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ORIGIN, DISTRIBUTION, TAXONOMY, BOTANICAL DESCRIPTION, GENETICS AND CYTOGENETICS, GENETIC DIVERSITY AND BREEDING OF YAMS (*DIOSCOREACEAE* SPP.)

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ABSTRACT

Yams belong to the Family Dioscoreaceae, Genus Dioscorea and Species Dioscorea *alata* L. The name "yam" appears to derive from Portuguese *inhame* or Canarian Spanish *ñame*, which derived from Fula, one of the West African languages during trade. The main derivations borrowed from verbs meaning "to eat". True yams have various common names across multiple world regions. Water yam, white yam, winged yam, greater yam=D. alata; air yam, air-potato, bitter yam=D. bulbifera; fiveleaf yam, five-leaved yam=D. pentaphylla; Chinese yam, cinnamon vine=D. polystachya; Zanzibar yam; West African yam=D. sansibarensis. Because it has become naturalized following its origins in Asia, specifically the Philippines, through tropical South America, and the southeastern U.S., *D. alata* is referred to by many different names in these regions. In English alone, aside from purple yam, other common names include ten-months yam, water yam, white yam, winged yam, violet yam, Guyana arrowroot, or simply yam. *Dioscorea alata* , also called purple yam, ube or greater yam, among many other names is a species of yam (a tuber). The tubers are usually a vivid violet-purple to bright lavender in color (hence the common name), but some range in color from cream to plain white. With its origins in the Asian tropics, *D. alata* has been known to humans since ancient times. Yams (family Dioscoreaceae, genus Dioscorea) are climbing perennial monocots with underground, and sometimes aerial, starchy tubers that are grown as a staple food. In Africa, yams are widely consumed in a variety of ways in a number of countries particularly in West Africa. Yams provide the staple foodstuff for millions of people in many tropical and subtropical countries, and are an important secondary food for many millions more. Furthermore, he indicates that apart from the yams that are cultivated as a food crop, there are also wild yams whose tubers are collected for eating in times of food shortages. These wild yams are a reliable standby nutritional backup for a large number of populations. The "bitter yam," *Dioscorea dumetorum* (Kunth) Pax, is popular as a vegetable. The wild forms of this species are very toxic and are sometimes used to poison animals when mixed with bait. D. dumetorum is found in Zambia, Zimbabwe, and Mozambique with a considerable number of vernacular names, ranging from "idiya" in Mozambique to "chinkolongo/inkolongo," "nkansa," and "ndiya" in Zambia. The tubers are used as a famine food after washing and drying to remove toxins. Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Yams are discussed.

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INTRODUCTION

Yams belong to the Family Dioscoreaceae, Genus Dioscorea and Species Dioscorea *alata* L. (Wikipedia, 2024a; NEW, 2024). The name "yam" appears to derive from Portuguese *inhame* or Canarian Spanish *ñame*, which derived from Fula, one of the West African languages during trade. The main derivations borrowed from verbs meaning "to eat". True yams have various common names across multiple world regions (Wikipedia, 2024). water yam, white yam, winged yam, greater yam=D. alata; air yam, air-potato, bitter yam=D. bulbifera; fiveleaf yam, five-leaved yam=D. pentaphylla; Chinese yam, cinnamon vine=D. polystachya; Zanzibar yam; West African yam=D. sansibarensis (Gucker, 2009).

Because it has become naturalized following its origins in Asia, specifically the Philippines, through tropical South America, and the southeastern U.S., *D. alata* is referred to by many different names in these regions. In English alone, aside from purple yam, other common names include ten-months yam, water yam, white yam, winged yam, violet yam, Guyana arrowroot, or simply yam (Wikipedia, 2024a). *Dioscorea alata* , also called purple yam, ube or greater yam, among many other names is a species of yam (a tuber). The tubers are usually a vivid violet-purple to bright lavender in color (hence the common name), but some range in color from cream to plain white. With its origins in the Asian tropics, *D. alata* has been known to humans since ancient times (Wikipedia, 2024a). Food yams are economically important staple foods in tropical and subtropical regions of the world. They belong to the genus *Dioscorea,* family

Dioscoreaceae and order *Dioscoreales.* More than 600 species are known, with the most important cultivated edible yams being *D. alata, D. rotundata, D. cayenensis, D. dumetorum, D. esculenta* and *D. bulbifera* (Atiri *et a*l., 2003). Wild yams are harvested by hunter/gatherers and domesticated yams are cultivated in Africa, Asia and South America. Cultivated yams are grown from Guinea to Kenya and from Angola to Uganda, but their importance varies greatly. Dioscoreaceae, or the yam family, contains eight or nine genera and some 750 species, many of which produce tuberous roots rich in starch; these tubers are staple foods in many tropical nations. The yampee, or cush-cush (Dioscorea trifida), originated in South America and the West Indies. D. alata, the white yam of India and the Malay Peninsula, is widely cultivated for its enlarged roots. In addition, several steroid compounds were originally obtained from Mexican species of Dioscorea to manufacture contraceptives and medicines (Alexander and Coursey, 2008). Dioscoreaceae**,** the yam family of the flowering plant order Dioscoreales, consisting of 4 genera and 870 species of herbaceous or woody vines and shrubs, distributed throughout tropical and warm temperate regions. Members of the family have thick, sometimes woody roots or tuber-like underground stems and net-veined, often heart-shaped leaves that sometimes are lobed. The small green or white flowers of most species are borne in clusters in the leaf axils. The fruit is a winged capsule or a berry. Several species of yams (vines of the genus Dioscorea) are grown for their edible tuberous roots, such as Chinese yam, or cinnamon vine (D. batatas); air potato (D. bulbifera); and yampee, or cush-cush (D. trifida). Dioscorea is a principal raw material used in the manufacture of birth-control pills (Hosch, 2008).

Root and tuber crops have long been staple crops to humans. Besides the well-researched and well-developed members of these crops, that is, potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), and cassava (*Manihot esculenta*), which are consumed in large quantities and traded on a worldwide level, there are also regionally important root and tuber crops that form the basis of nutrition to some indigenous people. One such example is yam (*Dioscorea* spp.). Yam is a tropical tuber crop that is cultivated in Africa, Asia, South America, the Caribbean, as well as the South Pacific islands. After cassava, yam is the second most important tuber crop in Africa. Even though more than 644 species belong to the genus *Dioscorea,* only a handful of them are cultivated (Andres *et al*., 2017). The crop plays an essential role in the nutrition and sociocultural life of more than 60 million people in five West African countries, that is, Nigeria, Ghana, Côte d'Ivoire (Ivory Coast), Benin, and Togo. In West Africa, some 50 million tons are cultivated on about 4 million hectares annually, accounting for more than 90% of the world's production. As the demand of yam is high in the urban society the prices could be high, especially during off-season periods. Consequently, yam is a major source of income for many farmers, especially in coastal regions of West Africa (Andres *et al*., 2017). Even though yams are indigenous to the West African sub-region, with the exception of *Dioscorea alata* (Asiatic origin), yams are often aptly described as an orphan crop due to the relatively little research effort compared to its significance in the sub-region in particular and the world at large. Breeding of yams therefore can be a challenge due to little literature available on the subject matter (Otoo, 2017). Yams are grown in tropical and subtropical Africa, Central and South America, parts of Asia, and the Caribbean and South Pacific Islands (Coursey, 1967; Adelusi and Lawanson, 1987). There are over 600 species of yam within the family, *Dioscoreaceae*, of which nine are medicinal plants and eight species, namely *D. rotundata* (white yam), *D. bulbifera* (air-potato yam), *D. cayenensis* (yellow Guinea yam), *D. dumentorum* (bitter or trifoliate yam), *D. praehensilis* (kokoasebayere), *D. esculenta* (lesser yam), *D. trifida* (cush-cush yam) and *D. alata* (greater or water yam) are edible. In the West African sub-region where 97% of world yam is produced, *D. rotundata*, *D. cayenensis*, *D. alata*, *D. dumentorum*, *D. praehensilis*, and *D. bulbifera* are the species ofimportance in that order (Otoo, 2017). Crop improvement or plant breeding is an applied branch of botany that deals with the improvement of crops and production of new crop varieties, which are far superior to existing types in one or more characters. Plant breeding therefore has been defined as science, art and technology of changing the traits of plants in order to produce desired characteristics. As an Art, it depends on the intuition and past experiences of each individual breeder. As a Science, it depends on the theoretical and practical knowledge in the field of genetics, statistics, agronomy, plant pathology, and many others. As a Technology, plant breeding generates a useful product such as improved variety, hybrids, synthetics and composites (Otoo, 2017). Yams (family *Dioscoreaceae*, genus Dioscorea) are climbing perennial monocots with underground, and sometimes aerial, starchy tubers that are grown as a staple food. In Africa, yams are widely consumed in a variety of ways in a number of countries particularly in West Africa. Yams provide the staple foodstuff for millions of people in many tropical and subtropical countries, and are an important secondary food for many millions more. Furthermore, he indicates that apart from the yams that are cultivated as a food crop, there are also wild yams whose tubers are collected for eating in times of food shortages. These wild yams are a reliable standby nutritional backup for a large number of populations (Muimba-Kankolongo, 2018). The "bitter yam," *Dioscorea dumetorum* (Kunth) Pax, is popular as a vegetable. The wild forms of this species are very toxic and are sometimes used to poison animals when mixed with bait. D**.** dumetorum is found in Zambia, Zimbabwe, and Mozambique with a considerable number of vernacular names, ranging from "idiya" in Mozambique to "chinkolongo/inkolongo," "nkansa," and "ndiya" in Zambia. The tubers are used as a famine food after washing and drying to remove toxins (Muimba-Kankolongo, 2018).

