Australian Journal of Crop Science

AJCS

AJCS 17(8):653-663 (2023) ISSN:1835-2707
doi: 10.21475/ajcs.23.17.08.p3921

Minor root and tuber crops in Africa: Cocoyams (*Colocasia esculenta* and *Xanthosoma sagittifolium*)

Jane Muthoni*[1,2] and Hussein Shimelis[2]

[1]Kenya Agricultural and Livestock Research Organization (KALRO), Kenya
[2]African Centre for Crop Improvement, University of KwaZulu-Natal, College of Agriculture, Engineering and Science, School of Agricultural, Earth and Environmental Sciences, Private Bag X01, Scottsxille 3209, Pietermaritzburg, South Africa

Abstract

Cocoyams [taro: *Colocasia esculentum* (L.) Schott and tannia: *Xanthosoma sagittifolium* (L.) Schott] are staple tuber crops in many countries in Africa, Asia and the Pacific. This review aims to present the value of cocoyam as a minor tuber crop and the extent and challenges of its production in Africa. Cocoyams are primarily grown for their edible corms or cormels, although other parts, such as stalks, leaves and inflorescence, are used for human consumption. Cocoyams are categorized as neglected food crops mainly grown for subsistence use. Taro is more widely grown than tannia globally. Taro is cultivated all over Africa, although West and Central Africa are the main producing regions. Tannia is mainly grown in West Africa where it is still less common than taro. Production of tannia is generally minimal and rarely appears in cocoyam output statistics for the continent. Africa is the main producer of cocoyam, accounting for over 70% of the global output; the bulk of production occurs in the West and Central African region. Despite the high production, food value and economic opportunities, African cocoyam is rarely sold in the international markets. The crop is cultivated to meet food security at small-scale and family farms. It is mostly consumed and marketed locally in fresh state. Cocoyams are commonly produced by resource-limited smallholder farmers who are mostly women. The crop is cultivated on marginal lands where primitive technologies with little inputs are employed. The crop receives little attention from mainstream research organizations in Africa. Other constraints limiting cocoyam production in Africa include a shortage of planting materials, lack of improved high-yielding cultivars, and paucity of information on the proper agronomic practices, and insect pests and diseases, among others. Industrial use and new product developments of cocoyam in Africa should be explored to enhance the crop's economic value, and by extension attract research attention.

Keywords: Africa; Cocoyam; *Colocasia esculenta; Tannia; Taro; Xanthosoma sagittifolium.*

Introduction

Cocoyam is an important tropical tuber crop grown purposely for its starchy corms (Si et al., 2018). It is widely cultivated in Oceania, Africa and Asia (Ramanatha et al., 2010). Cocoyam is categorised as a neglected food crop and is mainly grown for subsistence agriculture. It is regarded as one of the most important staple crops in the Pacific Islands and Asia (Onyeka, 2014). Cocoyams refer to taro (*Colocasia esculentum*) and tannia (*Xanthosoma sagittifolium*) (Owusu-Darko et al., 2014). Taro most likely originated in South East Asia and the Pacific islands. India and Indonesia are considered to be the primary centres of origin of some taro. It is considered to have originated in the Indo-Malaysian region, perhaps in eastern India and Bangladesh, from where it spread into the Pacific islands, the eastern Mediterranean and Africa (Wagner et al., 1999). In Africa, taro is reported to have spread through trade and migration (Mabhaudhi, 2012). Since the nineteenth century, taro has been cultivated in the Pacific islands and Asia (Owusu-Darko et al., 2014). Taro provides 15 to 53 % of food energy requirements in the Pacific region (FAOSTAT, 2016).

Tannia is believed to have originated in the tropical valleys of north-eastern South America; it was introduced to the Caribbean basin by migrating Indian tribes. Tannia was introduced from tropical America into West Africa from where it spread to other parts of the continent (Giacometti and Leon, 1994). Tannia is a valued food crop in the Caribbean islands, Florida (USA), western Africa, Egypt, India, and Oceania. In most regions, tannia is grown for local markets. Tannia has become the main edible aroid in many tropical areas (Quero et al., 2010). There are more than 200 varieties of cocoyams worldwide that were selected for their edible corms or cormels and ornamental purposes. Cocoyams fall into two main production groups: wetland and upland cocoyams. Wetland cocoyams grow in paddy fields where water is abundant, while the upland types are cultivated in places where water is supplied by rainfall or supplemental irrigation. Despite the high production, food value and economic opportunities of cocoyams, they are under-researched and utilized, often traded in local markets. Therefore, this review presents the value of cocoyam as a minor tuber crop and the extent and challenges of its production in Africa to guide future production and product development for the marketplace.

Description of cocoyams

Cocoyams are aroids, grown primarily for their edible corms. *Aroids* are members of the family Araceae. This family has 110 genera of which *Colocasia, Xanthosoma*, *Amorphallus*, *Alocasia* and *Cytosperma* are the important ones (Owusu-Darko et al., 2014). *Alocasia*, *Cyrtosperma* and *Amorphophallus* are also edible but of lesser economic importance. They are mainly cultivated in India, Southeast Asia, and the Pacific Islands for food (Rubatzky and Yamagushi, 1997; O'Hair, 1984).

The most widely cultivated aroids are *Colocasia esculenta* (taro) and *Xanthosoma sagittifolium* (tannia). Both species are commonly reffered to as "edible aroids" or "cocoyams". Taro is generally a small plant with large leaves. It is found in the tropics and is common in the Pacific regions. The crop is harvested after 8–10 months and yields 5–10 tons/ha; starch content in the corm is 12–20 %. Tannia is larger and is widely grown for its cormels, which are much bigger than those of taro. The corm yield in tannia is around 10–25 tons/ha and starch content is nearly 20 % (Moorthy, 2004). Some varieties of tannia have an aerial stem, which may reach 1 meter high in the adult plant. Taro never develops a main stem. Taro has received more research attention than tannia. Taro leaves are smaller, have a lighter green colour and are less shiny than those of tannia. In addition, the leaf blade is thinner, less stiff and more flexible than those of tannia. Taro leaf-stalk is thin, flexible, has no sheath and is attached near the center of the leaf blade (Mare, 2006; Owusu-Darko et al., 2014). In tannia, the leaf-stalk is long, stiff, thick, attached to the leaf edge, and continues to become the midrib (Owusu-Darko et al., 2014; Figure 1a, b, c). In tannia, secondary corms (cormels) are used for human consumption while the primary corms are used for vegetative propagation (Owusu-Darko et al., 2014). In taro, it is the bigger primary corm that is used for human consumption.

Cocoyams are a herbaceous monocotyledonous plant that can grow 0.5 - 2 meters tall. The plant consists of a central corm (below the soil surface) from which the leaves grow upwards, the roots downwards, while cormels (daughter corms) and runners (stolons) grow horizontally (Ubalua et al., 2016; Banjaw, 2017). The root system is fibrous and lies mainly in the top 1 meter of the soil (Joubert and Allemann, 1998). The main plants can produce side suckers that can grow to a height of 40-100 cm (Sibiya, 2015). In Pacific Island countries where cocoyams are widely cultivated, two botanical varieties of *Colocasia esculenta* are recognized. They are *C. esculenta var. esculenta*, commonly known as *dasheen*, and *C. esculenta var. antiquorum*, often referred to as *eddoe* (Onyeka, 2014; Lebot, 1999). *Dasheen* is the most important member of the aroids in terms of production and utilization; it is the most widely grown taro variety in the Asia/Pacific region (Onwueme, 1999). They have a larger central corm with very few smaller cormels and are usually diploids. The *eddoe* types have a relatively smaller central corm and a large number of well-developed cormels (Lebot, 1999) and they are triploids. The *eddoes* are better suited for upland production because of their high productivity with limited water (Oxfarm Oganic Ltd, 2022). Cocoyams require a warm, humid climate although taro requires more water for growth than tannia (Onyeka, 2014). Taro can grow in both wetland and upland conditions (Owusu-Darko et al., 2014). Tannia cannot withstand water-logging and is a partial shade-loving annual crop that prefers deep well drained soils (O'Hair, 1984).

