12,16,19].

The fruit is commonly enjoyed as fresh fruit, while seeds are eaten boiled or roasted. Long-term preservation products include ripe bulbs in sugar syrup, sweetened pulp, solar-dried ripe bulbs, and blanched and dehydrated unripe mature bulbs [20]. It is also used as an animal feed, processed to wine or as timber [9,21]. In some areas, people believe jackfruit should not be sold, as this can bring bad luck since it is often a reliable source of food and one should always have enough to offer neighbors [7,22].

There is limited utilization and value addition of jackfruit in Uganda and value chains for several potential products are not fully developed. Hence the need to explore these aspects, especially jackfruit-based products with nutritional value and other applications e.g. waste valorization – [see 3 for examples and more information]. The rising demand for plant-based products particularly in international export markets makes jackfruit a viable meat alternative [23] due to its due to its meat-like texture and ability to absorb flavors[3]. Thus, the economic impact and potential of jackfruit in Uganda extends beyond smallholder agriculture, driving growth in other industries including processing, packaging, and export [24].

2.4. Neglect, Underutilization, Challenges

[18] notes that jackfruit is underutilized in Uganda, with gaps in production and marketing for income and nutrition likely due to a lack of awareness of its nutritional value as well as differences within the species that may hinder access to suitable varieties. Jackfruit trees take a long time to start producing fruit which might be a disincentive for production. However, innovative grafting techniques can reduce the fruiting period [25]. Cultural beliefs about jackfruit in Buyende district suggest that eating it during pregnancy can lead to a big head size for the baby or complicate childbirth by making the baby fat, and may also result in excessive drooling after birth [26].

2.4.1. Conservation and Breeding: Limited research and lack of investment in jackfruit breeding programs hinder the development of improved varieties. While a few recent studies have characterized jackfruit varieties in different regions of Uganda [5,6,10,19,27,28], more research in that area is needed. Challenges with jackfruit breeding include long juvenility which delays fruit production, high genetic variation among clones and recalcitrant seeds that do not store well [29]. Jackfruit germplasm collections can be found at NaFORRI which has 217 landraces. CIFOR-ICRAF Uganda does not work on jackfruit (pers. comm, CIFOR-ICRAF Uganda, 9/12/2024). Farmers maintain diverse jackfruit landraces in their fields thus preserving genetic diversity, but deforestation and replacement of jackfruit trees with other crops threaten this in situ conservation [5]. Evidence indicates farmers have been selecting against jackfruit varieties with less desirable traits by cutting them for timber and fuel, which could lead to genetic loss [5,6]. This underscores the need to conserve these varieties in in-vitro or field genebanks.

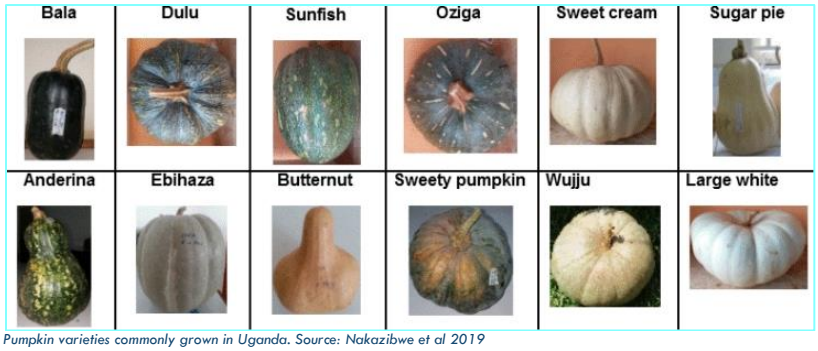
2.4.2. Processing and Value Chains: The underdeveloped processing infrastructure for jackfruit limits marketability. As a result, farmers often lack access to value chains that would allow them to capitalize on their efforts. Jackfruit is normally produced as a subsistence crop with a small proportion processed - a study in Mityana, Kayunga, Kamuli, Luuka and Jinja found that only a small portion of harvested jackfruits is processed (1%), while the majority is consumed (80%) or used as animal feed (6%) [9].

2.4.3. Market Access: Current production is not enough to meet the increasing market demand for domestic consumption as well as for export and industry [9]. Fragmented supply chains and lack of organization make it difficult for farmers to sell their produce profitably [9]. There are some isolated efforts to change this such as the work of Zahra Food Industries Ltd[1] [see 7].

2.5. Conclusion

Jackfruit holds significant potential for enhancing food and nutrition security and contributing to the economy in Uganda, but faces challenges that hinder its widespread utilization. Production is predominantly subsistence, with unorganized and small-scale practices limiting its potential [9]. Little is known about the genetic diversity of jackfruit in Uganda [5]. Farmers also lack information and access to elite germplasm [19]. To improve farmers' livelihoods and increase interest of current and potential stakeholders in the value chain, it is important to enhance production methods and quality through proper, organized agronomical management practices [9]. Further studies characterizing jackfruit varieties to establish their potential for industrial and commercial use are needed [10].

3. PUMPKIN



Pumpkin varieties commonly grown in Uganda. Source: Nakazibwe et al 2019

3.1. History of Domestication

Pumpkin (*Cucurbita spp*) is believed to be indigenous to the Americas [30] and has been cultivated in Uganda for centuries. Over time, it has become naturalized and is now categorized as an indigenous African vegetable that is fully integrated into local agriculture and cuisine. Cucurbita species grown in Uganda include C. *moschata*, C. *maxima and* C. *pepo* [30–33]. Pumpkins are grown throughout the country and are well adapted to the diverse climatic conditions. Production is largely small scale and mostly for home consumption [30,34]. Pumpkins are a reliable source of food due to their long shelf life [30].