Yam is a multi-species monocotyledonous crop extensively disseminated in Africa, Asia, Oceania and South America. The genus *Dioscorea* to which yam belongs encompasses about 600 species; however, a few are cultivated for food and income. *Dioscorea alata, D. cayenensis* and *D. rotundata* are by far the major cultivated species worldwide, while *D. bulbifera, D. esculenta, D. opposita, D. japonica, D. nummularia, D. pentaphylla, D. transversa, D. trifida* and *D. dumetorum* are also economically important (Darkwa *et al.,* 2020). *Dioscorea rotundata* is indigenous to West Africa and represents the most important species in terms of volume of production while *D. alata*, which was introduced to Africa from Asia, is the most widely cultivated species globally (Darkwa *et al.,* 2020). Yam is an important staple source of carbohydrates (starch, sugars and fibres), proteins, minerals, vitamins and small amounts of lipids in the diets of millions of people in the tropics and subtropics. Yam is not only cultivated for consumption and as a source of income, but it is a highly esteemed food crop integrated into the social, cultural, economic and religious aspects of life of West Africans. The rituals, ceremonies and superstitions often associated with yam cultivation and utilization in West Africa is a strong indication of the antiquity of use of this crop (Darkwa *et al*., 2020). The new yam festival, which symbolizes the beginning of yam harvesting, is an outstanding social event almost everywhere in the yam-growing belt of West Africa. *Dioscorea* species are also recognized for their secondary metabolites aside their food value. They contain steroidal saponins, diterpenoids and alkaloids, which have been exploited for making poisons and pharmaceutical products. Although Africa accounted for over 97% of the total yam production worldwide in 2017, only two countries in Africa are among the top five countries recording the highest yields per hectare. The top five countries producing high yield per unit area are Ethiopia, Mali, Japan, Papua New Guinea, and Portugal, while Nigeria, Cote d'Ivoire, Ghana, Benin and Togo are the top five countries in the world in terms of total area under yam cultivation (Darkwa *et al*., 2020). A number of constraints including high cost of planting materials, high labour costs, poor soil fertility, low yield potential of local varieties, pests and diseases (yam anthracnose, virus and nematodes), and shortage of quality seed yam of popular landraces and released varieties have been identified as the major constraints of yam production in Africa. The presence of virus in yam tubers not only causes yield loss but also hinders the international exchange of yam planting materials and germplasm (Darkwa *et al*., 2020). A number of improved yam varieties having multiple pest and disease resistance, wide adaptability and good organoleptic attributes have been developed with empirical breeding methods in Africa and Asia by collaborative efforts of the international institutes and national yam breeding programmes. This progress with selection based on phenotypic expression of the crop for the traits of interest has however been challenging and slow due to inherent biological constraints that impede the elucidation of the genetics of important traits in yam. Although empirical breeding approaches have led to crucial achievements, contemporary tools and resources must be developed and applied to create the paradigm shift necessary to contribute significantly to feeding the rapidly increasing global population amidst climate change, dwindling resources and dynamics of consumer preferences. The decreasing cost and rapid advancement in next-generation sequencing procedures, together with high-performance computational methodologies, have led to extensive discovery of advanced genomic resources in numerous model and non-model plants (Darkwa *et al.,* 2020). *Dioscorea dumetorum* (family: *Dioscoreaceae*) as the common English name (Bitter yam) suggests has a bitter taste and occurs predominantly in the wild tropics throughout Africa. Wild forms of *D. dumetorum* do contain bitter principles, and hence are referred to as bitter yam. It has trifoliate compound leaves which differentiate it from other yams having single heart-shaped leaves, and a slender stem that twines anticlock wisely. *D. dumetorum* stem is covered with hairs and spikes. The tuber is coarse and juicy and is usually produced in clusters. Bitter yam is not consumed raw because of itchiness, bitterness, or toxicity component in the raw tuber. They are usually detoxified by soaking in a vessel of salt water, in cold or hot fresh water or in a stream. The bitter principle has been identified as the alkaloid dihydrodioscorine. Bitter yam serves as food of choice for the diabetic patients and as herb for the treatment of various ailments (Uhuo *et al.,* 2020).

Yam is a common name for plant species in the genus *Dioscorea*, including 'nagaimo' (Chinese yam, D. polystachya), 'yamanoimo' (Japanese yam, D. japonica) and 'daijo' (water yam, D. alata), which are cultivated in Japan. It is also widely cultivated around the world, particularly in West Africa, where about 54 million tons, equivalent to more than 90% of the world's total yam production, are produced annually (Satoru, 2021). Yam is an important crop for the food and nutrition supply of the people of West Africa, and the demand is increasing year by year but the supply is not catching up. On the other hand, research and technological development on breeding of yam for productivity and quality improvement has hardly progressed. Therefore, Guinea yam is deeply rooted as a traditional crop in West Africa, with characteristics (color, taste and texture) that conform to food culture such as traditional cooking methods and processing techniques. There are many interesting stories about yam. In some regions of West Africa, the local people believe that eating yam increases the chances for twins to be born. Also, yam is used as an indispensable wedding gift at the ceremony to demonstrate the physical and financial strength of the groom (Satoru, 2021). Yams (*Dioscorea* spp.) are important crops with increasing food, feed and industrial applications in Sub-Saharan Africa and many other regions of the world. Yams possess great potential to contribute to food, nutrition and income security of many livelihoods worldwide, but this potential is yet to be fully exploited. Variety development through breeding is among key strategies targeted at unlocking the potential of yam for food, feed and industrial applications (Norman and Tongoona, 2022). In many tropical countries, yams are known as the "king of crops." Worldwide, they are the fourth most utilized root and tuber crop—after potatoes, cassavas, and sweet potatoes—and they feed hundreds of millions of people. Because yams are cultivated in many different regions, they're also incredibly diverse: to the tune of about 600 species, and each of those species comes in multiple cultivars, or varieties. The world's largest producer is the West African "yam belt," stretching from southeast Guinea to northwest Cameroon, with Nigeria contributing the highest yield. The yam not only helps provide food security and nutrition, it's also an integral socio-cultural symbol—yams often play an important role in wedding ceremonies and festivals (Bhattacharjee, 2022). Dioscoreales are an order of the monocotyledons. Their most diverse and important genus is *Dioscorea*, the type genus of the family *Dioscoreaceae* which includes about 600 species. Yam species are used for their pharmacologically active compounds in traditional medicine and have high therapeutic potential. Most species are harvested from the wild for their bioactive compounds but such activity is threatening their fragile natural resources. *Dioscorea alata* belongs to the Enantiophyllum section (with *D. cayenensis* and *D. rotundata*) and twines to the right (clockwise). The name *alata* comes from its winged stems. The stem cross-section is square with the corners being under the form of wings represented by a thin membrane of approximately 1–6 mm in width (Lebot *et al*., 2023). Cultivars can be classified by their ploidy levels, diploids, triploids and tetraploids, with diploids being the most common. Higher ploidy levels tend to produce larger tubers. These tubers weight an average of 3–5 kg/plant in 6–9 months, depending on cultivars. They present all sorts of shapes and the flesh colour can vary from homogeneous white or yellow to a deep purple. The shape of the leaves is very variable in size and form, with some being rounded, elongated, uplifted or sharply pointed. Tetraploids have leaves larger than diploids. The greater yam, just like all *Dioscorea* spp., is dioecious with male and female flowers on different plants. Many cultivars flower only rarely and, even more rarely, produce fertile seeds. The sex ratio is unbalanced and there are more male than female plants. The fruits are dry dehiscent capsules (1–3 cm long) that can host up to six seeds but this is very unusual. Some cultivars produce bulbils in the axils of the leaves. These bulbils can be used for the propagation of the plant (Lebot *et al*., 2023). Yam (*Dioscorea* spp.) is a vegetable part of the *Dioscoreaceae* family which is considered a staple food with cultural and social meanings in many populations worldwide. Its distribution has been seen in Africa, Asia, and parts of South America and the Caribbean, with Nigeria being the country that produces the most. It has been suggested that more than 600 species of yam exist around the world, including *Dioscorea rotundata* (white or West African yam), *Dioscorea alata* (water and purple yam varieties), *Dioscorea dumetorum* (bitter yam), *Dioscorea esculentum* (seed yam), *Dioscorea cayenensis* (yellow or guinea yam), and *Dioscorea bulbifera* (air yam). More recently, Chinese yam species, such as *Dioscorea polystachya (*or *Dioscorea batatas*) and *Dioscorea oppositifolia (*or *Dioscorea opposite)*, have gained momentum due to their increasing production and alleged medicinal properties (do Nascimento *et al.,* 2023).

Dioscorea alata is one of the most important staple crops in Austronesian cultures. It is one of various species of yams that were domesticated and cultivated independently within Island Southeast Asia and New Guinea for their starchy tubers, including the round yam (Dioscorea bulbifera), ubi gadong (Dioscorea hispida), lesser yam (Dioscorea esculenta), Pacific yam (*Dioscorea nummularia*), fiveleaf yam (Dioscorea pentaphylla), and pencil yam (Dioscorea transversa). Among these, *D. alata* and *D. esculenta* were the only ones regularly cultivated and eaten, while the rest were usually considered as famine food due to their higher levels of the toxin dioscorine which requires that they be prepared correctly before consumption. *D. alata* is also cultivated more than *D. esculenta*, largely because of its much larger tubers (Wikipedia, 2024a). The color of purple varieties is due to various anthocyanin pigments. The pigments are water-soluble, and have been proposed as possible food coloring agents. *D. alata* is sometimes grown in gardens for its ornamental value (Wikipedia, 2024a). *Dioscorea* is a genus of over 600 species of flowering plants in the family Dioscoreaceae*,* native throughout the tropical and warm temperate regions of the world. The vast majority of the species are tropical, with only a few species extending into temperate climates. It was named by the monk Charles Plumier after the ancient Greek physician and botanist Dioscorides (Wikipedia, 2024b). Several species, known as yams, are important agricultural crops in tropical regions, grown for their large tubers. Many of these are toxic when fresh, but can be detoxified and eaten, and are particularly important in parts of Africa, Asia, and Oceania. One class of toxins found in many species is steroidal saponins, which can be converted through a series of chemical reactions into steroid hormones for use in medicine and as contraceptives (Wikipedia, 2024b). Yam (*Dioscorea* spp.) is a crop that has acquired great relevance as a food and source of inputs for the population of different developing countries due to its adaptability to different edapho climatic conditions, the content of starch and other nutrients in its tuberous roots, in addition to its nutritional content. Likewise, the presence of different bioactive principles in yam tubers has been identified that allow their application in the pharmaceutical industry (Otálora *et al.,* 2024). Yam is one of the fastest growing crops in the economy and food for millions of people in Africa, Asia, Latin America and the Caribbean. The term "yam" is associated with different vine-type plants within the *Dioscorea* genus, characterized by the production of tuberous roots with starch storage capacity. Currently, the yam has other uses besides food and source of income, for example, as a source of active ingredients in medicine and even ornamental arrangements (Otálora *et al.,* 2024).