Nutritional value of cocoyams

Cocoyam is rich in carbohydrates with nutritional value comparable to potato (Wang, 1983), and superior to both cassava and yams in terms of higher protein, mineral and vitamin contents as well as easily digestible starch (Parkinson, 1984; Splittstoesser et al., 1973). Cocoyam also contains higher amounts of essential minerals (Ca, Mg and P) than cassava and yam (Opara, 2003). Cocoyam tubers have low dry matter content ranging from 27 to 40 % (Lebot et al., 2004) with tannia having higher levels than taro (Owusu-Darko et al., 2014). The dry matter content varies according to the variety, growing conditions and harvest time. Nutritionally, cocoyam tubers contain more than twice as much carbohydrate as potatoes and gives 135 kcal per 100 g. The corms contain 85–87 % starch on a dry matter basis (about 25 % starch on wet weight basis) with A-type structures characterized by small granule size (<1.5 µm)(Ahmed et al., 2020; Bhagyashree and Hussein, 2015; Owusu-Darko et al., 2014) depending on the variety. According to some studies, starch granules appear larger in tannia (0.74 - 1.19 µm) than in taro (0.08 - 0.25 µm) based on scanning electron microscopy (SEM) data (Lawal, 2004; Sefa-Dede and Sackey, 2002). The small size of the starch granules helps to increase bioavailability of nutrients through increased digestion and absorption efficiency. Non-starch polysaccharides in cocoyams confer gummy properties to the starch. The small particle size and high mucilage or gum content, make cocoyam flour a possible replacement for corn or wheat starch in the industries. Cocoyam tubers also contain about 11 % protein on a dry weight basis, which is more than for yam, cassava or sweet potato (Otekunrin et al., 2021). Because most protein is concentrated near the surface, the tubers should be peeled very thinly to minimize its loss. The high levels of dietary fiber in cocoyam are also beneficial due to their active role in regulating intestinal metabolism, and the consistency of stool due to their ability to absorb water. Cocoyam's fat content is also very low and consists mainly of cell membrane lipids (Table 1). Cocoyam is one of the few sources of non-animal zinc (Reichstädter, 2020; Lebot and Legendre, 2015). It is also a very good source of minerals including potassium (2271–4276.06mg/100g), sodium (82-1521.34mg/100g), magnesium (118–415.07mg/100 g), calcium (31–132 mg/100g), phosphorus (72.21–340 mg/100g), iron (8.66–10.8 mg/100 g), zinc (2.63 mg/100g) and copper (1.04 mg/100g) (Otekunrin et al., 2021). The high ratio of potassium to sodium is good for people with high blood pressure (Muñoz-Cuervo et al., 2016). However, cocoyam tubers are low in iron and manganese. The distribution of various minerals in the cocoyam corms vary depending on the element. Mergedus et al. (2015) found that P, Mg, Zn, Fe, Mn, Cu and Cd are found mainly in the upper part of the tubers while K, P, Mg, Zn, Fe, Cu and Cd are concentrated in the central part; Ca is abundant in the lower and marginal parts. Consequently, the central part is the most important from a nutritional point of view. The youngest tissue is found mostly in the upper part of the tuber (near the shoot) and is of poor nutritional quality due to low dry matter content (Otekunrin et al., 2021).

The nutritional composition of cocoyam tubers can vary significantly depending on the genotype, growing conditions and interactions between the genotype and the environment (Lebot, 2009; Sharma et al., 2020). Because cocoyam tuber starch is highly digestible (98.8 % digestible)

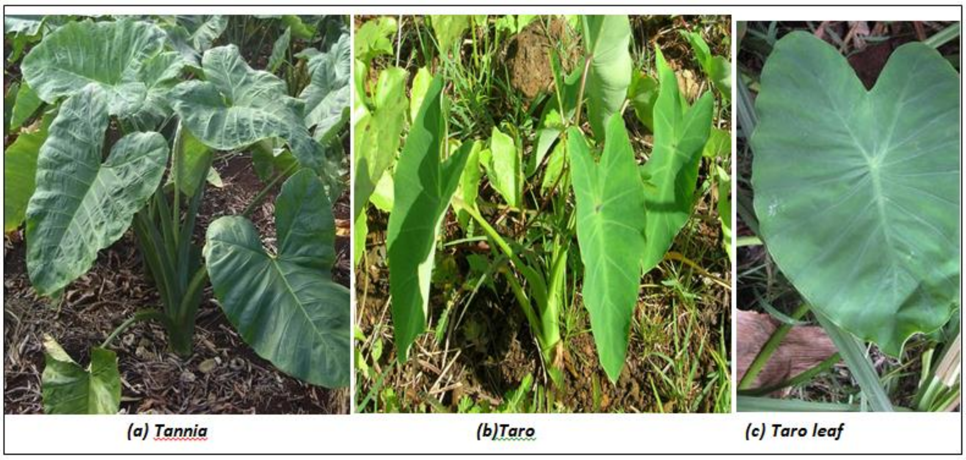

Figure 1. Cocoyam plants.

(Vinning, 2003), it is used in preparation of baby food and diets for gluten-allergic and lactose-sensitive people (Ahmed and Khan, 2013) in developed countries. The starch is gluten-free making it an ideal alternative to wheat for people who are allergic to gluten (Vinning, 2003). Consequently, cocoyam is highly recommended for diabetic patients, people with high blood pressure, the aged, nursing mothers, children with allergies and other persons with intestinal disorders (Plucknett, 1970; Okoye and Onyenweaku, 2007; Lebot et al., 2011). The high folate levels in cocoyam are good for pregnant or breastfeeding women (TOF, 2018).

Utilization of cocoyams

Cocoyams are mainly used as food although some plant parts are also used as fodder/feed and medicine (Nanbol and Namo, 2019). In addition to the tubers, cocoyam stalks, leaves and inflorescence are used for human consumption (Ekwe et al., 2009). The leaves are rich in minerals such as calcium, phosphorus, iron, and vitamins including C, thiamin, riboflavin, and niacin. In most African countries, the tubers are generally baked or boiled and eaten as a snack alongside beverages while the leaves are steamed as vegetables. In some parts of West Africa, tannia leaves are more often eaten as vegetable than taro (Bammite et al., 2018). Cocoyam tubers are also mashed with cassava to make 'fufu' in West and Central African region; this food is staple in Cameroon, Ghana, Guinea and Nigeria (Aniekwe, 2015). However, many people resort to cocoyam during critical periods for survival such as during food scarcity, social and natural disasters or when socio-economic status is low. In the eastern Democratic Republic of Congo for example, cocoyam has become a major food crop due to loss of banana to the devastating bacterial wilt disease (BXW), (Mwangi et al., 2007).

However, oxalic acid and oxalates are the major antinutrients limiting the food use of cocoyam (Ramanatha et al., 2010). Their presence gives a pungent taste or cause irritation to the lips, mouth, and throat when cocoyam is consumed raw or unprocessed (Adeyanju et al., 2019). The oxalates are also found in all the plant parts (cormels, petioles and leaves) (Ramanatha et al., 2010). Oxalates interfere with the bioavailability of other nutrients and may be detrimental to human health when consumed in excess (Doku, 1966). In high amounts, oxalic acid can interfere with the bioavailability of calcium in the food. This is because it binds to calcium to form calcium oxalate (Sefa-Dede and Sackey, 2002). Calcium oxalates content has been reported to decrease from outer to the inner of the corm (Sunell and Healy, 1979; Owusu-Darko et al. 2014) and are more abundant in distal than middle or apical sections (Sefa-Dede and Sackey, 2002). The levels of oxalate vary with different varieties (Ramanatha et al., 2010). Common processing techniques/treatments such as grating, soaking, steaming, and boiling have been demonstrated to be effective in reducing oxalate levels in cocoyam (Ramanatha et al., 2010); so do drying (oven, drum, sun, and solar) (Amandikwa, 2012) and fermentation (Adane et al., 2013).

In Africa, cocoyams are mostly consumed and marketed locally in fresh state with minimal storage and processing. The corms have high water content, and cannot be stored for more than a few days at ambient temperatures. Post-harvest losses are therefore heavy, and transportation costs high because the crop is bulky. Post-harvest losses can be higher due to mechanical damage of corms during harvest and microbial attacks on such damaged corms during storage (Owusu-Darko et al., 2014). Corms can start rotting as early as two weeks after harvesting, with tannia suffering less than taro (Owusu-Darko et al., 2014); possibly because tannia tubers contain less water than taro (Bradbury and Holloway, 1988). Mechanical damage to the corms during harvest is followed by the oxidation of polyphenols resulting in production of pigments that cause discolouration. Sprouting and chill injury at low storage temperature also reduce quality in stored corms (Opara, 2003).