3.2. Axonomy and Biology

Pumpkin, belongs to the kingdom Plantae, division Pteridobiotina, class Equisetopsida, order Cucurbitales, family Cucurbitaceae, genus *Cucurbita* which also includes squashes, zucchinis, and gourds [35,36]. All parts of the plant are edible, making it a versatile fruit-vegetable crop [30]. Pumpkin is an annual vine that consists of long, fast-growing stems growing over 10 metres long, with monoecious flowers and shortlived perennial roots [37]. It produces fleshy fruit that matures in about 3.5 months varying in shape, size, and colour[38]. Pumpkin fruits are large berries and can be globose, ovoid, obovoid, cushion-shaped, or cylindrical; smooth or sometimes deeply grooved, with small raised wart-like spots, and can weigh up to 50 kg when mature. [39]. The fruit can have varying skin colours but is usually white, cream or green, containing about 70% flesh and several large white seeds [40,41]. Flesh colour ranges from pale yellow to crimson [42]. Pumpkins grow well in loamy, well drained soils with a high humus percentage and an ideal pH range of 6.5-7.5 [43]. Pumpkins can grow in a range of soil types but must not be waterlogged to avoid rotting [44].

3.3. Importance, Sociocultural Aspects and Potential

[1] https://www.zahrafi.com/products/plant-based-meat-substitute

Pumpkin is vital for food and nutrition security, contributes to dietary diversity and income generation in Uganda [45]. Research indicates that Ugandan pumpkin varieties are rich in dietary fiber, protein, calcium, potassium, iron, and carotenoids with pro-vitamin A activity [46]. In Uganda, the crop is multipurpose, thus reducing food waste – leaves are eaten fresh or dried; pulp can be eaten fresh or dried; seeds can be processed into flour and the seeds and other parts have medicinal uses [33,45,46]; pumpkin pulp is locally used as a weaning/complementary baby food [33]. Other products made in Uganda include wine, butter, oil (see https://josmak.com/). Pumpkin seeds are also used as an aphrodisiac [47]. Locally acceptable home cooking methods of boiling and steaming used in Uganda have been shown to lead to higher retention of the micronutrients provitamin A carotenoids (PVACs) [32] as well as for nutrition rich complementary food for children [48]. Refer to [30] for a comprehensive list of pumpkin utilization methods and potential value addition opportunities. Women dominate pumpkin production in some areas [34] whereas men are the majority in others [49]. See footnote for other cultural beliefs[2].

Pumpkin has significant economic and market potential. However, the full economic potential remains untapped due to underdeveloped value chains [45]. A number of initiatives have been started to tap into this potential to increase utilization and show economic potential e.g. East –West seed established 520 demonstration plots and conducted trainings in various regions of Uganda [34]. [50] notes that that Uganda exports pumpkin to neighboring Kenya, hence there is potential in the regional export market.

3.4. Neglect, Underutilization, Challenges

Despite its nutritional, medicinal and other benefits, pumpkin is underutilized in Uganda [45,51]. It is important to understand these attitudes in order to find the best approaches to address the inherent cultural biases. Research on pumpkin is lagging behind with [49] noting lack of documentation on production constraints, management practices, inputs sources and farmer strategies.

3.4.1. Agronomic Issues: Although pumpkin is relatively easy to grow, a number of challenges may limit widespread cultivation. Pumpkin plants are often grown on a small scale and intercropped with other main crops OR close to the homestead kitchen gardens where they grow out of accidental seed drops on rubbish heaps [52]. Pumpkins therefore often receive less attention and fewer resources, such as fertilizers and pest control measures, compared to the main crops [34].

The majority of farmers use their own saved seeds or seeds from neighbors and friends as the source of planting materials and they recycle seasonally [49]. On the one hand, such seeds often contain impurities, which can lower germination rates and reduce plant vigor and production, while on the other hand seed sharing among farmers fosters gene flow, aiding species survival and genetic diversity [49]. Commercial seeds are available on the market: for example BRAC started commercial seed production for the 'Boromashi' variety around 2013/14 [53]. Other commercial seed providers available on the market include - Simlaw Seeds, East African Seed, Degro, East-West Seed, Top Harvest, Amazon Seeds, Africasia Seeds, Golden Bull (U) Ltd, Rock Seeds [34]. As highlighted earlier, existing studies indicate that most farmers rely on saved seeds, but there are no official statistics on the ratio of formal to informal seed systems. One study done 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 [49]. Other major constraints affecting production in Uganda include pests and diseases [30,34,49]; unpredictable weather patterns [30,49], price fluctuations [30] as well as lack of support [30] transportation challenges since the fruits are bulky [30] and high labor costs [49]. Technical knowledge gaps among agro-input dealers limits the effectiveness of their training services for farmers leading to misdiagnosis of diseases, misuse of agrochemicals, increased disease rates, pesticide resistance, and environmental pollution [34].

3.4.2. Conservation and Breeding: Pumpkin is not a priority crop for the National Agricultural Research Organization (NARO) in Uganda, resulting in inadequate efforts to conserve local pumpkin germplasm which poses a risk of genetic erosion [30]. There is no formal breeding program focusing on the crop. However, it is important to note that the Makerere University Regional Centre for Crop Improvement MaRCCI recently started a new initiative that will be targeting crop improvement for various orphan crops which include pumpkin[3]. MaRCCI has over 100 accessions that are landraces/farmer collections (pers. comm, MaRCCI, 27/11/24) [1] while the Uganda National Genebank has 27 accessions, all traditional cultivars/landraces[4]. WorldVeg Arusha has 4 pumpkin accessions which originated from Uganda (pers. comm, WorldVeg Arusha, 10/12/2024). A few studies characterize pumpkin varieties in Uganda – see [46,54,55]. However further research is needed to enhance understanding of the phenotypic and genetic diversity, physicochemical characteristics and the preferences of value chain actors.

3.4.3. Processing and Value Chains: The processing sector and value chain for pumpkins is underdeveloped particularly in some regions [45]. Uganda has a number of value added pumpkin infused products in local supermarkets which include porridges, flours, snacks such as fried or roasted pumpkin seeds and mixed with groundnuts or sesame etc. [30,33]. See [34,56] and https://josmak.com/ for examples of initiatives that specifically focus on pumpkin value addition and those targeting women's empowerment.