Yams are members of the flowering plant genus *Dioscorea.* They are monocots, related to palms, grasses, and orchids. There are about 600 species of yams found around the world, most of them in the tropics. Some species of yam are cultivated for their edible tubers, for medicinal use, and for other uses (NEW, 2024). Yams remain an important food crop, especially in Africa, and some varieties can be stored for months without refrigeration. In addition to addressing the physical needs of people—offering such nutrition as carbohydrates, protein, phosphorus, and potassium—yams also touch upon the human inner nature, bringing pleasure through their enjoyable taste and texture, and being central to various ceremonies related to their importance in traditional societies of Africa and the Pacific islands (NEW, 2024). Most yam species grow in the tropics and sub-tropics in areas with fairly heavy total annual rainfall, but with a definite dry season. During the rainy season, they produce one or more underground tubers to store food and water through the dry season. The tubers are thickened stems. At the end of the dry season, they send out shoots, which grow into vines that grow up into nearby trees and bushes. Many species grow bulbils, small tuber like growths, at the bases of their leaves. These can fall to the ground and produce new plants. Most yam plants have small flowers with one plant having only male or female flowers (NEW, 2024). Yam, inhame or ñame, is the common name of a series of plants belonging to the *Dioscoreaceae* family and widely cultivated in various tropical, subtropical, and temperate regions of the world due to their nutritional relevance within the human and even animal feed. Within this family, the plants belonging to the *Dioscorea* genus have been those of greater cultivation and greater relevance, so they are those with the highest relation to the term "yam" (Otálora *et al.,* 2024). Yam is the common name for some plant species in the genus *Dioscorea* (family *Dioscoreaceae*) that form edible tubers (some other species in the genus being toxic). Yams are perennial herbaceous vines native to Africa, Asia, and the Americas and cultivated for the consumption of their starchy tubers in many temperate and tropical regions. The tubers themselves, also called "yams", come in a variety of forms owing to numerous cultivars and related species (Wikipedia, 2024).

Originating from Africa, specifically West and Central Africa, white yams hold significant agricultural importance as a cash crop in the region. These yams are available year-round and exhibit an impressive size range, from potato-sized specimens to colossal ones weighing over 100 pounds. Characterized by a cylindrical shape, light brown, slightly hairy skin, and an easily peelable exterior, white yams house firm, white flesh inside. Despite their firmness, the texture is creamy, and the flavor is characterized by a mild and nutty profile (Hickey, 2024). White yams play a central role in the diverse cuisines of Ghana and other West African countries, making appearances in a range of dishes. Noteworthy dishes include ampesi, a delightful combination of boiled yams with a flavorful stew or gravy, and asana, a one-pot creation that brings mashed yams together with a medley of vegetables, fish, and spices. For those who crave a crispy treat, there are yam fries. They're exactly what they sound like — strips of yams seasoned with salt and fried in vegetable oil. Often served with pepper sauce, they're a popular street food in both Ghana and Nigeria (Hickey, 2024). Similar to white yams, yellow yams are among the most widely cultivated varieties in Africa. They're also known as Guinea yams, or yellow Guinea yams, reflecting their place of origin and the distinctive yellow color of their flesh. You'll also find them in the Caribbean, hence their other nickname: Jamaican yams. Their vibrant hue comes from carotenoids, the same pigments found in carrots and sweet potatoes. While sharing a flavor profile reminiscent of sweet potatoes, yellow yams distinguish themselves by their larger size and bark-like skin, offering a starchy and dry texture (Hickey, 2024). Much like their white counterparts, yellow yams exhibit remarkable versatility in the kitchen. They can be prepared through boiling, baking, frying, or roasting. These yams also find their way into various soups, stews, and curries. Their adaptability makes them a staple ingredient in a number of African and Jamaican dishes. This list includes jollof yam, a yam stew made by combining boiled yams with shrimp, fish, and vegetables, and Jamaican yellow yam stew, a delectable porridge made with coconut milk, vegetables, and yellow yams (Hickey, 2024). Similar to many yam varieties, the Indian yam is known by several names. These include true yam, yampee (also spelled yampi), tropical yam, igname, and cush-cush (also spelled kush-kush). True to their name, tropical yams thrive in the hot and humid parts of Asia, Africa, and Latin America. They feature a rough, bark-like dark brown skin that's challenging to peel in its raw state, but that softens with cooking. Due to their dry flesh and relatively bland taste, recipes incorporating these yams are designed to impart both flavor and moisture (Hickey, 2024). Setting aside its impressive background, lesser yams are sweet with a pleasant flavor reminiscent of sweet potatoes or chestnuts. They are versatile and can be boiled, baked, or fried — similar to how you'd prepare potatoes. They also mash well and can be baked whole, topped in the style of jacket potatoes. In Vietnam, they shine in dishes like chè củ từ, also known as lesser yam pudding. To make this dessert, boiled cubed yams are mixed with water, sugar, and tapioca starch, resulting in a gelatin-like treat that can be enjoyed hot or cold (Hickey, 2024).

Yams (*Dioscorea* spp.) are flowering plants of the *Dioscoreaceae* family. It includes more than 600 species of woody shrubs and climbing vines. They are underground tubers with heart-shaped leaves, tiny green or white blooms, and berry–shaped fruit. Yams are extensively spread throughout the tropical and warm temperate parts of the planet. However, human translocations have likely impacted their current geographic distribution**.** This tuber crop is grown in Africa, Asia, South and Central America, the Caribbean, and the South Pacific islands (Malichi, 2024). Yam flesh ranges in colour from white to yellow, pink, or purple and varies in taste from sweet to bitter to tasteless. Most yams contain an acrid principle that is dissipated in cooking. Indian yam (D. trifida) and winged, or water, yam (D. alata) are the edible species most widely diffused in tropical and subtropical countries. The tubers of D. alata sometimes weigh 45 kg. Guinea yam (D. rotundata) and yellow Guinea yam (D. cayenensis) are the main yam species grown in West Africa. Lesser yam (D. esculenta), grown on the subcontinent of India, in southern Vietnam, and on South Pacific islands, is one of the tastiest yams. Chinese yam (D. polystachya), also known as cinnamon vine, is widely cultivated in East Asia. The air-potato yam (D. bulbifera) is one of the few true yams cultivated for food in the United States (Petruzzell, 2024). Taxonomy, Botanical Description, Genetics and Cytogenetics, Genetic Diversity, Breeding, Uses, Nutritional Value and Health Benefits of Yams are discussed.

ORIGIN AND DISTRIBUTION

Yams not native to North America originated in tropical regions of Asia or Africa. Due to widespread early cultivation and transport of yams, exact origins for some species are unknown. Chinese yam is native to eastern Asia. Fiveleaf yam is native to tropical Asia or eastern Polynesia. Zanzibar yam is native to Africa. Water yam has been reported as native to Southeast Asia, but Coursey indicates that water yam is "unknown in the wild state anywhere in the world" but was first cultivated in Assam or Burma. Water yam was likely transported to the eastern coast of Africa 2,000 years before present. Air yam is known from both Asia and Africa, but it is unclear if air yam is native to both continents or was introduced from one to the other. Indigenous air yam populations were also reported on Australia's northern coastline (Gucker, 2009). Yams may have been present in Africa, Asia, South America, the Caribbean, as well as the South Pacific islands since a very long time, and reports suggest that *Dioscorea rotundata* was first domesticated in West Africa in about

5000 BC. Three main centers of origin of yams have been identified: West Africa, Southeast Asia, and tropical America. Different species of the genus *Dioscorea* may have different regions of origin. Yam cultivation is widespread in the tropics and spans the entire globe along the so-called 'yam belt,' a band some degrees north and south of the equator where people grow yams (Andres *et al*., 2017). While there has been progress in our understanding of the origin and history of agriculture in sub-Saharan Africa, a unified perspective is still lacking on where and how major crops were domesticated in the region. Here, we investigated the domestication of African yam (Dioscorea rotundata), a key crop in early African agriculture. Using whole-genome resequencing and statistical models, we show that cultivated yam was domesticated from a forest species. We infer that the expansion of African yam agriculture started in the Niger River basin (Scarcelli *et al.,* 2019).

Artifacts dated about 50,000 bc from West Africa indicate wild yams were used for food prior to that time. The growing of yams appears to have developed independently in two regions, in West Africa and Southeast Asia about 3000 bc. The present-day *D. bulbifera*, which is grown for the aerial tubers, is indigenous to both regions (Yamaguchi, 2020). The first humans reached New Guinea about 50,000 years ago when the temperatures and sea levels were lower than today. The Asian mainland extended as far east as Bali and Borneo to form a landmass known as "Sunda." At that time, New Guinea was not an island but formed the northern part of a large continent that also included Australia and Tasmania, known as "Sahul." Yams were most likely among the first plants to be consumed as a food crop in New Guinea. Excavations at archaeological sites in New Guinea have recovered stone artifacts dated from 49,000 to 36,000 years ago showing an abundance of grains consistent with starch from yams, specifically Dioscorea species. The size and morphology of the tuber-like starch grains from samples at Joe's Garden in the Ivane Valley of the New Guinea Highlands, which is among the oldest human sites in this region, were consistent with the greater yam Dioscorea alata (Chaïr, 2021). Yams likely originated from cultivation and domestication centers in Asia, Africa, and America over long-term evolution. D. trifida is the earliest known domesticated variety in South America and is widely cultivated, mainly in Brazil, Venezuela, Paraguay, and other regions. Asia is another main distribution center of yam, and the commonly cultivated and domesticated species in Asia are D. opposita, D. alata, D. esculenta, D. japonica, D. bulbifera, D. hispida, and D. quinquelaba (Cao *et al*., 2021).