Global cocoyam production

Global production of cocoyam has not changed much in recent times. Taro is more popular with tannia contributing a small proportion of the global production. Globally, taro ranks 5^{th} among root and tubers and 17^{th} among staple crops (FAOSTAT, 2022). Tannia accounted for less than 5 % of the global cocoyams output from 2011 to 2020 (Table 2). The area planted on tannia globally was less than 4 % of the total in the same period. These small proportions could be the reason production records for tannia are rarely considered in global statistics. Taro production in terms of total harvested area has substantially increased in the last decade; the case is opposite for tannia. Most of the global taro output comes from developing countries characterized by smallholder production systems relying on minimum resource input (Singh et al., 2012). Increased taro output in Africa recently has largely been due to an increase in production area despite declining yields (Onyeka, 2014). In 2020, more than 12.8 million tonnes of taro were produced globally from 1.8 million hectares with an average yield of 7 tons/ha. Nigeria was the largest producer with a global share

Table 1. Approximate composition of taro tubers in the fresh state.

Specification	Source: Hedges and Lister, 2006	Source: Onwueme, 1999	Source: Englberger et al., 2003
Dry matter	31.9	15–37	34.31
Carbohydrates	26.80	13–29	26.30
Proteins	0.34	1.43–3.3	1.1
Lipids	0.11	0.16–0.36	0.40
Crude fiber	2.50	0.6–1.18	2.10
Ash	1.91	0.6–1.31	2.11
Vitamin C (mg/100 g)	14.3	7.0–9.0	<1.0
Thiamine (mg/100 g)	0.028	0.18	0.11
Riboflavin (mg/100 g)	0.029	0.04	0.02
Niacin (mg/100 g)	0.78	0.92	1.32

Source: Otekunrin et al., 2021

Table 2. Global cocoyam production from 2011 to 2020.

Year	Total global cocoyam output (tonnes)	Percent contribution by tannia	Total area (ha) dedicated to cocoyam production globally	Percent area dedicated to tannia
2020	13236954	3.01	1841505	1.74
2019	12538561	3.22	1844709	1.80
2018	12648760	3.68	1836867	2.05
2017	12551170	3.68	1826988	2.00
2016	12096681	4.06	1884085	2.07
2015	12064069	4.27	1821127	2.30
2014	12276659	4.45	1613814	2.70
2013	11340760	4.24	1510334	3.14
2012	11200013	4.00	1511669	3.16
2011	10829795	3.64	1331269	3.28
Average	12078342.2	3.83	1702236.7	2.42

Source: FAOSTAT, 2022.

Table 3. Production of root and tuber crops in Kenya.

	Area (Ha)			**Production (Tons)**		
Year	**2012**	**2013**	**2014**	**2012**	**2013**	**2014**
Irish potatoes	99,475	104,560	115,604	1,436718	1,667,690	1,626,027
Sweet Potato	66,971	58,509	61,067	859,549	729,645	763,643
Cassava	73,144	65,634	63,725	930,922	935,089	858,461
Cocoyams	2869	3654	2155	26,716	45,346	27,619
Yams	874	998	1210	10,143	13,569	20,028

Source: MALFI, 2019

of 25 %, followed by Ethiopia, China, Cameroon, Ghana, and Papua New Guinea (FAOSTAT, 2022). In the same year, about 398,290 tonnes of tannia were produced globally on 32020 hectares (FAOSTAT, 2022).

In the global market, China is the leading exporter of cocoyams followed by Mexico, USA and Canada. This is despite the fact that cocoyam production in these countries is not as high as that of the top African producers (Otekunrin et al., 2021). None of the major cocoyam producing countries from Africa appears among the top ten exporters despite the continent accounting for over 70 % of global output. There is very little information on exportation of cocoyams from Africa. It is difficult to find reliable data on cocoyam import and export for most African countries (Onyeka, 2014). This could be because cocoyam production in Africa is mainly aimed at meeting food security needs (Onyeka et al., 2014). On the imports side, the top five cocoyam importing countries are USA, Japan, UK, Netherlands and France (Otekunrin et al., 2021). In 2018, USA imported about 393.68 thousand tonnes of cocoyams valued at 768.68 million US dollars. Cocoyam is less important than other tropical root crops such as yam, cassava and sweet potato but it still forms an important subsistence and emergency crop in many countries. Cocoyam is a staple crop in parts of Ghana, Japan, Nigeria and Hawaii. In South Pacific Island countries, taro forms a huge proportion of the root crops while in the Caribbean and West Africa, tannia dominates (Owusu-Darko et al., 2014; Opara, 2003).

Cocoyam production in Africa

Africa is the major producer of cocoyams; the continent contributed over 70 % of global output consistently in the past two decades. However, cocoyam is still a minor tuber crop in the continent (Figure 2). Both tannia and taro are cultivated. Taro is cultivated all over the continent (Grimaldi and van Andel, 2018) although West and Central Africa are the main producing regions. Tannia is mainly grown in West Africa (Opara, 2003) where it is still less common than taro. In Africa, production of tannia is generally minimal and rarely appears in cocoyam output statistics for the continent (FAOSTAT, 2022). In West Africa, taro is a staple food for millions of people and can be found in virtually all countries in the region. Nigeria, Ethiopia, Ghana, and Cameroon, accounted for about 67 % of Africa's taro production in 2020 (FAOSTAT, 2022). Cocoyam is commonly produced by resource-limited smallholder farmers who are mostly women, and the crop is cultivated on marginal lands where primitive technologies with little inputs are employed (Acheampong et al., 2015; Onyeka, 2014; Singh et al., 2012). The crop is mostly referred to as "poor man's crop" because it is mainly consumed by the low income households in the society (Onyeka, 2014). Cocoyam is used as a cheaper substitute to yam especially during period of food scarcity (hunger season) among many households in SSA particularly in Ghana and Nigeria (Onyeka, 2014). West and Central Africa (notably Nigeria, Cameroon, Ghana and Ivory Coast) contribute the bulk of African production. Despite this importance, the crop receives little attention from agricultural researchers and government policymakers in Africa (Rashmi et al., 2018; Chukwu et al., 2017; Wada et al., 2017). This could be because cocoyam production systems are often regarded as informal activities. Consequently, cocoyam remains an under-exploited and poorly understood crop despite its nutritional value and its potential as a food and cash crop. Lack of research and policy interventions for increased production and marketing (international trade) of cocoyam in most African countries has rendered the crop unpopular and under-utilized compared with other root and tuber crops such as cassava, yam and potato. As a result, the average yield of cocoyam in Africa has consistently declined from 6.6 tons/ha in 2000 to 5.76 tons/ha in 2019 (FAOSTAT, 2022); Nigeria witnessed a similar trend with yields decreasing from 6.62 tons/ha in 2000 to 3.92 tons/ha in 2019 (FAOSTAT, 2021). In contrast, other regions witnessed an increase in cocoyam productivity over the same period of time. For example, in 2019, Asia recorded yields of 16.50 tons/ha, America 10.41 and Oceania 8.73 tons/ha (Otekunrin et al., 2021). The high cocoyam output in Africa is simply due to a large production area.