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[2] Farmers report several taboos and cultural beliefs regarding pumpkin cultivation: 1) liquid from the vine's nodes can treat red eyes; 2) women should avoid the garden during menstruation to prevent fruit rot; 3) pointing at or touching young fruits may cause them to rot; 4) adding grasshopper wings or throwing rat dung in the garden is thought to increase fruit production; 5) if someone is sick and has pumpkin flowers in the garden, they are believed to recover rather than die (Nakazibwe et al 2019).

[3] https://rcci.mak.ac.ug/unveiling-the-horticulture-and-orphan-crops-improvement-program/).

[4] Genesys Platform - https://www.genesys-pgr.org/a/overview/v2D76x1ykEa, accessed 24/10/24

3.4.4. Market Access: Limited pumpkin production volumes and inconsistent yield hinder sustainable pumpkin market development, as small volumes cannot attract big produce buyers [34]. The value chain is not well developed, making it vital to facilitate linkages between farmers and buyers as well as share market information for effective planning [34].

3.5. Conclusion

While pumpkin plays a significant role in enhancing food security and economic potential in Uganda, it faces numerous challenges that hinder its cultivation and commercialization. Addressing issues related to agronomy, breeding, processing, and market access is essential for maximizing the benefits of pumpkin and ensuring its sustainable integration. There is need to document indigenous knowledge, utilization and production of pumpkins in Uganda [45]. More research and efforts to commercialize the production of pumpkin seeds for oil production [55] are also needed.

4. AMARANTH

4.1. History of Domestication

Amaranthus spp, commonly known as *dodo* in Uganda, are herbaceous plants native to the Americas [57,58]. The common amaranthus varieties grown in Uganda include grain and vegetable types. Grain types include A. *hypochondriacus*, *A. caudatus* and *A. cruentus*, while vegetable varieties include *A. dubius*, *A. lividus*, *A. tricolor*, *A. viridis*, *A. cruentus* and *A. blitum* [59,60]. Grain, vegetable and ornamental types have different centers of domestication and origin [58,61]. In Uganda, the crop was introduced centuries ago and has successfully adapted to the local climate, due to its drought tolerance and ability to thrive in low-fertility soils [62]. The promotion of amaranth in Uganda has been driven by efforts from international organizations such as the McKnight Foundation, which supported its cultivation as part of food security projects [63] and the NGO Volunteer Efforts for Development Concerns (VEDCO), which introduced grain amaranth in Kamuli District in 2005 [64,65] among others.

Local research institutions, such as Makerere University, have contributed to understanding the agronomy of amaranth, exploring ways to improve its yield and nutritional content [65–67]. Research indicates that smallholder farmers can easily grow amaranth, which provides a reliable source of food e.g. during drought periods when other crops might fail [58]. Its versatility has led to its integration into both subsistence and commercial agriculture, with small-scale farmers benefiting from its dual-purpose as a leafy vegetable and a grain crop [68]. A study from 2010 noted that while vegetable amaranth is widely grown in Uganda, grain amaranth is still gaining popularity [69].

4.2. Taxonomy and Biology

Amaranth, belongs to the kingdom Plantae, division Pteridobiotina, class Equisetopsida, order Caryophyllales, family Amaranthaceae and genus *Amaranthus* [70]. There is no consensus on the taxonomy of amaranths and number of species [71]. According to [72], there are about 70 genera and more than 800 species. Amaranth is an annual herb [58,73] which is often referred to as a pseudo cereal. The plant grows vertically, reaching heights of up to 3m [74] with broad leaves, brightly coloured stems and flowers in shades of green, purple, orange, red, and gold [73,74]. Amaranth is often referred to as a pseudo-cereal because it is used similarly to traditional cereal grains but it is not part of the grass family [75]. Amaranths are warm-season annual plants that mainly self-pollinate [72]. They produce seed heads approximately 50cm long which vary from pendulous to spiked [76]. Each plant can produce up to 50,000 small seeds (0.9-1.7mm in diameter) which can be cream, golden, or pink in colour [73]. Most grain amaranth varieties mature in 4-5 months, though in monsoonal regions they mature more quickly, while in some highland areas, maturation can take up to 10 months [73]. Amaranth leaves can be harvested 20–45 days after sowing, depending on the variety and the planting season [77]. Amaranth can grow in a variety of soil conditions and performs best in soils rich in potash and nitrogen, with an optimal pH range of 5 to 8 [78].

4.3. Importance, Sociocultural Aspects and Potential

Amaranth is considered a "superfood" due to its nutrient profile and agronomic versality [79]. Over the years, it has gained significant economic and nutritional importance because of its rich nutrient content [61]. The highly nutritious leaves and seeds contain proteins, calcium, iron, and essential vitamins like A, C, and K [61,65]. Amaranth grain contains higher levels of protein, dietary fiber, calcium, iron, and magnesium compared to other grains [79]. Varieties grown in Uganda have been found to have protein content of 12-13%, which is higher than that of most cereal grains and other common staples [65]. Compared to other leafy vegetables, amaranth leaves have higher calcium, potassium, magnesium [80], and have a protein content that is 23-32% higher [81]. Studies on its powder from seeds/grains and extracts have revealed antidiabetic, antioxidant, antimalarial, anticancer, and anti-inflammatory properties [79,82]. This makes it a favorable crop for addressing malnutrition and micronutrient deficiencies in vulnerable populations such as children, the elderly, and pregnant women in both rural and urban areas in Uganda [65,68].

Amaranth holds cultural significance in certain communities, with traditional taboos and norms sometimes influencing how it is cultivated and consumed. For instance, traditionally, the cultivation and processing of leafy vegetables, including amaranth for household consumption is women's responsibility [62]. Thus, gender-focused programs should promote social inclusion by ensuring that women have equal access to resources and markets since they often do not own factors of production such as land [62,65,83]. In Uganda, amaranth

can be eaten in various forms which include soup, porridge, *posho* (stiff porridge), paste (usually mixed with groundnuts), pops, baked snacks including cookies, cakes, *baggia* (snack made by cold extrusion of dough then deep fried) and can be blended with other grains such as (maize, millet, rice, sesame), cassava, beans for flour etc., see [65,84] for a comprehensive list of products and recipes.