Dioscorea spp., *Dioscoreaceae* family, is formed by about 633 species known as yams (and variations in different languages: "inhame," "ñame," "igname," "niam," "enyame," "nyami," etc.), of which only 10 are used as a food source in the world: *D. alata* L., native to Tropical Asia; *D. rotundata* (Poir.) J. Miège/ *D. cayenensis* Lam., native to West Africa; *D. bulbifera* L., native to Africa, Asia, and northern Australia; *D. esculenta* (Lour.) Burkill., native to Southeast Asia; *D. oppositifolia* L., native to Myanmar (Burma) and to the Indian Subcontinent (India, Sri Lanka, Bangladesh); *D. dumetorum* (Kunth) Pax., native to West Africa; *D. transversa* R. Br., native to eastern and northern Australia; *D. pentaphylla* L., native to southern and eastern Asia (China, India, Indochina, Indonesia and Philippines) as well as New Guinea and northern Australia; *Dioscorea trifida* L., native to the Caribbean and Central and South America; and *D. altissima* Lam., indigenous to forested areas of Brazil, Bolivia, Peru, Central America north to Panama, and the Caribbean. These regions are considered as centers of diversity and domestication of the yam crop. The genus had a wide worldwide dispersion at the end of the Cretaceous period and later during the Miocene, having evolved in different directions in the New and Old World, thus originating different species, which currently presents a great dispersion (Siqueira *et al*., 2023). The origin of the yam dates mainly to the African continent, with its subsequent distribution by slaves to America and Asia (Otálora *et al.,* 2024). The origin of the Dioscorea depends on the species and they can come from Africa, Asia, Latin America, and the Caribbean (LAC). However, it is dated that the main origin occurred in Africa and was distributed to other continents, where genetic variability allowed obtaining other types of species. Thus, for example, *D. trifida* originates from tropical America; *D. rotundata, D. cayenensis, D. bulbifera*, and *D. dometorun* in West Africa; while, *D. alata, D. esculenta*, and *D. oposita* are of Asian origin (Otálora *et al*., 2024). Yams are native to Africa, Asia, and the Americas. Three species were independently domesticated on those continents: *D. rotundata* (Africa), *D. alata* (Asia), and *D. trifida* (South America) (Wikipedia, 2024). Artifacts dating from about 50,000 BC show evidence of wild yams being used for sustenance in West Africa before that time. This shows that yams have been our ancestors' steadfast source of nourishment. Yam cultivation appears to have developed independently in two regions, in West Africa and Southeast Asia, about 3000 BC. According to some accounts, *Dioscorea rotundata,* a common yam species, was domesticated for the first time in West Africa around 5000 BC. The origin of yams is not bound to West Africa alone, as some research shows they also originated from Southeast Asia and tropical America. Today, yam cultivation is a widespread practice in the tropics, found globally, primarily within the "yam belt," a region a few degrees to the north and south of the equator that provides the ideal climate and conditions for yam growth (Malichi, 2024). There are two centers of yam cultivation worldwide. The first is the high rainfall region of western Africa, from the Ivory Coast to Cameroon. Here the most important species are the white yam (*Dioscorea rotundata*) and the yellow yam (*D. cayenensis)*, named for the color of their tuber's flesh. The second center is Vietnam, Cambodia, Laos, and neighboring regions where the most commonly cultivated species is the Asiatic yam (*D. alata*). Secondary areas of yam cultivation are the West Indies, Pacific islands, and southeastern United States (from Louisiana to Georgia). Most yam species originated in Asia and Africa; only one, the cush-cush yam (*D. trifida*), is native to the New World (Science, 2024).

TAXONOMY

Yams belong to the Family Dioscoreaceae, Genus Dioscorea and Species Dioscorea *alata* L. (Wikipedia, 2024a; NEW, 2024). Yam is the common name for members of the genus *Dioscorea* (family *Dioscoreaceae*). There are more than 150 different species/varieties of yam. Some species are cultivated for the consumption of their starchy tubers in Africa, Asia and Latin America. The word *yam* comes from Portuguese *inhame* or Spanish *ñame*, which both ultimately derive from the Wolof word *nyami*, meaning "to eat". They are used in a similar fashion to potatoes, and are sometimes called a potato substitute, though in areas where yams are grown, potatoes are the newer vegetable. Yam tubers can grow up to seven feet (approx. two meters) in length and weigh up to 68 kilograms. The yam has a rough skin which is difficult to peel, but which softens after heating. Yam skins vary in color from dark brown to light pink. The majority of the yam is composed of a much softer substance known as the "meat". This substance ranges in color from white to bright orange in ripe yams. Yams are a primary agricultural commodity in West Africa and New Guinea. They were first cultivated in Africa and Asia about 8000 B.C., probably because they were able to flourish in environments where growing leafy vegetables and keeping livestock was difficult. To this day, the yam tuber remains crucial to survival in the region; it can be stored for four to six months without refrigeration, which makes it a valuable resource for the yearly period of food scarcity at the beginning of the wet season (MediaWiki, 2024).

Dioscoreaceae, also called the yam family, in the order of Dioscoreales, is a family of monocotyledonous flowering plants, with about 750 known species in 9 genera, widely distributed in tropical and temperate regions, mostly in tropical America, usually perennial twining, herbaceous or woody vines. They are rhizomatous or tuberous. Leaves are usually simple, alternate. Flowers are usually unisexual, bracteate, axillary, and solitary to cymules, spikes, racemes, thyrses, or panicles. Fruit is a loculicidal capsule or a berry. Seeds are winged or not and endospermic (Xu and Chang, 2017). The scientific name for the genus commonly known as yams is *Dioscorea* L. (*Dioscoreaceae*). This review summarizes information available as of 2009 on the following 5 yam species (Gucker, 2009). Yams are flowering plants of the family *Dioscoreaceae*, consisting of more than 800 species of climbing vines and woody shrubs. Many members of the yam family produce subterranean tubers or tuberous stems, and have heart-shaped leaves, small green or white flowers, and a fruit that is a winged capsule or berry. Yams are distributed widely throughout the tropical and warm temperate regions of the world, though current geographic distribution has almost certainly been influenced by human translocations. Today yams are widely used as an important food staple and as a fallback food in Africa, Asia, the Caribbean, Pacific islands, and South America (Barton, 2014). Yam is the common name for over 600 Dioscorea species. The species of yams widely cultivated worldwide are D. bulbifera, D. panthaica, D. esculenta, D. japonica, D. trifida, D. pentaphylla, and D. rotundata. Yams are also one of the top 10 most important edible tuber and root plants worldwide.Yams play an important role in sustaining many livelihoods in the tropics and subtropics (Cao *et al.,* 2021). It has been suggested that more than 600 species of yam exist around the world, including *Dioscorea rotundata* (white or West African yam), *Dioscorea alata* (water and purple yam varieties), *Dioscorea dumetorum* (bitter yam), *Dioscorea esculentum* (seed yam), *Dioscorea cayenensis* (yellow or guinea yam), and *Dioscorea bulbifera* (air yam). More recently, Chinese yam species, such as *Dioscorea polystachya (*or *Dioscorea batatas*) and *Dioscorea oppositifolia (*or *Dioscorea opposite)*, have gained momentum due to their increasing production and alleged medicinal properties (do Nascimento *et al*., 2023).

Within this genus there are approximately 600 species of which only 12 species are cultivated and used as food. Among the most important species are the tejocote yam (*D. rotundata*), the yellow yam (*D. cayennensis*) and the greater yam (*D. alata*), which are cultivated by small farmers and sold to varying degrees in tropical countries such as Nigeria, Ghana, Ethiopia, Brazil, Colombia, Costa Rica, among others (Otálora *et al.,* 2024). About 600 species have been identified in this genus, of which around 25 have presented relevance as food, 15 have presented medicinal relevance and 6 have ornamental relevance (Otálora *et al*., 2024). In terms of morphology, the characteristics of the yam plant vary according to the species. However, it is possible to cite some general characteristics. The plant develops in a vine shape and can be divided into two sections: an aerial section and an underground section. The first consists of a stem that grows with a spiral shape and may require support or stake for its development, as is the case of *D. rotundata*. Likewise, it is possible to make a distinction between the type of yam according to the direction in which its stem is wound. An example is the distinction between *D. alata*, which winds clockwise, and *D. rotundata*, which winds counterclockwise. Along the stem alternate or opposite cordate leaves develop, with long petioles and colors ranging from yellowish green to violet. Also, aerial tubers or "bulbils" can be developed, in which starch granules are stored. This type of tuber also has nutritional and economic value in species that are capable of developing them effectively, such as *Dioscorea bulbifera* or commonly called air yam. mall cluster flowers can also develop. However, food species are characterized by poor flowering. The bulbils are continuously produced and replaced after degradation processes, while the underground tubers are not (Otálora *et al*., 2024).

On the other hand, fibrous roots and tuberous roots develop in the underground section. The former grows horizontally through 30 cm below the ground, even reaching lengths of 1 meter. The tuberous roots are responsible for the energy storage of the plant in the form of starch. These roots are the usable part of the plant for food and have economic value due to their starch content, reaching values of up to 80 % in dry weight. Tubers vary greatly in shape and size, even on the same plant. They can be spherical, fusiform, or claviform, and often with small ramifications. The tuber cortex is rough with colorations from light brown to dark brown and with a thickness that may depend on the species. Likewise, the yam pulp is uniform, compact, and with a color ranging from white and yellow to purple. Each tuber can weigh 300 to 400 grams. In addition to the position in the plant, the underground tubers differ from the bulbils in size and production throughout the life of the plant (Otálora *et al.,* 2024). A monocot related to lilies and grasses, yams are vigorous herbaceous, perennially growing vines from a tuber. Some 870 species of yams are known, a few of which are widely grown for their edible tuber but others of which are toxic (such as *D. communis*) (Wikipedia, 2024). Yams are any of the 10 economically important species of *Dioscorea*, a genus in the monocotyledonous family *Dioscoriaceae*. These species, all tropical in their origin, are cultivated for their edible tubers (enlarged, fleshy, usually underground storage stems) (Science, 2024). *Dioscorea* spp has more than 800 species, though not all of them are cultivated. Let us look at some of the major species that are cultivated. Some of the significant species of yam include the Indian yam, known by its scientific name (*Dioscorea trifida*), and the winged or water yam (*Dioscorea alata*) are the most common species of yam and are among the edible species. They are widely spread in the tropical and subtropical areas. Guinea yam, known by its scientific name *Dioscorea rotundata,* is mainly grown in West Africa with another species known as *Dioscorea canyenensis* or by its common name, yellow guinea yam. *Dioscorea esculenta* known by its common name as Lesser yam, is grown on the subcontinent of India, on the South Pacific islands, and in Vietnam. It is one of the tastiest yams that can be cultivated. *Dioscorea polystachya* , known as Cinnamon vine and Chinese yam, is cultivated in East Asia. *Dioscorea bulbifera*, Air yam is also one of the most important species in the family *Dioscoreaceae* and is native to Africa, Asia, and northern Australia. It is important to note that the common names of yam may differ from one place to another based on the language (Malichi, 2024).