Cocoyam production in West and Central Africa

West and Central Africa is the largest cocoyam producing region on the continent. In the past two decades, the major cocoyam producers in Africa were found in this region led by Nigeria (Figure 3). In most West and Central African countries, cocoyam ranks third in terms of importance, total output and production area, after cassava and yam, among the root crops that are cultivated and consumed locally (Onyeka, 2014; Chukwu, 2015). Despite the importance of cocoyam in West and Central Africa, the average yields have remained relatively low, ranging between 5 and 7.5 tons/ha in Nigeria and Ghana, 4 and 8.5 tons/ha in Cameroon (Onyeka, 2014) and 1.2 tons/ha in Togo (Bammite et al., 2018). This is far below the obtainable yield of 17.5 to 19 tons/ha in China and 23.5 to 35 tons/ha in Egypt (Onyeka, 2014). The low yields could be attributed to the fact that cocoyam production in West and Central Africa is with minimal input and often on marginal soils. Cocoyam is often dismissed as a 'woman's crop', and the value chain is mainly dominated by women who depend on the crop to feed their families (CGIAR, 2020; Scott et al., 2000). However, it has been observed that in places where cocoyam has high commercial value, more men tend to go into its production (Bammite et al, 2018; Markwei et al., 2010; CGIAR, 2020). A similar trend was observed in Uganda (Tumuhimbise et al., 2016) and in the Lake Victoria regions of Kenya, Uganda and Tanzania (Talwana et al., 2009; Serem et al., 2008). In West Africa, cocoyam farmers remain the main custodians of germplasm and varietal information (Acheampong et al., 2015; Ramanatha et al., 2010); genetic diversity of the crop is generally low (Bammite et al., 2015; Traore et al., 2013; Richard et al., 2018). In Nigeria, cocoyam is a staple food mainly for resource-poor rural inhabitants (Amadi et al., 2015) and it is regularly consumed as a main component or as a soup thickener in the south-eastern parts of the country (Ubalua et al., 2016). In this country, taro is more popular than tannia (Ijioma et al., 2014). The bulk of cocoyam produced is consumed as food, either as a primary product (corm, cormel, leaves and inflorescence) or as a secondary product (flour, cake, crisp, and chip). The corms and cormels are eaten in various food forms while the leaves and flowers are commonly used as a spice to garnish and flavour food (Akoroda, 2012; Chukwu et al., 2012). In 2007, the National Root Crops Research Institute, Umudike, Nigeria, launched cocoyam re-birth initiative (CRI) to increase awareness on nutritional, health and economic importance of cocoyam. The CRI was a paradigm of strategies to reposition cocoyam as a major staple food and agro-industrial raw material in sub-Saharan Africa. This was meant to promote cocoyam research, production, marketing and consumption (Chukwu, 2015). However, the crop is still generally neglected and there is no germplasm repository in charge of preserving and disseminating taro germplasm; farmers have been the primary users and guardians of cocoyam genetic resources (Tilahun et al., 2021). The bulk of Nigerian cocoyam is produced in the humid forest and derived savannah agro-ecological zones. Here, cocoyam is an integral part of the farming system and occupies about 10-30% of the cropland. In Cameroon, cocoyam is widely grown in three agro-ecological zones; high plateau of the west, humid forest with monomodal rainfall, and the humid forest with bimodal rainfall. In these three zones annual precipitation ranges between 1600 and 3000 mm. Cocoyam can also be found growing in all the five agro-ecological zones of Cameroon (Onyeka, 2014). In Ghana, cocoyam is predominantly grown in the wetter forest zones. In this country, tannia is more popular (Acheampong et al., 2015). It is an important food security crop due to its better storability compared to other root and tuber crops. However, cocoyam production dropped by 19.3 % from 1.6 to 1.27 million tonnes between 1999 and 2012 (MoFA-SRID, 2013) while the area under the crop reduced by 21 % within the same period. In Togo, tannia is very common and is more often commercially traded than taro. It is mostly grown in areas with high rainfall in intercropping systems. Taro is known and grown as food crop by a small proportion of farmers (Bammite et al, 2018). Consequently, data on production and productivity of taro are not recorded in agricultural statistics for the country (Bammite et al, 2018). In the northern region of the country, farmers cultivate *eddoe* type of taro while in the south, *dasheen* is grown. The *dasheen* is often grown in home gardens, along the boundary of Togo with Ghana and is also found wild along the southern rivers (Bammite et al, 2018). In Benin, taro is one of the underutilised crop and has been neglected by research despite its socio-cultural and economic importance (Dansi et al., 2012).

Cocoyam production in East and Southern Africa

In East Africa, cocoyam cultivation is generally restricted to wetlands. There is widespread, small-scale cocoyam production within the wetlands of Lake Victoria basin in Kenya, Uganda and Tanzania (Serem et al., 2008). As with other parts of Africa, cocoyam receives minimum attention to address its research and development needs; its contribution to food security and the economy is underestimated. Consequently, there is little information on cocoyam production in East Africa (Talwana et al., 2009; Akwee et al., 2015). Cocoyam production and yields are low and the crop is generally underexploited. Its economic potential remains unknown due to limited utilization (Akwee et al., 2015). Production of cocoyams in Kenya is lower than in the neighbouring countries such as Uganda, Rwanda and Burundi (Akwee et al., 2015). Awareness on the nutritional benefits of cocoyams has been growing recently; this is elevating the commercial value of the crop (AFSA, 2019). This has seen cocoyams enter into lucrative markets resulting in better incomes for smallholder farmers in some countries. In Kenya, cocoyam is still a minor tuber crop and its production is generally low compared to others like irish potatoes, sweetpotatoes and cassava (Table 3). Cocoyam is one of the most productive and high-value crop that fetches good prices for farmers in Kenya. The demand for cocoyams is high in major towns such as Nairobi where one kilogram retails at Ksh. 100 (1 US dollar) in the open-air markets (TOF, 2018). However, this demand is skewed; cocoyam is mainly eaten for breakfast by the well-to-do city dwellers who can afford it. It is also eaten as snack during high profile meetings. In Kenya, both taro and tannia are grown; taro is the most common and is mainly cultivated in the wetlands in the Lake Victoria basin, Western, and Mt. Kenya regions of the country. Upland cocoyams are relatively new in Kenya; they mature faster (about six months) and use less water (Chege, 2020) compared to wetland types. They are tolerant to low moisture and their starch content is higher due to the low amount of water required for its growth. (TOF, 2018). Upland cocoyams are being promoted in the dry non-traditional areas of Central Kenya (Chege, 2020) mostly in kitchen gardens.

In Ethiopia, tannia is an important part of the agricultural and food systems among the communities in southern and southwestern regions of the country (Wada et al., 2017; Asfaw, 2001). It has spread into the lowlands (below 1000 m.a.s.l.), and has almost replaced taro in home gardens (Fujimoto, 2009). However, it is not as popular as other root and tuber crops such as irish potato, sweet potato, taro, and cassava (Wada et al., 2017). Taro is grown and used extensively as a food and cash crop in the South, West, and South Western parts of Ethiopia mostly by small-scale farmers. The crop was ranked third after potato and sweet potato in terms of area planted and second in terms of production and productivity after sweet potatoes among the root crops (CSA, 2018). As with other African countries, shortage of well-adapted improved taro cultivars is one of the production problems that contribute to low yields and small planted areas across Ethiopia (Legesse and Bekele, 2021). Three improved taro cultivars have been released by Jimma and Areka agricultural research centres in Ethiopia (MoANR, 2016). One of these cultivars (Boloso-1) produced an average fresh yield of almost 67 t/ha under experimental field conditions (Yared et al., 2014) which demonstrates that use of improved cultivars coupled with right agronomic practices can raise taro productivity.

Taro is widely grown in Uganda. However, there is limited information on its production and consumption (Tumuhimbise et al., 2009). The crop has received inadequate research attention by agricultural research organizations; it is marginalized, neglected and under-exploited despite its high economic potential (Tumuhimbise et al., 2016). The average taro yields in Uganda remain very low (<1 ton/ha) for the majority of smallholder producers (Talwana et al., 2009). Taro is predominantly grown in small plots of 0.5 acre, mainly by men. It is largely grown in a monoculture system in the wetlands (Tumuhimbise et al., 2016).

In Malawi, cocoyams and other minor root and tuber crops are getting lost due to lack of knowledge on their importance, and lack of research and appropriate conservation measures. These crops are grown and conserved by the older generations for subsistence use (Malawi Government Report, 1996). Although there are several local genotypes of cocoyam in Malawi, little work has been undertaken to study them (Sandifolo, 2007).

In South Africa, cocoyam has been cultivated in the Eastern Cape and KwaZulu-Natal provinces for so long that it is erroneously regarded as an indigenous food crop. Cocoyam is an important staple crop in the Eastern Cape and the rest of coastal KwaZulu-Natal province (Mabhaudhi, 2012) where it is cultivated mainly for subsistence (Lewu et al., 2010). The crop is also cultivated, to a lesser extent, in Mpumalanga and Limpopo provinces (Modi and Mabhaudhi, 2016; Shange, 2004). The crop remains generally unpopular and is not well known outside these areas. As with the rest of Africa, minimal agronomic, nutritional and economic research has been conducted on cocoyam in South Africa despite the crop's contribution to food security (Mare, 2009; Mabhaudhi et al., 2014; Chivenge et al., 2015). Furthermore, cocoyam production is regarded as an informal activity, managed outside conventional economic systems.