Studies have shown that amaranth can be a lucrative crop particularly for smallholder farmers owing to its short growth cycle and low input requirements [61]. Economic evaluation of grain amaranth production revealed that farmers can achieve significant profits, particularly when cultivating improved varieties that yield more per hectare [62,65]. Therefore, amaranth holds considerable economic potential in Uganda, especially when integrated with other agricultural activities. Additionally, amaranth has a broad range of market opportunities. Its seeds are gaining popularity in both domestic and international markets, driven by growing demand for gluten-free, high-protein grains [61]. Several byproducts derived from amaranth such as vegetables or flour can also contribute to its economic potential. The seeds can be processed into flour, which is used in baking, cereals, and snack products. These value-added products have higher market prices compared to raw seeds, providing farmers and processors with opportunities to increase their incomes. The commercial value chain for amaranth includes production, processing (into flour and oils), and distribution through both local markets and export channels [59]. Moreover, efforts to improve market integration have been supported by initiatives aimed at strengthening the linkages between producers, processors, and consumers [85]. There is also potential for employment creation especially in urban areas [59].

4.4. Neglect, Underutilization, Challenges

Amaranth is often categorized as a NUS in Uganda [62,65]. This may be attributed to the general perception that amaranth is not economically significant compared to other staple food crops like maize and beans [61]. This neglect is compounded by several challenges that make amaranth less attractive to various stakeholders. Amaranth is often seen as an inferior vegetable for the poor [86] and as a weed [59] resulting in it being uprooted from gardens [87]. These perceptions may contribute to its neglect and underutilization. Certain taboos and social practices influence amaranth use and consumption in various communities. In Karamojong-Matheniko, pregnant women typically avoid wild amaranth due to beliefs that it could lead to miscarriage if the baby is male [88]. In Buyende district, there are also concerns that consuming amaranth (*dodo*) might cause preterm labor [26]. *Emboga* (*Amaranthus spp.)* is associated with bad luck in some communities/ethnic groups, leading to its near-total replacement by *Emboge* (*Amaranthus graecizans),* a species that carries no such taboos [89]. When ground and mixed with water and sprinkled around the house, *Emboge* is said to ward off snakes [89]. These practices serve significant social functions, hence the need to be aware of and understand them.

4.4.1. Agronomic Issues: Farmers have limited access to quality seeds and lack technical knowledge which hampers optimal production [85]. In terms of seed systems, the development and availability of quality amaranth seeds remain inadequate, limiting farmers' ability to produce high-yields. Poor quality seed is mentioned as a constraint for both grain and grain amaranth [59,62]. Other challenges are pests and diseases, inconsistent yields due to adverse weather, high costs of inputs [59].

4.4.2. Conservation and Breeding: Seed development, market integration, and farmer training are essential for unlocking the full potential of amaranth as a sustainable crop that addresses food security, nutrition, and economic empowerment in Uganda. As such, seed conservation initiatives are critical to preserving local crops varieties such as amaranth varieties both in situ and ex situ [90]. The Uganda National Gene bank has 17 accessions which are all landraces[5]. WorldVeg Arusha holds 47 amaranth accessions which originated from Uganda (pers. comm, WorldVeg Arusha, 10/12/2024). The Makerere University Regional Centre for Crop Improvement (MaRCCI) recently started a new initiative that will be targeting crop improvement for various orphan crops which include grain amaranth[6]. The centre has over 30 amaranth germplasm accessions at their genebank sourced from the USA National Gene Bank through a collaboration with Iowa State University (pers comm, MaRRCI, 27/11/24). The breeding program aims to enhance yield and resistance to biotic and abiotic traits [1].

4.4.3. Processing and Value Chains: Processors often face difficulties in establishing reliable supply chains [85]. On the other end, consumers may be unaware of the nutritional benefits of amaranth, leading to low demand. Furthermore, traditional dietary habits often prioritize more familiar crops, making it hard for amaranth to gain popularity [68,83] and reach its full potential. Although amaranth vegetable is often available in the urban markets some studies indicate it is less preferred than other vegetables like *nakati* (*Solanum aethiopicum*) [60]. In Buganda tribe, *nakati* is appreciated for its bitter flavor, commonly used in sauce for a staple cuisine *matooke* (steamed and mashed cooking bananas), and it also holds cultural significance in marriage ceremonies [91]. More efforts are needed to increase use, access and utilization of vegetable amaranth as well as processed and value added grain amaranth products such as blended porridges and flours, some of which are currently available on the market [65].

4.4.4. Market Access: Low market, low output price and price fluctuations are some of the major challenges [92]. Some studies found that negative perceptions of amaranth, which people view to be a weed, affect its marketability and discourage potential producers [59]. Short shelf life or perishability are also highlighted for vegetable amaranth, hence the need to assess preservation options [59].

4.5. Conclusion

Maintaining genetic diversity is essential for ensuring resilience against environmental stresses and safeguarding the future of amaranth. Conservation initiatives not only contribute to sustainable agriculture but also enhance the economic viability of amaranth, offering income

[5] Genesys Platform - https://www.genesys-pgr.org/a/overview/v2D76x1ykEa, accessed 24/10/2024
[6] https://rcci.mak.ac.ug/unveiling-the-horticulture-and-orphan-crops-improvement-program/

diversification opportunities for smallholder farmers [65]. Participatory development and dissemination of recipes containing the nutrient rich grain amaranth further promote its consumption contributing to food and nutrition security [93].