Major cultivated species

Many cultivated species of *Dioscorea* yams are found throughout the humid tropics. The most economically important are discussed below (Fig. 1):

D. rotundata*, the white yam, and *D. cayenensis, the yellow yam, are native to Africa. They are the most important cultivated yams. In the past, they were considered as two separate species, but most taxonomists now regard them as the same species. Over 200 varieties between them are cultivated. White yam tuber is roughly cylindrical in shape, the skin is smooth and brown, and the flesh is usually white and firm. Yellow yam has yellow flesh, caused by the presence of carotenoids. It looks similar to the white yam in outer appearance; its tuber skin is usually a bit firmer and less extensively grooved. The yellow yam has a longer period of vegetation and a shorter dormancy than white yam (Wikipedia, 2024). These are native to Africa and are the most widely cultivated types of yams in this region. They can grow quite large with vines reaching lengths of up to 12 m. The tubers usually weigh between 2.5 and 5 kg each, but can attain weights of as much as 25 kg or even more (Andres *et al*., 2017). The color of the tubers distinguishes two common species of yam cultivated in Southern Africa. D. rotundata Poir. is the “white yam” whereas D. cayennensis Lam. is the “yellow yam.”

The tubers of the white yam are roughly cylindrical in shape, the skin being smooth and brown, and the flesh usually white and firm. Yellow yam is named after its yellow flesh. D. rotundata is cultivated by many small-scale farmers in Botswana, Malawi, Mozambique, Zambia, and Zimbabwe. The yellow color is caused by the presence of carotenoids in the tubers. The tuber skin is usually less extensively grooved in yellow yams, but otherwise they resemble white yams in outer appearance. In addition, yellow yam has a longer vegetative period and a shorter dormancy than white yam (Muimba-Kankolongo, 2018). *Dioscorea rotunda,* the white yam, and *D. cayenensis,* the yellow yam, are native to Africa. They are the most important cultivated yams. In the past, they were considered two species but most taxonomists now regard them as the same species. There are over 200 cultivated varieties between them. They are large plants; the vines can be as long as 10 to 12 meters. The tubers most often weigh about 2.5 to 5 kg each, but can weigh as much as 25 kg. After 7 to 12 months growth the tubers are harvested. In Africa, most are pounded into a paste to make the traditional dish "fufu" (NEW, 2024).

Dioscorea rotundata- White yam is a commonly farmed yam species in Africa, having over 200 variations. The white yam tuber is generally cylindrical in shape, with a smooth and brown exterior and white, firm flesh (Andres *et al.,* 2016). These are the most important varieties of yam especially in the western and central parts of Africa. They can grow quite large with vines reaching lengths of up to 12 m. The tubers usually weigh between 2.5 and 5 kg each but can attain weights of as much as 25 kg or even more (Alhassan, 2022). Yellow yams are similar to sweet potatoes, however they are not a sweet potato substitute. The primary distinction between the two tubers is that yams are larger and have a thicker skin, whilst sweet potatoes are smaller and have a thin peel (Andres *et al.,* 2016).

Dioscorea alata: These yam varieties are believed to originate from Asia and they are also known as winged yam or purple yam. It has the largest distribution worldwide of any cultivated yam. Although it is not grown in the same quantities as African varieties. It is grown in Asia, the Pacific islands, Africa, and the West Indies. Even in Africa, the popularity of water yam is second only to white yam. The vines grow to 10 m or more in length and are freely branching. The tubers are large with purple flesh. The plants normally grow for 8–10 months, and then go dormant for 2–4 months. During dormancy, the aerial stems dieback (Alhassan, 2022). *D. alata*, called purple yam (not to be confused with the Okinawan purple "yam", which is a sweet potato), greater yam, ube, winged yam, water yam, and (ambiguously) white yam, was first cultivated in Southeast Asia. Although not grown in the same quantities as the African yams, it has the largest distribution worldwide of any cultivated yam, being grown in Asia, the Pacific islands, Africa, and the West Indies. Even in Africa, the popularity of water yam is second only to white yam. The tuber shape is generally cylindrical, but can vary. Tuber flesh is white and watery in texture (Wikipedia, 2024). Water yam, winged yam, and purple yam, was first cultivated somewhere in Southeast Asia. Although it is not grown in the same quantities as the African yams, it has the largest distribution worldwide of any cultivated yam, being grown in Asia, the Pacific islands, Africa, and the West Indies. In the United States, it has become an invasive species in some southern states (NEW, 2024). Water yam also called ‘winged yam’ or ‘purple yam,’ is a perennial, vigorously twining vine with winged stems. The vines grow to 10 m or more in length and are freely branching. The tubers are large with purple flesh. The plants normally grow for 8–10 months, and then go dormant for 2–4 months.

During dormancy the aerial stems die back. Water yam was first cultivated in Southeast Asia. It is the most widely distributed yam worldwide, although it is not grown in large quantities. Besides Africa and Asia, it is also being grown in the Pacific Islands and the West Indies (Andres *et al.,* 2017). Water yam vines twine clockwise and may reach 30 m long. Vines have ridged stems and are prickly at the base. Water yam leaves are large, elongate, and heart-shaped. Leaf blades typically measure 6-16 cm long, 4-13 cm wide, and have entire margins. Leaf petioles are generally as long as the leaf blade. Leaf arrangement appears inconsistent. Some report that water yam leaves are alternate at the stem base and opposite near the stem end, while others report that leaves are primarily opposite, but can appear alternate due to leaf abortion. Bulbils are oblong and rough with fleshy protrusions. Bulbils may reach 10 cm long and 4 cm in diameter. Staminate flowers occur in a zig-zag pattern along a rachis up to 25 cm long; pistillate flowers occur in 4- to 20- flowered inflorescences that may reach 35 cm long. Water yam fruits are capsules that could produce 2 seeds per each of 3 locules, but often if 1 seed is produced it is aborted before maturity. Capsules are rare even when male and female plants are in close proximity. Tubers produced by water yams are described as massive. Water yam may begin producing tubers 14 to 40 days after planting, and tubers grow rapidly near the end of the growing season. Although single tubers are most common, several are possible. Tubers are branched, grow vertically, and may be deeply buried. Water yam tubers weigh 10 kg to more than 50 kg (Gucker, 2009). Purple or winged yam is another name for this yam. The tuber’s shape is usually cylindrical, but it can vary. The flesh of the tuber is white and has a watery appearance. Because of its extensive agricultural network, it is the most widely spread yam. It’s a tuber that can be found in Asia, Africa, and the Caribbean. They’re also known as purple yam, greater yam, or English winged yam (Andres *et al*., 2016).

Dioscorea alata L. is called “water yam,” “winged yam,” and “purple yam” and was first cultivated in Southeast Asia. This yam has the largest distribution worldwide of any cultivated yam, and it is grown throughout Africa where its popularity is second only to white yam. D. alata is easily found in Angola, Malawi, Mozambique, and Zambia. Smaller quantities of water yam are produced compared to the white and yellow African yams, however. It has square, winged vines and the tuber shape is generally cylindrical, but can vary. The tuber flesh is white and watery in texture (Muimba-Kankolongo, 2018).

Dioscorea bulbifera: It is appreciated for its bulbils, which form at the base of the leaves and are about the size of potatoes, hence the name ‘air potato’ and weighing from about 0.5 to 2.0 kilograms. It is not grown much commercially since its flavor pales in comparison to that of other yams. However, it is popular in home vegetable gardens because it produces a crop after only four months of growth and continues producing for the life of the vine, as long as two years. The bulbils are however more important food products compared to the yam tubers (Alhassan, 2022). Air potato, is found in both Africa and Asia, with slight differences between those found in each place. It is a large vine, 6 m or more in length. It produces tubers, but the bulbils which grow at the base of its leaves are the more important food product. They are about the size of potatoes (hence the name "air potato"), weighing from 0.5 to 2.0 kg. Some varieties can be eaten raw, while some require soaking or boiling for detoxification before eating. It is not grown much commercially since the flavor of other yams is preferred by most people. However, it is popular in home vegetable gardens because it produces a crop after only four months of growth and continues producing for the life of the vine, as long as two years. Also, the bulbils are easy to harvest and cook. In 1905, the air potato was introduced to Florida and has since become an invasive species in much of the state. Its rapid growth crowds out native vegetation and it is very difficult to remove since it can grow back from the tubers, and new vines can grow from the bulbils even after being cut down or burned (Wikipedia, 2024). Air potato, is found in both Africa and Asia with slight differences between those found in the two places. It is a large vine, 6 meters or more in length. It produces tubers; however the bulbils that grow at the base of its leaf are the more important food product.

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Dioscorea esculenta: It is also known as the lesser yam and is arguably one of the first yam species cultivated. It is native to Southeast Asia and not cultivated in large quantities in other parts of the world. Its vines rarely reach more than 3 meters in length and the tubers are fairly small. Because of the small size of the tubers, mechanical cultivation is possible; which, along with its easy preparation and good flavor, could increase the popularity of the 'lesser yam' in the future (Alhassan, 2022). Lesser yam, was one of the first yam species cultivated. It is native to Southeast Asia and is the third-most commonly cultivated species there, although it is cultivated very little in other parts of the world. Its vines seldom reach more than 3 m in length and the tubers are fairly small in most varieties. The tubers are eaten baked, boiled, or fried much like potatoes. Because of the small size of the tubers, mechanical cultivation is possible, which along with its easy preparation and good flavor, could help the lesser yam to become more popular in the future (Wikipedia, 2024). Lesser yam, was one of the first yam species cultivated. It is native to Southeast Asia and is the third-most commonly cultivated species there, although it is cultivated very little in other parts of the world. Its vines seldom reach more than 3 meters in length and the tubers are fairly small in most varieties. The tubers are eaten baked, boiled, or fried much like potatoes. Because of the small size of the tubers, mechanical cultivation is possible; which, along with its easy preparation and good flavor, could help the lesser yam become more popular in the future (NEW, 2024). Lesser yam was among the first yam species cultivated. It is native to Southeast Asia and is among the most commonly cultivated species there. Its vines seldom grow longer than 3 m and the tubers of most varieties are rather small. Besides its easy preparation and good flavor, the small size of the tubers allows for mechanical cultivation, all of which may favor cultivation of lesser yam in the future (Andres *et al*., 2017). This is the third most popular yam variety. The origins of this species can be traced back to Southeast Asia. The tubers are baked, boiled, or fried in the same way that potatoes are. Mechanical cultivation is possible due to the tiny size of the tubers, which, together with its ease of preparation and flavor, could help the lesser yam become more popular in the future (Andres *et al.,* 2016).

Discorea dumetorum: it is popular in the western parts of Africa and is known as bitter yam for its bitter taste. Its cultivation requires less labour than other yams. Its wild forms may be highly toxic (Alhassan, 2022).