Constraints to cocoyam production in Africa

Cocoyam production in Africa has been facing many constraints, such as diseases and insect pests, low and irregular rainfall, low soil fertility, shortage of good quality planting materials, lack of high-yielding improved cultivars, high post-harvest losses and lack of extension services among others (Quaye et al., 2010; Amusa et al., 2011; Tumuhimbise et al., 2016; AFSA, 2019; Akwee et al., 2015; Tilahun et al., 2021).

The two main diseases that affect cocoyam production in Africa are cocoyam root rot disease (CRRD), a fungal disease caused by *Pythium myriotylum* and taro leaf blight (TLB) caused by *Phytophthora colocasiae* Raciborski. Taro leaf blight is the most destructive disease of *C. esculenta* globally. The disease has had considerable impact in the Pacific region where taro is grown extensively and has now spread all over the tropics (Mbong et al., 2015). The disease is believed to have spread to Africa in the last few years (Onyeka, 2014; Sarkar et al., 2017); it was not known in West Africa before 2009, when simultaneous outbreaks occurred in Nigeria, Cameroon, Ghana, and other neighbouring countries. The impact of these diseases is exacerbated by the fact that cocoyam's vegetative mode of propagation transmits diseases from one generation to the next. The recycling of infected planting materials from farmers' fields

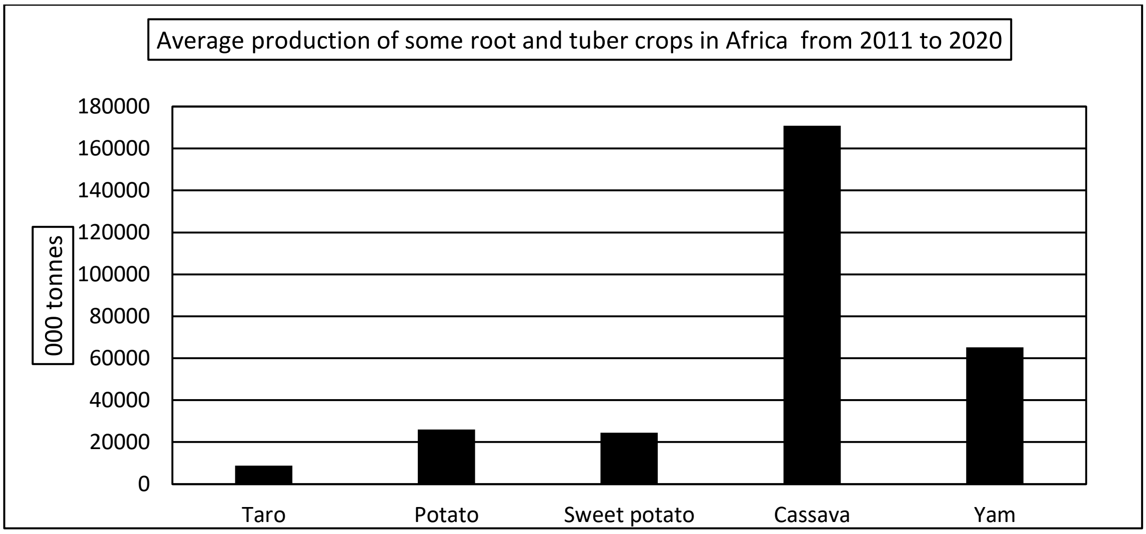

Figure 2. Average production of some root and tuber crops in Africa from 2011 to 2020. (FAOSTAT, 2022).

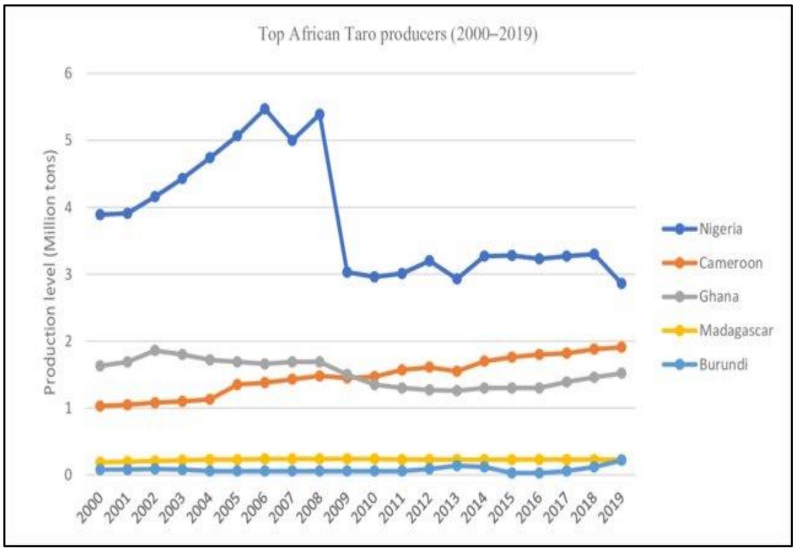

Figure 3. Top 5 African Taro producers (2000-2019). Source: Otekunrin et al. (2021).

leads to build-up of diseases particularly for CRRD. The disease often results in total crop failure in tannia. For a long time, the most important disease of cocoyam in Africa was CRRD mostly affecting tannia. The outbreak of TLB later, especially in West and Central Africa, worsened the situation and drastically reduced the productivity of taro in this region. Taro leaf blight can reduce tuber and leaf yields by 50 and 95 %, respectively (Scot et al., 2011). Some farmers in Nigeria were abandoning TLB infected fields due to the misconception that the disease could be transferred to humans (Onyeka, 2014).

Low and irregular rainfall is another major constraint limiting cocoyam production especially in the drier parts of Africa; the situation has been worsened by the adverse effects of climate change. The high post-harvest losses can be attributed to minimal processing, poor storage techniques and the high perishability of the cocoyam tuber. Lack of information on post-harvest handling explains why most cocoyams are eaten fresh after harvesting or sold locally to minimize post-harvest losses. Lack of extension services could be linked to the fact that the crop is not recognized by the government policymakers. There is also minimal research on cocoyams by local national agricultural research systems (NARS) in many African countries. The situation is worsened by the fact that cocoyam was removed from the focus crops of the CGIAR centers some decades ago (Onyeka, 2014; Obidiegwu, 2015). The crop is largely maintained by smallholder farmers, and the genetic resources have remained with the local farming communities (Ramanatha et al., 2010).

Shortage of planting materials is a major problem in cocoyam production particularly in places with occasional drought. This is because in most cases, the planting materials are conserved as living plants growing in the fields (Talwana et al., 2009; Serem et al., 2008). Around Lake Victoria basin in Kenya, Uganda and Tanzania, farmers use different materials for cocoyam propagation. These are: side suckers produced as a result of lateral proliferation of the main plant in the previous crop, small corms (unmarketable) from the previous crop, pieces of the apical corm with the bases of the petioles attached from harvested plants, and large corms that are cut into smaller pieces (Talwana et al., 2009). Pieces of the apical corm and suckers are preferred because the growing period from planting to harvest is shorter than that of cormels, corms, or corm pieces (setts) (Onwueme, 1999). In Burundi, the Good Seed Initiative was started to enhance farmers' access to quality planting materials in the cocoyam growing north eastern parts of the country. The Initiative aimed at increasing production, productivity and farm incomes, and impacting positively on food security and economic development of the local farming communities. It targeted both seed and ware cocoyam growers and linked them to markets. Farmers were trained on seed production after which they registered with the National Office of Inspection and Certification of Seeds (NOICS). They produced planting materials under the Quality Declared Seed (QDS) system, and sold them within their communities or to agro-dealers. As a result, production and use of good quality cocoyam planting materials increased. The cultivation of both seed and ware cocoyams increased farmers' incomes, and improved food and nutritional security for their families (AFSA, 2019).