5. PEARL MILLET

Diversity in pearl millet germplasm collection at ICRISAT genebank

5.1. History of Domestication

Pearl millet (*Cenchrus americanus*) ranks as the sixth most important cereal globally, following wheat, rice, maize, barley, and sorghum [94]. It was likely introduced to Uganda from Sudan around 3000 BC and initially cultivated by pastoral communities in the northern region of Uganda [95]. Currently, pearl millet is predominantly grown in Uganda's arid and semi-arid areas, including the north, northeast, and eastern regions [96]. The crop is highly resilient, thriving in extreme conditions characterized by high temperatures and low rainfall—factors that typically lead to poor crop yields and severe food insecurity [95–98]. Pearl millet research in Uganda began in the 1950s however it stalled in the last 50years due to limited funding, insurgencies and insufficient human and infrastructural capacity which has led to loses in genetic diversity [95]. Despite the development of technologies by international research institutes aimed at increasing its productivity in these challenging environments, the full potential of pearl millet in Uganda remains underexplored due to insufficient research and investment [96,99]. Consequently, its capacity to mitigate food insecurity in these vulnerable regions remains largely unrealized.

5.2. Taxonomy and Biology

Pearl millet belongs to the kingdom Plantae, division Pteridobiotina, class Equisetopsida, Order Poales, family Poaceae, genus *Cenchrus* and species *Cenchrus Americanus* [100]. It is an annual grass [95] with plants reaching heights of up to 4 meters [101]. It thrives in warm conditions and is a short-day plant, requiring long nights to begin flowering [102]. Although pearl millet has self-pollinating spikelets, its protogynous nature results in cross-pollination as the main method of reproduction [99]. The grains are small, oval-shaped and come in different colors, including white, pale yellow, brown, grey, slate blue, or purple measuring about 3 to 4 mm long [101]. On average, 1,000 seeds weigh around 8 grams [101]. It can grow well in various soils, including sandy, acidic, and less fertile soils [102]. The optimum soil pH is 6–7, but it may grow in soil pH as high as 8 [103].

5.3. Importance, Sociocultural Aspects and Potential

Pearl millet is an important crop which contributes to both household dietary and income needs due to its ability to withstand severe weather and soil conditions. It is a good source of proteins and minerals such as iron and zinc (Satyavathi et al., 2021). In Uganda it is consumed in various forms: ground flour is used to make thin porridge known as *ugi* in Teso region or thicker porridge known as *atapa* or *kwon* in eastern and northern areas respectively [104]. It is also used to make food (*kalo*), eaten as boiled grains and used as yeast for brewing alcohol [95,105]. In the east, flour from pounded whole grains is mixed with tamarind and cassava flour to improve taste [99]. Traditionally, the crop is mostly managed by the women who provide a larger share of the labor and is considered a woman's crop [96]. Men are mainly responsible for land preparation and planting, women do the weeding, harvesting, and threshing, while children help by scaring off birds [106]. Despite its potential as a food security crop, farmers are still using traditional methods to grow it, including late planting in the second rainy season (September – January), and use low yielding local varieties thereby limiting its production and productivity [95,96,98]. Although new varieties have been introduced, farmers indicate they grow local varieties due to lack of quality seeds of improved varieties, lack of alternative options and the desirable attributes offered by local varieties such as high tillering ability, early maturity, drought tolerance and having spikes that scare birds.

Studies show that using pearl millet in crop rotations may alleviate nematode problems in wheat and soybean [107], thus promoting eco-friendly pest management. In another study done in Uganda, farmers in Kumi district (Eastern region) indicated that they strategically grew pearl millet to control striga and to increase honey production [99]. Pearl millet is highly resilient, tolerant to heat, drought, and soil salinity and has fewer disease and insect pest challenges compared to other cereals. In terms of economic and market potential, there are promising opportunities for pearl millet flour and its derivatives. According to [108], a key strategy for successful commercialization of pearl millet is to target premium or niche markets that highlight the unique benefits of these grains, such as producing malt for beverages, weaning foods, or glucose production. Additionally, pearl millet stover shows promise in the fodder industry, building materials and fuel [109,110].

5.4. Neglect, Underutilization, Challenges

Pearl millet remains unpopular among various stakeholders in Uganda for several reasons. For instance, there is limited investment in research, development, and promotion [97,105], hence it is mostly cultivated at the subsistence level, with only the surplus sold. Consumers are similarly uninformed about the crop's significant nutritional benefits, further reducing demand [95,96,98]. The limited financial investment is largely responsible for the low farm-level productivity, limiting its potential as a food security crop [95,96]. Thus, targeted funding in the research and development of pearl millet is important in promoting the crops' economic and nutritional benefits [96,111].

5.4.1. Agronomic Issues: Low productivity is an issue, as many farmers rely on indigenous varieties and have limited knowledge about improved, higher-yielding varieties. The pearl millet seed system is not well developed and farmers plant food grain as seed whilst others buy seed grain – a study by [96] found that 48.7% of interviewed farmers bought seed grain while 47.1% used their own saved

seed. Several factors hinder production, including the crop's labor-intensive cultivation process. For example, birds such as *Quelea quelea ethiopica* frequently target the grains in Uganda [96] and the processing of pearl millet can be cumbersome, particularly for women who are often responsible for preparing it at the household level [97].

5.4.2. Conservation and Breeding: The potential of pearl millet continues to be underfunded and untapped in Uganda despite its significant advantages as a drought-tolerant crop [95,105]. The Uganda National Genebank holds 219 pearl millet accessions (15 landraces, 177 breeding/research material and 27 wild cultivars)[7], the National Semi-Arid Resources Research Institute (NaSARRI) which holds around 450 accessions and at the ICRISAT GeneBank in India where several accessions from Uganda are also conserved [95]. Over the years, ICRISAT has partnered with NARO, Bioversity International (now Alliance of Bioversity and CIAT), Rockefeller Foundation and other institutions to collect germplasm from across Uganda [95]. However some of the diversity at the Uganda National Gene bank collected through such initiatives has been lost in the past due to poor maintenance hence the need for continued investments to ensure proper upkeep of current accessions [95]. These collections are maintained to address production challenges and specific needs of various growing regions such as drought tolerance [95]. There is a breeding program at NaSARRI but it requires additional resources [105]. Little research has been conducted on the crop in Uganda and there remains a gap in investment to support the breeding of improved varieties [95,96]. Previous breeding programs were halted in the past due to limited funding and war [105]. Two pearl millet varieties have been officially released in Uganda: ICMV 225 in 2012, and ICMV 221, which was introduced from ICRISAT India [112,113] most likely in the 2000s. Seed companies FICA and Grow More Seeds are licensed to sell ICMV 225 seed. [114]. As of September 2023, three pearl millet varieties were in the breeding pipeline at NaSARRI [115].
In the past, ICRISAT has partnered with NARO in conservation efforts whereby pearl millet varieties were collected from Uganda for preservation at the ICRISAT Gene Bank and Uganda National Gene Bank.