The bitter yam is a plant native to Africa. It contains a fleshy, potato-like root (tuber) that can be used for food or medicinal in times of famine. Bitter yams found in the wild are likely to contain poisons, thus they must be soaked and boiled before eating. Farmers' bitter yams, on the other hand, are normally free of poisons because safer varieties are produced selectively (Andres *et al.,* 2016). *D. dumetorum*, the bitter yam, is popular as a vegetable in parts of West Africa, in part because their cultivation requires less labor than other yams. The wild forms are very toxic and are sometimes used to poison animals when mixed with bait. It is said that they have also been used for criminal purposes (Wikipedia, 2024). The cultivation of this species requires less labor than other yams. Its wild forms may be highly toxic, which explains why they are sometimes mixed with some bait and subsequently used to poison animals (Andres et al., 2017). The "bitter yam," *Dioscorea dumetorum* (Kunth) Pax, is popular as a vegetable. The wild forms of this species are very toxic and are sometimes used to poison animals when mixed with bait. According to Wilkin (2001), D**.** dumetorum is found in Zambia, Zimbabwe, and Mozambique with a considerable number of vernacular names, ranging from "idiya" in Mozambique to "chinkolongo/inkolongo," "nkansa," and "ndiya" in Zambia. The tubers are used as a famine food after washing and drying to remove toxins (Muimba-Kankolongo, 2018).

Chinese yam (D. polystachya): Chinese yam vines are slender, twine clockwise, and may reach 5 m or more in length. Chinese yam leaves may grow to 11 cm long and wide. Leaves are deeply lobed at the base, and upper leaves may have 3-lobed margins. Like water yam, the arrangement of Chinese yam leaves is variable. Leaves may be alternate near the top of stems or occassionally found in whorls of 3, and others report that leaves are generally alternate near stem bases and opposite near the end of stems. Chinese yam produces small, rounded, warty bulbils. Bulbils are typically less than 3 cm long and less than 2 cm in diameter. Flowers are rare and smell like cinnamon. Male flowers occur in bundles, spikes, or panicles at branch ends. and female inflorescences are few-flowered and generally less than 5 cm long. Chinese yams produce 1 to many large, cylindrical tubers. Tubers grow vertically from long stalks and typically as deep as 1 m below ground. Mature tubers can weigh 3.6-4.5 kg (Gucker, 2009).

Chinese yam i**s** an ornamental vine that comes from Asia. It grows in North America as well, but it is unrelated to the popular sweet potatoes known as yams. Cinnamon vine and shan yao are two other names for Chinese yam. Chinese yam has traditionally been used to treat stomach, spleen, lungs, and kidney diseases in Chinese herbal medicine. Diosgenin, found in the roots of Chinese yam, can be utilized to make steroid hormones like estrogen and progesterone in the lab. While both the tuber and the bulbs of the Chinese yam are edible, only the tuber is commonly eate (Andres *et al*., 2016). *D. polystachya*, Chinese yam, is native to China. The Chinese yam plant is somewhat smaller than the African, with the vines about 3 m long. It is tolerant to frost and can be grown in much cooler conditions than other yams. It is also grown in Korea and Japan. It was introduced to Europe in the 19th century, when the potato crop there was falling victim to disease, and is still grown in France for the Asian food market. The tubers are harvested after about 6 months of growth. Some are eaten right after harvesting and some are used as ingredients for other dishes, including noodles, and for traditional medicines (Wikipedia, 2024).

Chinese yam (*Dioscorea opposita*): As the name suggests – is native to China and the plant is smaller than the African yams. Its tolerance to frost enables cultivation in much cooler climates. Today it is mostly being grown in China, Korea, and Japan. The tubers are harvested about 6 months after planting (Andres *et al.,* 2017).

Fiveleaf yam (D. pentaphylla): Fiveleaf yam vines are prickly, twine counterclockwise, and may grow to 10 m long. Leaves are alternate and compound with 3 to 5 leaflets. Leaflets measure 5-10 cm long and 2-4 cm wide. Bulbils are horseshoe shaped and about 1 cm in diameter. Male flowers, if produced, occur in spikes up to 30 cm long at the branch ends; female flowers also occur in spikes, but these are shorter, 5-25 cm long. Fiveleaf yam typically produces single, irregular to elongated, egg-shaped tubers. Tubers may occur near the soil surface or more than 1 m underground. Fiveleaf yam tubers dug in Hawaii ranged from 2.6-17 cm long and were about equally wide. The largest tuber weighed 1,370 g (Gucker, 2009).

***D. trifida*, the cush-cush yam,** is native to the Guyana region of South America and is the most important cultivated New World yam. Since they originated in tropical rainforest conditions, their growth cycle is less related to seasonal changes than other yams. Because of their relative ease of cultivation and their good flavor, they are considered to have a great potential for increased production (Wikipedia, 2024). *Dioscorea opposite,* Chinese yam, is native to China. It is tolerant to frost and can be grown in much cooler conditions than other yams. It is now grown in China, Korea, and Japan. It was introduced to Europe in the 1800s when the potato crop there was falling victim to disease. It is still grown in France for the Asian food market. The Chinese yam plant is somewhat smaller than the African yam, with the vines about 3 meters (10 feet) long. The tubers are harvested after about 6 months of growth. Some are eaten right after harvesting and some are used as ingredients for other dishes, including noodles, and for traditional medicines (NEW, 2024). *Dioscorea trifida,* the cush-cush yam, is native to the Guyana region of South America and is the most important cultivated New World yam. Since they originated in tropical rainforest conditions, their growth cycle is less related to seasonal changes than other yams. Because of their relative ease of cultivation and their good flavor they are considered to have a great potential for increased production (NEW, 2024). Dioscorea trifida- Cush-cush yam i**s** a perennial climbing plant with 3 meter-long twining stems that grow from a tuberous rootstock. These stems scramble across the ground or entangle themselves into the vegetation. The plant's edible root is commonly farmed in tropical places, particularly in South America and the Caribbean (Andres *et al*., 2016).

Zanzibar yam (D. sansibarensis**):** Zanzibar yam vines twine counterclockwise. Vine stems are about 3 cm thick and may grow to 25 cm or more. Stems can reach support trees prior to producing leaves. Zanzibar yam leaves and petioles are long. Leaf blades are heart-shaped and can be up to 46 cm long and 58 cm wide. Petioles may be 26 cm long, and leaves often have a tail-like projection at the tip. Leaves are generally opposite, and the margins of juvenile leaves may be irregularly lobed. Bulbils are small, smooth, often a purplish color, and can measure 6 cm in diameter. Male inflorescences typically have 2 to 4 flowers and may be up to 50 cm long; female inflorescences are slightly shorter. Irregular, rounded lobes are common on the generally globose tubers produced by Zanzibar yams. Generally tubers are shallowly buried (15 cm deep) and may reach 40 cm in diameter (Gucker, 2009).

BOTANICAL DESCRIPTION

Air yam vines twine counterclockwise and may grow to 30 m long. Air yam stems are not angled and do not have prickles. Leaves are simple, heart-shaped, and arranged alternately along the stem. Leaves may reach 26 cm wide and long; leaf petioles are generally shorter than the leaf blade. Air yam size and appearance can be variable. Variability in bulbil form and size may be partly due to the different air yam types that exist in Asia and Africa. The Asian type produces relatively smooth, spherical bulbils that may weigh 1 kg. African types produce sharply angled bulbils. Flowers, if produced, are widely spaced or reduced to a single flower in simple staminate spikes 11-70 cm long. Pistillate spikes are generally stiff, up to 23 cm long, and occur in clusters of 2 or more. Most references indicate that air yam generally produces tubers, although they may be small and solitary. However, some suggest that air yam may lack underground tubers. Tubers are commonly 5-10 cm in diameter and weigh less than 1 kg. However, tuber shape is likely related to ecotype. Air yams from Asia produce spherical tubers, while air yams from Africa produce irregular branching tubers (Gucker, 2009).

		
***D. rotundata*, the white yam,**	***D. cayenensis*, the yellow yam**	**Dioscorea alata**
		
Dioscorea alata	***Dioscorea Bulbifera***	***D. esculenta***
		
D. dumetorum	***Chinese yam (D. polystachya):***	***D.opposita***
		
D. pentaphylla	***D. trifida***	***D. sansibarensis***

Fig. 1. Major cultivated species of yams

The Dioscoreaceae consist of dioecious or hermaphroditic, perennial herbs. The stems are rhizomatous or tuberous, often with climbing aerial stems, secondary growth present in some taxa. The leaves are spiral, opposite, or whorled, petiolate (typically with a pulvinus at proximal and distal ends), simple to palmate, undivided to palmately lobed, stipulate or not, with parallel or often net (reticulate) venation, the primary veins arising from the leaf base. The inflorescence is an axillary panicle, raceme, umbel, or spike of monochasial units (reduced to single flowers), with prominent involucral bracts in *Tacca*. The flowers are bisexual or unisexual, actinomorphic, pedicellate, bracteate or not, and epigynous. The perianth is biseriate, homochlamydeous, 3 + 3, a hypanthium absent or present. The stamens are 3 + 3 or 3 + 0, whorled, diplostemonous or antisepalous, distinct or monadelphous, free or epitepalous. Anthers are longitudinal and introrse or extrorse in dehiscence, tetrasporangiate, dithecal. The gynoecium is syncarpous, with an inferior ovary, 3 carpels, and 3 locules. The style**(s)** are 3 or 1 and terminal; stigmas are 3. Placentation is axile or parietal; ovules are 1–2 [∞] per carpel. The fruit is a capsule or berry, often winged, 1–3 locular at maturity. Seeds are exalbuminous (Simpson, 2019). The Dioscorea genus is relatively broad, which is why it has been divided into several taxonomic sections, such as Enantiophyllum, Combilium, Opsophyton, Macrogynodium, and Lasiophyton, within which the yam species with nutritional value are found (Otálora *et al*., 2024). All species of the genus Dioscorea are dioecious twinned climbing plants and all those of importance for human consumption produce tubers. Morphologically, yam plants can be described in two sections: an aerial section and an underground section. The aerial section includes a description of the stem, leaves, and flowers. Whereas, the underground section mainly includes fibrous and tuberous roots. In the aerial section, the yam plant has a stem incapable of supporting the weight of the leaves, therefore it requires a scaling process on support or develops on the ground. The stem can be wound clockwise or counterclockwise, depending on the yam species. This phenomenon has allowed the distinction between yam species (Otálora *et al*., 2024).