Conclusion

Cocoyam (taro: *Colocasia esculentum* and tannia: *Xanthosoma sagittifolium*) is a staple tuber crop in many developing countries in Africa, Asia and the Pacific. Cocoyams are mostly grown for their edible corms or cormels, although other parts such as leaves and flowers are useful. Cocoyam is categorised as a neglected food crop and is mainly grown for subsistence agriculture. In Africa, both tannia and taro are grown. Taro is cultivated all over the continent although West and Central Africa are the main producing regions. Tannia is mainly grown in West Africa where it is still less popular than taro. Africa is the major cocoyam producer accounting for over 70 % of the global output; within the continent, the bulk of production occurs in the West and Central African region. Despite the high production, African cocoyam is rare sold in the international markets; the crop is grown for subsistence use at the family level. It is commonly produced by smallholder, resource-limited farmers who are mostly women, and the crop is cultivated on marginal lands where primitive technologies with little inputs are employed. The crop receives little attention from the mainstream research organizations in Africa. Other constraints to cocoyam production in Africa include shortage of planting materials, lack of improved high yielding cultivars, paucity of information on the right agronomic practices, pests and diseases, among others.

References

Acheampong P, Osei-adu J, Amengo E, Sagoe R (2015) Cocoyam value chain and benchmark study in Ghana. Report to the West Africa Agricultural Productivity Programme. Doi: 10.13140/RG.2.1.4295.6326

Adane T, Shimelis A, Negussie R, Tilahun B, Haki GD (2013) Effect of processing method on the proximate composition, mineral content, and anti-nutritional factors of taro (*Colocosia esculenta* L.) grown in Ethiopia. Afr J Food Agric Nutr Dev. 13: 7383–7398.

Adeyanju JA, Babarinde GO, Abioye AO, Olajire AS, Bolarinwa ID (2019) Cocoyam processing: Food uses and industrial benefits. Inter J Sci Engi Res. 10 (9):1658-1663.

AFSA (2019) The Good Cocoyam Seed Initiative. Alliance for food sovereignty in Africa. Available at: https://afsafrica.org/wp-content/uploads/2019/11/burundi-english.pdf

Ahmed A, Khan F (2013) Extraction of starch from taro (*Colocasia esculenta*) and evaluating it and further using taro starch as disintegrating agent in tablet formulation with over all evaluation. Inventi Rapid: Novel Excip. 2: 1–5.

Ahmed I, Lockhart PJ, Agoo EM, Naing KW, Nguyen DV, Medhi DK, Matthews PJ (2020) Evolutionary origin of taro (*Colocasia esculenta*) in Southeast Asia. Ecol Evol. 10: 1–14.

Akoroda M (2012) Better co-ordinated root crop systems for food and cash in Nigeria. p. 3 – 32. In: Amadi, C.O. Ekwe, K.C, Chukwu, G.O, Olojede, A.O and Egesi, C.N. (eds) Root and tuber crops research for food security and empowerment. *NRCRI, Umudike*, Nigeria.

Akwee PE, Netondo G, Kataka JA, Palapala VA (2015) A critical review of the role of taro *Colocasia esculenta* L. (Schott) to food security: A comparative analysis of Kenya and Pacific Island taro germplasm. Scientia Agric. 9 (2): 101-08.

Amadi CO, Onyeka J, Chukwu GO, Okoye BC (2015) Hybridization and seed germination of taro (*Colocasia esculenta*) in Nigeria. J Crop Improv. 29 (1):106-116.

Amandikwa C (2012) Proximate and functional properties of open air, solar and oven dried cocoyam flour. Inter J Agric Rural Dev. 15: 988–994

Amusa T, Enete A, Okon U (2011) Socioeconomic determinants of cocoyam production among small holder farmers in Ekiti state Nigeria. Inter J Agric Econ Rural Dev. 4:97–109.

Aniekwe L (2015) Improving food security with cocoyam production by the smallholder female farmers in Ebonyi State, Southeastern Nigeria. J Biol Agric Healthcare 5 (13): 15-21.

Asfaw Z (2001). Home gardens in Ethiopia: Some observations and generalizations. p.125-139. In: Watson JW, Eyzaguirre PB (eds) Home gardens and *in situ c*onservation of plant genetic resources in farming systems. Proceedings of the second international home gardens workshop, Witzenhausen, Germany.

Bammite D, Matthews PJ, Dagnon DY, Agbogan A, Odah K, Dansi A, Tozo K (2018) Constraints to production and preferred traits for taro (*Colocasia esculenta)* and new cocoyam (*Xanthosoma mafaffa)* in Togo, West Africa. Afr J Food Agric Nutr Dev. 18(2): 13388-13405.

Bammite D, Dagon YD, Agbogan A, Tozo AK, Dansi A, Akpagana K (2015) Evaluation de diversite agromorphologique et genetique du taro (*Colocasia esculenta* (L.) Schott) au Togo Colloque internationale, UAC.

Banjaw DT (2017) Review of taro (*Colocasia esculenta*) genetics and breeding. J Horti. 4(1):1-4.

Bhagyashree RP, Hussein MA (2011) Anthepatotoxic effect of *Colocasia esculenta* leaf juice. Inter J Adv Biotech Res. 2: 296–304.

Bradbury JH, Holloway WD (1988) Chemistry of tropical root crops: Significance for nutrition and agriculture in the Pacific. Australian Centre for International Research, Canberra, Australia.

CGIAR (2020) Undervalued and underutilized – cocoyam is ripe for development. Consultative Group for International Agricultural Research: Research program on roots, tubers and bananas. Available at https://www.rtb.cgiar.org/news/

Chege J (2020) The role of fortified crops in mitigating food security in the rural households in Muranga County: A case of women farmers of dry land arrowroots. Master of Arts Thesis, University of Nairobi, Nairobi, Kenya.

Chivenge P, Mabhaudhi T, Modi A, Mafongoya P (2015) The potential role of neglected and underutilised crop species as future crops under water scarce conditions in Sub-

Saharan Africa. Inter J Environ Res Public Health 12(6): 5685-5711.

Chukwu G, Okoye B, Nwosu K (2012) Cocoyam rebirth in Nigeria. Lap-Lambert Academic Publishing, Germany, 100 pp.

Chukwu GO (2015) Land use for cocoyam in Nigeria-implications for cocoyam re-birth. Global J Agric Res. 3 (2):25-36.

Chukwu GO, Okoye BC, Agugo BA, Amadi CO, Madu TU (2017) Cocoyam rebirth: A structural transformation strategy to drive cocoyam value chain in Nigeria. p. 216–227. In: Structural transformation in root and tuber research for value chain development and employment generation in Nigeria; ASURI, NRCRI: Umudike, Nigeria.

CSA (2018) Report on area and production of major crops (private peasant holdings, Meher season). Agricultural Sample Survey 2017/18 (2010 E.C.). Statistical Bulletin, Volume I. Central Statistical Agency. The Federal Democratic Republic of Ethiopia. Addis Ababa, Ethiopia.

Dansi A, Vodouhe R, Azokpota P, Yedomonhan H, Assogba P, Adjatin A, Loko Y, Dossou-Aminon I, Akpagana K (2012) Diversity of the neglected and underutilized crop species of importance in Benin. The Sci World J. 2012:1-19. doi:10.1100/2012/932947

Doku EV (1966) Root crops in Ghana. Ghana J Sci. 6: 15–36.

Ekwe KC, Nwosu KI, Ekwe CC, Nwachukwu UI (2009) Examining the under exploited values of cocoyam (*Colocasia* spp. and *Xanthosoma* spp.) for the enhanced household food security, nutrition and economy in Nigeria. Acta Horticulture 806: 71-78.

Englberger L, Aalbersberg W, Ravi P, Bonnin E, Marks GC, Fitzgerald MH, Elymore J (2003) Further analyses on Micronesian banana, taro, breadfruit and other foods for provitamin A carotenoids and minerals. J Food Compos Anal. 16: 219–236.

FAOSTAT (2016) Statistical database for agricultural production of primary crops. Food and Agriculture Organisation of the United Nations Statistical Division, Rome, Italy. Available at: http://www.fao.org/statistics/en/ (accessed on 10.12. 2022.).

FAOSTAT (2021) Statistical database for agricultural production of primary crops. Food and Agriculture Organisation of the United Nations Statistical Division, Rome, Italy. Available at: http://www.fao.org/statistics/en/ (accessed on 10.12. 2022.).

FAOSTAT (2022) Statistical database for agricultural production of primary crops. Food and Agriculture Organisation of the United Nations Statistical Division, Rome, Italy. Available at: http://www.fao.org/statistics/en/ (accessed on 10.12. 2022.).