5.4.3. Processing and Value Chains: Pearl millet has **antinutrients** that reduce digestibility, palatability and bio-availability of other nutrients [97]. The most common anti-nutrients are tannins, phytic acid and polyphenols [108,116]. Processing methods such as decortication, milling, roasting, boiling, soaking, blanching, dry heating, germination, malting and fermentation have proven useful for reducing the antinutritional factors, increasing digestibility and shelf life of derived food products [97,116].

On a larger scale, pearl millet can be used to make confectionary products such as bread [94]. However, the crop's small grain makes it highly labor-intensive during post-harvest handling. [96] reports that harvesting and post-harvest processing are mostly done by women using traditional, labor-intensive methods. These include cutting panicles with a knife, drying them on mats or bare ground at home, threshing the dried panicles by striking and winnowing to remove the chaff. This often discourages participation from value chain actors, who prefer to focus on cereals with more established and profitable value chains like maize. Storage constraints affecting Uganda pearl millet farmers include rodents, rotting, molding as well as insects, weevils, moths and poultry [99]. This underscores the need to address post-harvest losses effectively. Hence, there is a need to assess and introduce labor-saving mechanized tools. [117] notes that harvesting and processing machinery for pearl millet is less advanced than for other crops, with research still in its early stages

5.4.4. Market access: The overall market is hindered by inconsistent supply and weak value chains, reducing incentives for further investment in the crop [95,105]. Other challenges faced by farmers include lack of markets, lack of government support, low prices for their produce, high market taxes, lack of transportation to markets, unscrupulous middlemen, high transport costs, long distances to markets and poor road conditions [96].

5.5 Conclusion

Pearl millet holds great potential for addressing food and nutrition security among marginalized populations in Uganda's arid and semi-arid regions. With adequate support in breeding improved varieties, raising awareness of its nutritional benefits, and promoting the crop to enhance its appeal to farmers, processors, and consumers, pearl millet could play a significant role in boosting food security and improving livelihoods across the country.

6. COWPEA

Diversity of cowpea seeds. Photo by IITA.

6.1. History of Domestication

Cowpea (*Vigna unguiculata*), is believed to be native to West Africa, specifically Nigeria, where it has been cultivated for thousands of years [118]. The crop was likely introduced to Uganda by traders and farmers in the late 19th century, where it became an essential component of local diets and farming systems [119]. Cowpea is widely grown across Uganda, particularly in the northern and eastern regions, which are considered the secondary center of its diversity [120]. Production is in transition where it was traditionally grown almost exclusively as a food crop for domestic consumption [121]. Following the decline of cotton as the primary cash crop in Northern Uganda and the rise of significant external markets, 50% of farmers in the region have shifted from growing cowpea mainly for domestic consumption to cultivating it as a cash crop [121] but this specific study does not specify if this applied to both seed and leaves. Other sources indicate that both grain and leaves are produced as cash crops in some areas [122,123].

[7] Genesys Platform - https://www.genesys-pgr.org/a/overview/v2D76x1ykEa, accessed 24/10/2024

As part of government input subsidy programs, the National Agricultural Advisory Services (NAADS) distributed a total of 30,845kg of cowpea seed in the Karamoja region in the FY 2022/23 [124]. In 2022, approximately 13,260t were produced in Uganda from 28,994ha with a grain yield of 457 kg/ha [125] which is much lower compared to the potential yield of up to 3000kg/ha [122].

6.2. Taxonomy and Biology

Cowpeas belong to the kingdom Plantae, division Pteridobiotina, class Equisetopsida, order Fabales, family Fabaceae, genus *Vigna* and species *Vigna unguiculata* [126]. They are annual herbaceous legumes characterized as a warm-season annual plant that exhibits significant morphological variability [127].The plants can either grow upright plant, reaching up to 2 meters in height, or as spreading climbers, extending up to 80 cm [128]. Their leaves have three oval-shaped leaflets, while the flowers, which grow in clusters, can be purple, pink, white, blue, or yellow. The seeds are typically globular to kidney-shaped, with smooth or wrinkled surfaces and range in size from 5 to 12 mm [129]. The seed color varies widely, including white, cream, yellow, red, brown, or black and some are speckled or blotched [129]. These seeds are contained in long, smooth, cylindrical pods, each containing 8 to 20 seeds [128,129]. Cowpeas can take anywhere from 60 to 240 days to mature, depending on the cultivar and climate [129]. Cowpea thrives in well-drained sandy loam to clay loam soils that support good rooting with a pH range of 6-7, preferring slightly acidic to slightly alkaline conditions [130].

6.3. Importance, Sociocultural Aspects, and Potential

Cowpea is a versatile crop with various uses including food, animal feed and soil improvement. It plays a significant role in food and nutrition security in Uganda, offering an alternative source of protein, vitamins, and essential minerals (such as calcium, iron and phosphorus), which is crucial for resource-poor rural households that predominantly rely on starchy foods such as millet, sorghum, maize and cassava [121,131]. Cowpea is a rich source of folic acid and vitamin B, two essential nutrients during pregnancy for preventing birth defects in the spine and brain. Past research in Kumi and Soroti districts indicates that the crop has important sociocultural significance and is served on important occasions such as funerals, child naming and to general visitors [132]. In Acholi region, some taboos and cultural beliefs encourage consumption of cowpeas during pregnancy as it is believed to result in a healthy baby. In the Thur/Labwor ethnic group in Karamoja, infants below six months are given *Ngor*, cowpea leaves during naming [88] whereas in Bukenye district eating the leaves is thought to cause death of the baby [26].