Plants belonging to the Enantiophyllum section are known to be characterized by a twisted stem clockwise, while plants of the other sections have a stem that winds counterclockwise. Likewise, the development of the plant stem may require support or a stake in which it can be rolled . In this sense, for example, *D. rotundata* needs support for the development of its stem, while *D. alata* can develop on the ground or climb on support. The stems can be winged, prickly or spineless, hairy or glabrous, and of circular, rectangular, or polygonal section. The presence of spines on the stems is associated with a defense mechanism developed by several species and a characteristic morphology that allows the development of the stem. On the other hand, the stems can reach lengths of a few meters, as *D. esculenta*, up to 15 meters, as *D. nummularia*, and they can develop on the ground up to 1 meter until reaching support. Leaves develop along the stem and they can have alternate or opposite positions. Species with alternate leaves can be found at the bottom of the stem and opposite at the top. The leaves of yam plants show high variability in terms of shape, color, and size. This variation can occur between species, between cultivars, and even between different parts of the same plant. Thus, the leaves can have cordate, simple, elongated shapes, with long or spiked petioles. It is also possible to found compound leaves, with even three leaves on the same petiole. The surface area of the leaves can be between 50 and 200 cm^2. Generally, the leaves have a greenish hue, however, in young leaves of some species other anthocyanin pigments can be seen. In addition to the leaves, flowers can develop in the aerial part of the plant. However, the majority of cultivars with nutritional value do not show flowering. Low flowering is associated with the evolution of yam plants after their domestication and the development of dependency on the action of the human being for their reproduction. When flowering occurs, the flowers are small with diameters between 2 and 4 mm, composed of a calyx with 3 sepals and a corolla with three petals. In all species, there is a greater presence of male flowers than females, and they are colonized by nocturnal flying insects. The color of the flowers can vary and tends to be insignificant due to their size. However, they have a perfumed smell. Like flowers, fruit and seed production is scarce. When developed, the fruits are dry dehiscent trilocular capsules 1 to 3 cm long and each fruit can produce theoretically six seeds. Yam seeds have been found to have low germination in the field (Otálora *et al.,* 2024). Some species of the *Dioscorea* genus, such as *D. alata, D. bulbifera*, and *D. pentaphylla*, develop bulbils in the axils of the leaves. These bulbils have a structure similar to the tubers developed by plants and have a storage tissue or pulp composed of starch. However, the bulbils have a slight odor and a bitter salty taste. This has allowed species such as *D. bulbifera* to have commercial value, which is capable of producing these bulbils in a large proportion. The bulbils develop in the maturity stage of the plant and their production is continuous. That is, the bulbils mature, fall off, and are replaced by new bulbils. They have a gray to dark brown coloration and round shapes with weights of up to 1 kg (Otálora *et al*., 2024). In the underground section, the fibrous and tuberous roots of the plant develop. The fibrous roots grow horizontally below about 30 cm from the ground and reach up to 1 meter deep below the ground. This root system develops abundantly in the first stage of the plant life, for six weeks after seeding, and they fulfill the function of nutrient absorption. On the other hand, the tuberous roots allow the storage of nutrients and energy in the form of starch, hence its large amount of this natural polymer. The resulting tubers vary greatly in shape, color, and size, depending on the species. They can be spherical, fusiform, or claviform, with possible small ramifications in some yam species, and can reach weights from hundreds of grams to kilos. For example, Enantiophyllum species produce one to three long tubers, while *D. esculenta* (Combilium) and *D. trifida* (Macrogynodium) produce a larger number of tubers, but with a smaller size. The surface of the tubers is rough and has a color ranging from white to dark brown. Some species can produce tubers with shallow spines. On the other hand, the pulp inside is uniform and compact, with a color ranging from white, yellow to purple, and with a characteristic flavor after cooking (Otálora *et al*., 2024).

Yam plants can grow up to 15 metres in length and 7.6 to 15.2 centimetres high. The tuber may grow into the soil up to 1.5 m deep. The plant disperses by seed. The edible tuber has a rough skin that is difficult to peel but readily softened by cooking. The skins vary in color from dark brown to light pink. The majority, or meat, of the vegetable is composed of a much softer substance ranging in color from white or yellow to purple or pink in mature yams (Wikipedia, 2024). Yam is part of the family of roots and tubers whose edible parts are found underground. Yam plants are known to produce thick tubers at the base of the stem, which store all the nutrients produced by the plant. The part of the plant that grows above the ground is long and slender, with stems that grow while climbing. Therefore, it is essential to use supporting structures like sticks and poles to stake the yam so the stems do not grow on the ground. Staking also increases the size of the tuber that grows underground. Yam tubers are root vegetables with scaly brown skin with white, purple, or red flesh and starchy and usually dry. Yam can produce one tuber or more depending on the species, and these tubers can be cylindrical, curved, or lobed with colors such as brown, grey, black, or pink skin with white, orange, or purple flesh. Yams can be produced as annual plants and harvested after a season. In contrast, some can be made over years, with tubers increasing each year and the vines dying back at the end of one growing season and growing back once the conditions become favourable (Malichi, 2024). Yams are herbaceous plants whose stems twine up and around bushes, trees, or poles. Depending on the species of yam, stems twine either clockwise or counterclockwise. The stems bear stalked, palmately veined leaves that are simple and entire, although a few species have three-lobed leaves. All yams have a dioecious lifestyle, which means that the staminate and pistillate flowers are borne on separate plants. The flowers are inconspicuous, being only 1/8 in (2-4 mm) long and whitish or greenish. The fruits produced from the flowers are three-angled and contain winged seeds. Some cultivars of yam, however, rarely flower or set seed (Science, 2024). In commonly cultivated yams, the tubers lie underground and are one (rarely two or three) per plant. These tubers resemble huge, elongated potatoes, typically growing 2-6 ft long (0.6-2 m) and weighing 11-33 lb (5-15 kg). A thin skin protects their outer surface, and on the inside they are filled with starch which can be white or yellow depending on the species. One cultivated yam (*Dioscorea bulbifera*) bears small tubers along the aerial stems in the leaf axils (the angle between the stem and leaf stalk) (Science, 2024). Yam is the name given to several plant species in the genus *Dioscorea* including *Dioscorea alata* (white yam), *Dioscorea bulbifera* (potato yam), *Dioscorea cayenensis* (yellow yam), *Dioscorea esculenta* (Asiatic yam) and *Dioscorea batatas* (Chinese yam) that are grown for their edible tubers. Yam plants are herbaceous annual or perennials with climbing or trailing vines. The vines can be smooth or prickly, reaching 10 m (32.8 ft) or more in length depending on the variety. The leaves of the plant are simple and usually oval to heart-shaped with petioles which are the same length, or slightly longer, than the leaf blade itself. Some varieties possess spikes at the bases of the leaves. The plant can produce one singular tuber or several tubers which extend from stolons from a central corm (up to 20) depending on the species. The tubers can be cylindrical, curved or lobed, with brown, grey, black or pink skin and white, orange or purplish flesh. Most yams are annual plants, harvested after one season, but some are perennial with tubers

Minisetts

Planting

Planted on mound

Planted on mound

Staking of plants

Plants

Plants

Plants

Plants

Leaves

Bubils

Bubils

Roots being harvested

Roots being harvested

Roots

Fig. 2. Botanical Description

increasing in size each year with the vines dying back at the end of the growing season and regrowing on the return of favorable conditions. The origin of yams is uncertain and genetic information suggests that there may be more than one point of origin (Plantvillage, 2024). Botanical Description is given in Fig. 2.

Life Cycle

The growth cycle of yam plants can be divided into five phases: (i) tuber germination, (ii) foliage development, (iii) tuber bulking, (iv) foliage senescence, and (v) dormancy. Initially, a bud is generated a few days after seeding. This bud or bud set constitutes the basal nodal complex, from which the first roots are generated. This section of the initial plant can produce a stem, and fibrous and tuberous roots, in addition to inducing priority root growth. The stem develops without leaf production and can be up to 4 meters long in some species. This stage lasts up to 6 weeks after planting. In the second stage, the rapid and abundant production of the foliage is carried out until approximately week 14. In this same stage, the stem continues to grow and the plant reaches self-sufficiency. In the third stage, nutrients begin to translocate to the storage roots from the canopy, so the growth of the tubers is promoted until approximately week 20. After this, the senescence of the leaves begins between weeks 20 and 40. It is characterized by the drying and falling of the old and basal leaves and the drying of the tips. At this point, the greatest maturation of the tubers is reached and the photosynthetic translocation is completed. Finally, the plant begins an inactivation stage, in which a suberized bark is generated in the tubers with dark coloration. Tubers can be harvested at this stage and can't germinate for less than a month to five months (Otálora *et al*., 2024).

Pollination

Yam (*Dioscorea* spp.) is a monocotyledonous herbaceous vine cultivated for its starchy underground or aerial tubers in the tropics and subtropics. It is an allogamous and polyploidy species that reproduces by both sexual and asexual mechanisms. However, many of the landrace cultivars, including most of the popular varieties, reproduce exclusively by vegetative propagation (planting the tubers). These varieties are either sterile or produce sparse and irregular flowering with high flower abortion rate, low fruit and seed set. Production of crossbreed seeds for genetic improvement and for maintaining genetic diversity in yams is, therefore, mainly achieved through natural or managed pollination. Flowering in yam is mostly dioecious and, in some instances, monoecious. Flowering asynchrony, sticky nature of the pollen grains, and cross incompatibility are among the challenges in making genetic progress in yam breeding. There are many limitations in basic and applied knowledge of yam flower biology and pollination (Mondo et al., 2020). We compared self-pollination, intracultivar cross-pollination and intercultivar cross-pollination in three monoecious cultivars (Amoula, Heapala and Yassi). Results showed that pollen viability (49%) and stigma receptivity (40%) were similar in monoecious and dioecious plants, suggesting that autogamy could occur in monoecious plants. However, fruit and seed sets were significantly lower after self-pollination compared to cross-pollination. Overall, autogamy reached 11% and pollen lability was almost zero (<1%). The low percentage of pollen grains germinating on the stigma (37%) and pollen tubes reaching the ovules (25%) after self-pollination partly explained the low seed set. Strong inbreeding depression was observed after self-pollination and almost all fruits and about 75% of the seeds resulting from self-pollination showed malformations. Seed germination was also 20 times lower after self-pollination compared to cross-pollination. Sexual reproduction remained low in D. rotundata even after cross-pollination as fruit and seed set did not exceed 18% and 13% respectively. Moreover, comparison between intracultivar cross-pollination and self-pollination revealed intravarietal genetic diversity inside the analyzed yam cultivars. Overall, our results showed that *D. rotundata* has a very low tolerance to autogamy in monoecious cultivars and has developed pre- and postzygotic mechanisms to limit selfing (Denadi *et al*., 2022).