Fujimoto T (2009) Taro (*Colocasia esculenta* (L.) Schott) cultivation in vertical wet-dry environments: Farmers" techniques and cultivar diversity in southwestern Ethiopia. Econ Bot. 63(2):152-166.

Giacometti DC, Leon J (1994) Tannia, yautia (*Xanthosoma sagittifolium*). p. 255-258. In: Hernandez-Bermejo JE, Leon J (eds) Neglected Crops: 1492 from a different perspective. FAO Plant Protection Series No. 26, Rome.

Grimaldi IM, van Andel TR (2018). Food and medicine by what name? The ethnobotanical and linguistic diversity of Taro in Africa. Econ Bot. 72:217 -228.

Hedges, LJ, Lister CE (2006) Confidential crop and food research report No. 1569: Root and tuber health attributes. New Zealand Institute for Crop and Food Research: Christchurch, New Zealand.

Hickey, GM, Pelletier B, Brownhill L, Kamau GM, Maina IN (2012) Preface: Challenges and opportunities for enhancing food security in Kenya. Food Sec. 4: 333–340.

Ijioma JC, Effiong JB, Ogbonna MO Onwuamaoka EA (2014) Determinants of adoption of selected NRCRI cocoyam technologies among farmers in Umuahia South Local Government Area of Abia State, Nigeria. Amer Inter J Contemp Res. 4 (6) :181-189.

Joubert FJ, Allemann L (1998) Madumbe. KwaZulu-Natal Department of Agriculture, Horticultural Production Guidelines.

Lawal OS (2004) Composition, physicochemical properties and retrogradation characteristics of native, oxidised and aceteylated and acid-thinned new cocoyam starch. Food Chem. 87: 205-218.

Lebot V (1999) Biomolecular evidence for plant domestication in Sahul. Genet Resour Crop Evol. 46: 619–628.

Lebot V (2009) Tropical root and tuber crops: Cassava, Sweet Potato, Yams and Aroids; CABI: Cambridge, UK, 2009.

Lebot V, Legendre L (2015) HPTLC screening of taro hybrids (*Colocasia esculenta* (L.) Schott) with high flavonoids and antioxidants contents. Plant Breed. 134: 129–134.

Lebot V, Malapa R, Bourrieau M (2011) Rapid estimation of taro (*Colocasia esculenta*) quality by near-infrared reflectance spectroscopy. J Agric Food Chem. 14: 9327–9334.

Lebot V, Prana MS, Kreike N, van Eck HJ, Pardales J, Okpul T, Gunua T, Thongjiem TM, Hue H, Viet N et al. (2004) Characterization of the genetic resources of taro (*Colocasia esculenta* (L.) Schott) in Southeast Asia and Oceania. Genet Resour Crop Evol. 51: 381–392.

Legesse T, Bekele T (2021) Evaluation of improved taro (*Colocasia esculenta* (L.) Schott) genotypes on growth and yield performance in North-Bench Woreda of Bench-Sheko zone, South-Western Ethiopia. Heliyon 7.

Lewu MN, Adebola P, Afolayan JA (2010) Comparative assessment of nutritional value of commercially available cocoyam and potato tuber in South Africa. J Food Quality 33(4): 461 – 476.

Mabhaudhi T (2012) Drought tolerance and water-use of selected South African landraces of taro (*Colocasia esculenta* L. Schott) and bambara groundnut (*Vigna subterranea* L. Verdc) (Doctoral dissertation, University of KwaZulu-Natal, Pietermaritzburg).

Mabhaudhi T, Modi AT, Beletse YG (2014) Parameterisation and evaluation of the FAO-AquaCrop model for a South African taro (*Colocasia esculenta* L. Schott) landrace. Agric forest meteorol. 192:132-139.

Malawi Government Report (1996) Country report to the FAO international technical conference on plant genetic resources. Leipzig: FAO, pp. 9-28.

MALFI (2019) National Root and Tuber Crops Development Strategy 2019-2022. Ministry of Agriculture, Livestock, Fisheries and Irrigation, Nairobi, Kenya.

Mare RM (2006) Phytotron and field performance of taro [*Colocasia Esculenta* (L.) Schott] Landraces from Umbumbulu (Doctoral dissertation, University of KwaZulu-Natal Pietermaritzburg).

Mare RM (2009) Taro (*Colocasia esculenta* L. Schott) Yield and quality response to planting date and organic fertilisation. Unpublished PhD thesis. University of Kwazulu Natal, South Africa.

Markwei C, Bennett-Lartey SO, Quarcoo E (2010) Assessment of cultivar diversity and agronomic characteristics of cocoyam (*Xanthosoma sagittifolium*) in Ghana through ethnobotanical documentation. In: Ramanatha RV, Matthews PJ, Eyzaguirre PB, Hunter D (eds.), The global diversity of taro: Ethnobotany and conservation. Bioversity International, Rome, Italy.

Mbong G, Fokunang C, Manju E, Njukeng A, Tembe-Fokunang E, Hanna R (2015) Mycelia growth and sporulation of *Phytophthora colocasiae* isolates under selected conditions. Amer J Exp Agric. 8: 193–201.

Mergedus A, Kristl J, Ivancic A, Sober A, Sustar V, Krizan T, Lebot V (2015) Variation of mineral composition in different parts of taro (*Colocasia esculenta*) corms. Food Chem. 170: 37–46.

MoANR (2016) Crop variety register. Issue No. 19. Plant variety release, protection and seed quality control directorate. Ministry of Agriculture and Natural Resources Addis Ababa, Ethiopia.

MoFA-SRID (2013) Agriculture in Ghana: facts and figures 2012. Statistics, research and information directorate. Ministry of Food and Agriculture, Accra, Ghana.

Modi AT Mabhaudhi T (2016) Developing a research agenda for promoting under-utilised, indigenous and traditional crops. Water research commission report No. KV362/16. www.wrc.org.za/wp-content/uploads/mdocs/KV362_172.pdf

Moorthy SN (2004) Tropical sources of starch. p. 321-359. In Ann-Charlotte Eliasson (ed) Starch in food: Structure, function and applications. Woodhead Publishing Series in Food Science, Technology and Nutrition.

Muñoz-Cuervo I, Malapa R, Michalet S, Lebot V, Legendre L (2016) Variety of secondary metabolites in taro, *Colocasia esculenta* (L.) Schott, corms. J Food Compos Anal. 52: 24–32.

Mwangi M, Nakato V, Ndungo V (2007) Importance of cocoyams (*Xanthosoma* sp.) in farming systems affected by banana *Xanthomonas* wilt in Eastern Democratic Republic of Congo. Poster presented at the 10th triennial symposium of the International Society for Tropical Root Crops - African Branch, October 8-12, 2007, Maputo, Mozambique.

Nanbol KK, Namo OAT (2019) The contribution of root and tuber crops to food security: A review. J Agric Sci Technol. 9: 221-233.

O'Hair, SK (1984) Farinaceous crops. p.109-138. In: Martin FW (ed) Handbook of Tropical Crops, CRC, Boca Raton.

Obidiegwu EJ (2015) Towards genetic engineering in cocoyam food crop: Challenges and prospects. Adv Genetic Engi. 4: 121.

Okoye BC, Onyenweaku CE (2007) Economic efficiency of smallholder cocoyam farmers in Anambra State, Nigeria: A trans-logstochastic frontier cost function approach. Mendwell Journals 4: 535-546.

Otekunrin AO, Sawicka B, Adeyonu AIG, Otekunrin AO, Racho´n L (2021) Cocoyam [*Colocasia esculenta* (L.) Schott]: Exploring the production, health and trade potentials in Sub-Saharan Africa. Sustainability 13:4483.

Onwueme I (1999) Taro cultivation in Asia and the Pacific. RAP publication 1999/16: 1-9. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, Thailand. Available at http://www.fao.org/DOCREP/005/AC450E/ac450e03.htm#TopOfPage

Onyeka J (2014) Status of cocoyam (*Colocasia esculenta* and *Xanthosoma* spp) in West and Central Africa: Production, household importance and the threat from Leaf Blight; CGIAR Research Program on Roots, Tubers and Bananas (RTB): Lima, Peru. Available at www.rtb.cgiar.org (accessed on 5.12. 2022.).