It can be eaten in different forms, including fresh leaves (which can be harvested in under a month), dried leaves, immature pods, mature seeds (which can be eaten fresh), dried seeds (which can be stored for future use), cooked whole or milled into flour and used in various recipes [133]. Tender vegetable leaves can be harvested regularly, starting at four weeks after planting and every two weeks thereafter until flowering[134]. Its quick growth helps families fill the gap between cereal harvests, with many smallholder farmers in eastern and northern Uganda cultivating it using basic traditional methods [121]. The leaves and stems also produce high quality hay for animal feed [133]. Furthermore, cowpea is a valuable crop for farmers, as it improves soil quality by fixing nitrogen, preventing erosion, and providing organic matter through its green manure [133].

In Uganda, cowpea is widely accepted, thus creating market and economic potential. It is an important food and potential cash crop for smallholder farmers, especially for export-demanded varieties, and presents significant economic potential as the government seeks to diversify exports and promote non-traditional cash crops [121]. Value-added products that have not entered or are not common on the Uganda market such as composite flours, canned or frozen seeds provide economic opportunities. A study revealed that consumers in Northern Uganda were willing to pay for iodine biofortified cowpea [135].

6.4. Neglect, Underutilization, Challenges

Cowpea is often neglected in terms of research and development, leading to its underutilization in Uganda, where average yields remain low at 200–400 kg/ha compared to potential yields of 3000 kg/ha [122]. Limited research on cowpea production methods, processing, and post-harvest handling in Uganda has led to its perception as a 'backyard' crop primarily cultivated by women [122].

6.4.1. Agronomic issues: Although on-station trials report yields of 1.5 to 3 MT/ha, farm-level yields of below 0.5 MT/ha are attributed to various constraints, including low-yielding local varieties, pests, poor agronomic practices, land shortages, seed scarcity, drought and poor soil [119,134]. There is a resurgence of cowpea scab disease in Uganda, with only one of the five improved cowpea cultivars released by NaSARRI being moderately resistant and not widely available to most farmers, see [136,137]. It is important to note that several studies have focused on cowpea diseases in Uganda [120,136–144], suggesting a growing research investment and interest in that particular topic or recognition that diseases pose significant challenges to production. However, research on other aspects remains underdeveloped e.g. comparatively fewer studies document preferences [132,145,146], marketing aspects [119,147] or the adoption rates of released varieties.

6.4.2. Conservation and Breeding: The Uganda National Genebank holds 34 cowpea accessions, all traditional cultivars/landraces.[8] NaSARRI has an established a breeding program to address existing constraints by collecting cowpea landraces from various regions of the country and acquiring additional lines from the International Institute for Tropical Agriculture (IITA) in Nigeria [133,148]. Limited investment in breeding programs and the lack of improved seed varieties contribute to the low productivity problem, with many farmers relying on traditional landraces that are susceptible to pests and diseases [137]. Additionally, there is a narrow genetic base, with insufficient collection and conservation of cowpea germplasm, hindering efforts to improve varieties suited to local conditions [137]. A total of 11 cowpea varieties developed by NaSARRI have been released: 5 in 2013 [133] and 6 in 2016 [149] (see Table 1); however no studies were found that assessed their adoption rates. MaRCCI seems to have had a breeding program in the past [150]. Five of the released varieties have been commercialized (SECOW 1WT, SECOW 2W, NAROCOW 3, NAROCOW 4 and NAROCOW 5), and the

[8] Genesys Platform - https://www.genesys-pgr.org/a/overview/v2D76x1ykEa, accessed 24/10/2024

seeds are marketed by 12 different seed companies namely FICA, Equator, Ayellape, Daylight, Pearl, Rhino Seeds Africa, Golden Bull (U) Ltd, Savanna Seeds, GrowMore Seeds, Masindi Seeds, Syova, and Century Seeds [114]. According to [151] 1,7MT of cowpea quality declared seed was produced in Uganda in 2019.

6.4.3. Processing and Value Chains: Value addition for cowpea is minimal, primarily involving sorting and grading, with most sold as whole grain or occasionally as split grain [121,152]. While trade has largely been limited to local markets, there is a growing regional market in South Sudan and Kenya [121]. Traditionally sun drying is used to preserve leaves but modern methods such as solar drying, freeze drying, convection oven drying and refractance window drying hold potential, especially for commercialization[9]. A main post-harvest constraint is pest infestation during storage [153].

6.4.4. Market Access: Challenges in cowpea marketing in Uganda include limited access to markets, insufficient market integration, lack of market information and price fluctuations [119]. Cowpea marketing is mainly limited to local markets and farm gates due to farmers' restricted access to urban markets caused by poor road infrastructure and transportation [121]. Consequently, substantial local trade exists, and inter-regional trade is also notable, with cowpeas being a profitable crop that often reaches Kenyan markets [121]. Cowpea programs in Uganda have primarily concentrated on enhancing productivity without clear documentation on the evaluation of markets for improved varieties [137]. Previous research in 2000 identified several marketing problems faced by cowpea traders include high transportation costs, poor storage conditions, seasonal fluctuations in demand, inefficient distribution, lack of financing, inadequate information services, and poor infrastructure [147]. These issues still seem to persist in recent years.

6.5. Conclusion

Cowpea holds significant potential for improving food and nutrition security and contributing to the economy in Uganda. However, numerous challenges hinder its widespread utilization, including low productivity, underdeveloped processing infrastructure, and limited market access. To enhance farmers' livelihoods, improvements in production methods, better agronomic practices, and further research into cowpea breeding and germplasm characterization are essential. Increasing awareness of cowpea's nutritional benefits and market potential could also encourage its adoption as a cash crop, contributing to both food security and economic growth in Uganda.

7. RECOMMENDATIONS ON HOW BOLDER PROJECT CAN ADDRESS RELEVANT ISSUES

The BOLDER project can focus on several key areas to enhance cultivation, utilization, economic and market potential for the NUS in Uganda. BOLDER should continue efforts to establish collaborative partnership with various stakeholders to leverage resources and expertise in researching and promoting NUS crops. The Uganda Bureau of Statistics (UBOS) publications on agriculture[10] provided no or limited data on the NUS crops, while FAOSTAT only included production statistics for cowpeas. Although millet data was available in both sources, it was aggregated and did not distinguish between pearl and finger millet. This highlights the lack of attention and resources allocated for researching and documenting these NUS. Furthermore, some existing studies are outdated, indicating the need for more recent research. Therefore, research and documentation of evidence should be a key focus of BOLDER. Additionally, there is need to implement a robust monitoring and evaluation framework to assess the impact of the project on crop production, farmer livelihoods, and market development. Utilization of digital platforms throughout the process is encouraged.

In terms of collaborative efforts and coordination, more research is required to document, assess and enhance the effectiveness of the connections. MaRCCI indicated that they have engaged in discussions with the Uganda National Gene bank to explore potential areas of collaboration in germplasm sharing and capacity building (pers comm, MaRCCI, 27/11/24).

Potential specific focus areas for BOLDER include:

1. Research and Development

- Socio Economic Studies and Policy Analyses: Research can focus on exploring the social, economic, and cultural dimensions of the selected NUS, examining their impact on livelihoods, food security, and local economies. Given the lack of production and consumption data, studies could also address this gap. Additionally, policy analyses can evaluate current policies influencing the cultivation and promotion of NUS and identify areas for advocacy and improvement to enhance their role in food and security nutrition, sustainable agriculture and resilience.
- Variety characterization, Conservation, Breeding: Further research is needed to map and define the roles of various organizations, their interconnections, and their relationship with the national gene bank in the management of NUS plant genetic resources. In addition a more comprehensive study on stakeholders involved in germplasm collection and type of varieties (e.g. if landraces, improved) within country and across the region could be beneficial. Additional areas could involve supporting breeding programs to develop improved varieties of the NUS. Key activities include assessing genetic diversity, conducting varietal characterization exercises, facilitating participatory selection of genotypes with desired traits to be integrated into breeding and understanding preferences of value chain actors.
- Agronomic Practices: Research on optimal cultivation techniques tailored to local conditions, including planting methods, soil management, and pest and disease control.
- Nutritional Studies and Food Product Development: Conduct comprehensive studies to assess the nutritional benefits of the NUS to promote their consumption. Additionally, collaborate with local communities to co-develop and promote recipes and food products that incorporate these crops, emphasizing their nutritional value through participatory development and dissemination methods.

[9] https://tinyurl.com/3ne4jbde
[10] https://www.ubos.org/?pagename=explore-publications&p_id=2

2. Market Development

- Value Chain Analysis: Assess the existing value chains for the NUS and identify opportunities for improvement in processing, marketing, and distribution.
- Market Access: Facilitate connections between farmers and markets, including local, regional, and export opportunities for products from the NUS.

3. Capacity Building

- Training Programs: Implement training for farmers on best practices for cultivating the crops, focusing on sustainable agriculture techniques.
- Awareness Campaigns: Conduct campaigns to raise awareness among consumers about the benefits of these crops and how to incorporate them into diets.

4. Policy Advocacy

- Supportive Policies: Support advocacy efforts for policies that promote the cultivation and utilization of the NUS, including access to funding and resources for farmers.
- Integration into Food Security Programs: Support incorporation of these NUS into national frameworks

Table 1: Summary table

Crop	Any research being/has been conducted	Any breeding program or breeding efforts for crop in the country (past and current)?	Have any varieties been released? How many (), When were they released? Who developed the released varieties?	Are there any conservation efforts (in situ, ex situ?); any collections at national gene banks	How can we characterize the current seed system for the crop (informal, formal, or intermediary)?	How developed is the seed value chain for the crop (None, minimal, well developed
Pearl millet	Yes	Yes[A]	Yes (2) ICMV 221 from ICRISAT India^ and ICMV 225 NaSARRI has 3 in pipeline as of 2023[B]	Yes, Plant Genetic Resources Centre (PGRC)[D] and NaSARRI	Mostly informal, formal also available	Somewhat developed
Cowpea	Yes	Yes (NaSARRI)	Yes (11) NaSARRI: (5) in 2003 - (SECOW 1T, SECOW 2W, SECOW 3B, SECOW 4W and SSECOW 5T) NaSARRI: (6) in 2017 - (NAROCOW PEA1, NAROCOW PEA2, NAROCOW PEA3, NAROCOW PEA4, NAROCOW PEA5, NAROCOW PEA6)[E]	Yes, accessions at PGRC[D]	Mostly informal; formal also available	Somewhat developed
Pumpkin	Yes	Yes (MarCCI)[C]	Yes (1) 'Boromashi' variety. Released by BRAC in 2013-14	Yes, accessions at PGRC[D]	Intermediary (farmers mostly use informal)	Somewhat developed
Jackfruit	Yes	No	No	Yes at NaFFORI and ICRAF - Uganda	Informal	None to minimal
Amaranth	Yes	Yes (MarCCI)[C]	No	Yes (MarCCI)	Informal, formal seed available	Somewhat developed

Notes: Please note the overview is not exhaustive and can be expanded with additional research and data

* https://naro.go.ug/wp-content/uploads/2023/11/NARO-Variety-Allocation-List.pdf

^ https://oar.icrisat.org/4600/1/Impacts_of_genetic_enhancement_in_pearl_millet.pdf (page 237)

[A] improved breeds were produced at the then East African Agriculture and Forestry Research Organization – EAAFRO before station closed in the 1970s and 80s due to lack of funding [96]

[B] https://www.newvision.co.ug/category/agriculture/new-seed-innovations-to-look-out-for-in-2023-NV_151137

[C] https://rcci.mak.ac.ug/unveiling-the-horticulture-and-orphan-crops-improvement-program/

[D] https://bold.croptrust.org/genebanks/uganda/ (as of Sept 2023)

[E] https://www.nasarri.go.ug/news%20letter/NaSARRI%20News%20Letter%20July-Aug%20217.pdf

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