Opara LU (2003) Edible aroids: Post harvest operations. Food and Agriculture Organization of the United Nations, Rome, Italy. org/10.13140/rg.2.1.4295.6326

Owusu-Darko PG, Paterson A, Omenyo EL (2014) Cocoyam (corms and cormels)—an underexploited food and feed resource. J Agric Chem Environ. 3(1): 22-29.

Oxfarm Oganic Ltd (2022) Upland arrowroot farming without a swamp. Available at https://oxfarm.co.ke/crop-farming/

Parkinson S (1984) The contribution of aroids in the nutrition of people in the South Pacific. p. 215-224. In Chandra S (ed) Edible Aroids. Clarendon Press, Oxford, UK.

Passam HC (1982) Experiments on the storage of eddoes and tannia (*Colocasia* and *Xanthosoma* spp) under tropical ambient conditions. Tropical Science 24: 39.

Plucknett DL (1970) Status and future of the major edible aroid *Colocosia, Xanthosoma, Alocasia, Cyrstosperma* and *Amorphophallus*. p. 127-135. In: Tropical root crops tomorrow: Proceedings of the 2nd international symposium on tropical root crops, Hawaii.

Quaye W, Adofo K, Agyeman K, Nimoh F (2010) Socioeconomic survey of traditional commercial production of cocoyam and cocoyam leaf. Afr J Food Agric Nutr Dev. 10(9):4060–4078.

Quero-Garcia J, Ivancic A, Lebot V (2010) Taro and cocoyam. p.149–172. In: Bradshaw JE (ed) Root and Tuber Crops: Handbook of Plant Breeding 7. Springer.

Ramanatha RV, Matthews PJ, Eyzaguirre PB, Hunter D (eds)(2010) The global diversity of taro: Ethnobotany and conservation. Biodiversity International, Rome, Italy.

Rashmi DR, Raghu N, Gopenath TS, Pradeep P, Bakthavatchalam P, Karthikeyan M, Gnanasekaran A, Ranjith MS, Chandrashekrapp GK, Basalingappa KB (2018) Taro (*Colocasia esculenta*): An overview. J Med Plants Stud. 6: 156–161.

Reichstädter M (2020) Application of diffusive gradients in Thin Films Technique in food and environmental analysis. Ph.D. Thesis, Brno University of Technology Faculty of Chemistry, Institute of Food Science and Biotechnology, Brno, Czech Republic.

Richard MA, Gilles HTC, Corneille A, Serge SH, Traore ER (2018) Endogenous perception of the diversity of taro (*Colocasia esculenta*) cultivars produced in Benin. J Plant Sci 6 (4):144-148.

Rubatzky VE, Yamagushi M (1997) Edible aroids. p.183-196. In: Rubatzky VE, Yamagushi M (eds) World Vegetables: principles, production and nutritive value. 2nd Edition, Chapman and Hall: International Thomson Publishing, New York.

Sandifolo VS (2002) Estimation of crop losses due to different causes in root and tuber crops: the case of Malawi. Proceedings of the expert consultation on root crop statistics, Harare, Zimbabwe, 3–6 December 2002.

Scot N, Brooks F, Glenn T (2011) Taro Leaf Blight in Hawai'i. University of Hawai'i at Mänoa. Plant Disease 71:1-14.

Scott GJ, Best MR, Bokanga M (2000) Roots and tubers in the global food system: A vision statement to the year 2020. Centro Internacional de la Papa (CIP), Lima, Peru.

Sefa-Dede S, Sackey EKA (2002) Starch structure and some properties of cocoyam (*Xanthosoma saggitifolium* and *Colocasia esculenta)* starch and raphides. Food Chem 79: 435-444.

Serem AK, Palapala V, Talwana H, Nandi JMO, Ndabikunze B, Korir MK (2008) Socioeconomic constraints to sustainable cocoyam production in the Lake Victoria Crescent. Afr J Environ Sci Technol. 2 (10) :305-308.

Shange LP (2004) Taro (*Colocasia esculenta* (L.) Schott) production by small-scale farmers in KwaZulu-Natal: Farmer practices and performance of propagule types under wetland and dryland conditions. M.Sc. Thesis. University of KwaZulu-Natal, South Africa.

Sharma S, Jan R, Kaur R, Riar CS (2020) Taro (*Colocasia esculenta*). In: Nayik GA, Gull A (eds) Antioxidants in vegetables and nuts—Properties and health benefits, Springer: Singapore.

Si H, Zhang N, Tang X, Yang J, Wen Y, Wang L, Zhou X (2018) Transgenic research in tuber and root crops. A Review. p. 225–248. In: Rout GR, Peter KV (eds) Genetic engineering of horticultural crops. 1st ed. Academic Press, Elsevier.

Sibiya SG (2015) Planting density effect on growth and yield of taro (*Colocasia esculenta*) landraces (Doctoral dissertation, University of KwaZulu-Natal, Pietermaritzburg).

Singh D, Jackson G, Hunter D, Fullerton R, Lebot V, Taylor M, Iosefa T, Okpul T, Tyson J (2012) Taro Leaf Blight: A threat to food security. Agriculture 2:182-203.

Splittstoesser NE, Martin FW, Rhodes AM (1973) The nutritional value of some tropical root crops. Proceedings of the tropical region of the American Society for Horticultural Sciences 17: 290-294.

Sunell LA, Healy PL (1979) Distribution of calcium oxalate idioblasts in corms of taro (*Colocasia esculenta*). Amer J Bot. 66: 1029-1032.

Talwana HAL, Serem AK, Ndabikunze BK, Nandi JOM, Tumuhimbise R, Kaweesi T, Chumo EC, Palapala V (2009) Production status and prospects of cocoyam (*Colocasia esculentum* Schott.) for improving food and income security in East Africa. J Root Crops 35: 98 – 107.

Tilahun WF, Oselebe HO, Nnamani CV, Afiukwa CA, Uyoh. EA (2021) Systematic review on farmers' perceptions, preferences and utilization patterns of taro [C*colocasia esculenta* (L.) Scott] for food and nutrition security in Nigeria. J Plant Sci. 9(4): 224-233.

TOF (2018) Grow arrowroots for food security, diversify incomes. The Organic farmer, June 2018.

Traoré ER, Nanema RK, Bationon/Kando P, Sawadogo M, Nébié
B, Zongo JD (2013) Variation agromorphologique dans une collection de taro (*Colocasia esulenta* (L.) Schott) adapté aux conditions de culture pluviale au Burkina Faso. Inter J Biol Chem Sci. 7: 1490-1502.

Tumuhimbise R, Gwokyalya R, Kazigaba D, Basoga M, Namuyanja V, Kamusiime E (2016) Assessment of production systems, constraints and farmers' preferences for taro (*Colocasia esculenta* (L.) Schott) in Uganda. American-Eurasian J Agric Environ Sci. 16(1):126–132.

Tumuhimbise R, Talwana HL, Osiru DSO, Serem AK, Ndabikunze BK, Nandi JOM, Palapala V (2009) Growth and development of wetland-grown taro under different plant populations and seedbed types in Uganda. Afr Crop Sci J. 17 (1): 49 – 60.

Ubalua AO, Ewa F, Okeagu OD (2016) Potentials and challenges of sustainable taro (*Colocasia esculenta*) production in Nigeria. J Applied Biol Biotech. 4(01) :053-059.

Vinning G (2003) Select markets for taro, sweet potato and yam. A report for the rural industries research and development corporation. Rural Industries Research and Development Corporation (RIRDC), p.126.

Wada E, Asfaw Z, Feyissa T, Tesfay K (2017) Farmers' perception of agromorphological traits and uses of cocoyam (*Xanthosoma sagittifolium* (L.) Schott) grown in Ethiopia. Afr J Agric Res. 12(35): 2681-2691.

Wagner WL, Herbst DR, Sohmer SH (1999) Manual of the flowering plants of Hawaii. Revised edition. Vol. 2. University of Hawaii Press/Bishop Museum Press.

Wang J (ed)(1983) Taro: A review of *Colocasia esculenta* and its potentials. University of Hawaii Press, Honolulu.

Yared D, Mulualem T, Kifle A (2014) Development of high yielding taro (*Colocacia esculenta* L.) variety for mid altitude growing areas of southern Ethiopia. J Plant Sci 2 (1): 50-54.