Yam plants have thick tubers (generally a development of the base of the stem) which often have thick, almost barklike skin. The long, slender, annual, climbing stems bear lobed or entire leaves that are either alternate or opposite. The unisexual flowers are borne in long clusters. The flowers are generally small and individually inconspicuous though collectively showy. Each consists of a greenish bell-shaped or flat perianth of six pieces, enclosing six or fewer stamens in the male flowers and surmounting a three-celled three-winged ovary in the female flowers. The ovary ripens into a membranous capsule, bursting by three valves to liberate numerous flattish or globose seeds (Fig. 3, 4) (Petruzzell, 2024).

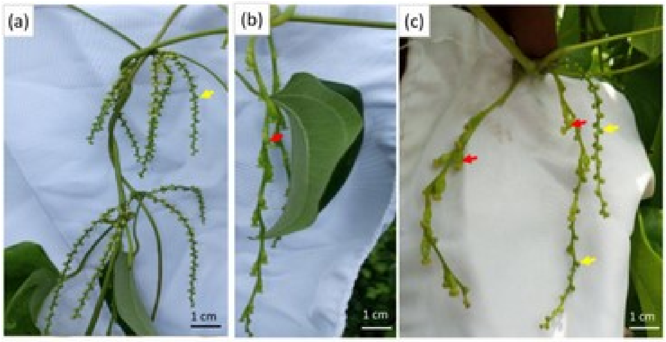

Fig. 3: Inflorescences of (a) male, (b) female and (c) monoecious individuals of *D. rotundata* . Yellow arrows and red arrows indicate, respectively, male and female flowers.

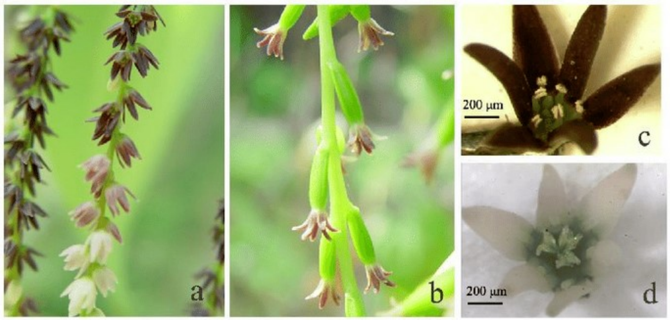

Fig. 4. Floral traits of Dioscorea bulbifera: (a) staminate inflorescence; (b) Pistillate inflorescence; (c) staminate flower; (d) Pistillate flower

Genetics and Cytogenetics: *Dioscorea alata* is a polyploid species with several ploidy levels and its basic chromosome number has been considered by most authors to be x = 10. Standard chromosome counting and flow cytometry analysis were used to determine the chromosome number of 110 D. alata accessions of the CIRAD germplasm collection. The results revealed that 76% of accessions have 2n = 40 chromosomes, 7% have 2n = 60 chromosomes and 17% have 2n = 80 chromosomes. Progenies were produced from 2n = 40 types of D. alata and the segregation patterns of six microsatellite markers in four different progenies were analysed. The Bayesian method was used to test for diploid versus tetraploid (allo- and autotetraploid) modes of inheritance. The results provided the genetic evidence to establish the diploidy of plants with 2n = 40 chromosomes and to support the hypothesis that plants with 2n = 40, 60 and 80 chromosomes are diploids, triploids and tetraploids, respectively, and that the basic chromosome number of D. alata is x = 20. The findings obtained in the present study are significant for effective breeding programs, genetic diversity analysis and elucidation of the phylogeny and the species origin of *D. alata* (Arnau *et al*., 2009). 10 chromosome counts genotypes showed mainly 2n = 40, Da176 was a mixoploid with 20 and 40 chromosomes. Four levels of ploidy were detected by flow cytometry technology, and 87.3% of accessions had 40 chromosomes. Our findings demonstrated a broad variation of cultivated greater yam at phenotypic, genotypic and ploidy levels in two groups of observed cultivars (Wu et al., 2019).

The basic chromosome number of the American yams is $n = 9$ while those of Asian and African origins are $n = 10$. Yams show high polyploidy; a race of *D. cayenesis* is reported to have a $2n = 140$ (Yamaguchi, 2020).

The objective of this study was to contribute to the understanding of D**.** alata genetic diversity by genotyping 384 accessions from different geographical regions (South Pacific, Asia, Africa and the Caribbean), using 24 microsatellite markers. Diversity structuration was assessed via Principal Coordinate Analysis, UPGMA analysis and the Bayesian approach implemented in STRUCTURE. Our results revealed the existence of a wide genetic diversity and a significant structuring associated with geographic origin, ploidy levels and morpho-agronomic characteristics. Seventeen major groups of genetically close cultivars have been identified, including eleven groups of diploid cultivars, four groups of triploids and two groups of tetraploids. STRUCTURE revealed the existence of six populations in the diploid genetic pool and a few admixed cultivars (Arnau *et al.,* 2017). In the present study, we assessed the genetic diversity of Chinese greater yam by analyzing their morphology, genotype, chromosome and ploidy. 142 cultivated greater yams were collected from eight geographical regions of China. 16 morphological characters were used for phenotypic variation assessment. Genotypic diversity was analyzed using 186 EST-SSR markers, while the chromosomes counting and ploidy evaluation were detected by flow cytometry. A broad morphological diversity was found, i.e. significant differences among accessions were found at each quantitative trait. The genetic similarity coefficients ranged from 0.42 to 0.91 with an average of 0.70. UPGMA and PCA indicated that the population was separated into two major clusters. The variation within pops accounted for 99.0% (Wu *et al*., 2019).

In this study, 26 phenotypic traits of 112 yam accessions from 21 provinces in China were evaluated, and 24 simple sequence repeat (SSR) and 29 sequence-related amplified polymorphism (SRAP) markers were used for the genetic diversity analysis. Phenotypic traits revealed that Dioscorea opposita had the highest genetic diversity, followed by D. alata**,** D. persimilis**,** D. fordii**,** and D. esculenta. Among the 26 phenotypic traits, the Shannon diversity indexes of leaf shape, petiole color, and stem color were high, and the range in the variation of tuber-related traits in the underground part was higher than that in the aboveground part. All accessions were divided into six groups by phenotypic trait clustering, which was also supported by principal component analysis (PCA). Molecular marker analysis showed that SSR and SRAP markers had good amplification effects and could effectively and accurately evaluate the genetic variation of yam. The unweighted pair-group method with arithmetic means analysis based on SSR-SRAP marker data showed that the 112 accessions were also divided into six groups, similar to the phenotypic trait results. The results of PCA and population structure analysis based on SSR-SRAP data also produced similar results. In addition, the analysis of the origin and genetic relationship of yam indicated that the species D. opposita may have originated from China. These results demonstrate the genetic diversity and distinctness among the widely cultivated species of Chinese yam and provide a theoretical reference for the classification, breeding, germplasm innovation, utilization, and variety protection of Chinese yam resources (Cao *et al*., 2021).

Study was conducted with the objective to investigate the diversity of wild and cultivated yams based on morphological characters and to assess its correspondence with folk taxonomy. The local classification system in South-west Ethiopia was studied by recording attributes of each landrace used in the folk taxonomy. Farmers differentiate various named plants based on variations in morphological, physiological, plant cycle and tuber quality attributes. A total of 75 accessions representing 30 differently named landraces were assessed using 37 qualitative and 13 quantitative characters. Principal component analysis showed that all the traits used were useful for capturing the variability among accessions. Traits such as leaf position, twining direction, type of tuber, petiole colour on young leaves, the entire wing traits, flowering and size of leaves were useful for capturing the variability among species. All the other traits were useful for capturing the variability among accessions of the same and different species. The cluster study separated the 75 accessions into four and five major clusters based on qualitative and quantitative traits, respectively. The study indicates that the local classification corresponds well with the morphological variability, but farmers somewhat underestimate the diversity of yams at lower level taxa (Asfaw *et al.,* 2021).

Genetic diversity of 26 landraces from southern China were carried out by using 18 phenotypic traits and 9 simple sequence repeat (SSR) markers, respectively. The results showed that three phenotypic traits of the leaf shape, leaf vein color and tuber flesh color, displayed higher Shannon's diversity index (*I*) and variation coefficient, which could identify the purple yam resources effectively. In addition, all accessions were divided into four groups at the Euclidean distance of 1.43, and the taxa has a high correlation with regional distribution of yam accessions, the purple yam germplasm from Jiangxi and Fujian province were mainly clustered into Group IV and Group III respectively. Based on the SSR markers analysis, the Euclidean distance among all germplasms ranged from 0.17 to 0.79, and the 26 landraces were also clearly separated into four clusters at the Euclidean distance of 0.49. Clustering results based on SSR markers and phenotypic traits were consistent roughly. Furthermore, population structure revealed the existence of three sub-populations in all accessions. These results demonstrate the genetic diversity and distinctness among the purple yam from southern China and provide a theoretical basis for the identification and utilization of purple yams (Chen *et al*., 2022).

A survey covering 540 farmers in 54 villages was conducted in six major yam growing territories covering three provinces in DR Congo to investigate the diversity, management and utilization of yam landraces using pre-elaborate questionnaires. Subject to synonymy, a total of 67 landraces from five different species were recorded. Farmers' challenges limiting yam production were poor tuber qualities (69%), harvest pest attack (7%), difficulty in harvesting (6%), poor soil status (6%). The overall diversity was moderate among the recorded yam germplasm maintained at the household level (1.32) and variability exist in diversity amongst the territories and provinces. Farmers' in territories of Tshopo and Mongala provinces maintained higher level of germplasm diversity (2.79 and 2.77) compared to the farmers in territories of Bas-Uélé (1.67). Some yam landraces had limited abundance and distribution due to loss of production interest in many villages attributable to poisons contained hence, resulting in possible extinction. Farmers' most preferred seed source for cultivation were backyard (43%) and exchange with neighboring farmers (31%) with the objective of meeting food security and generating income. In villages where yam production is expanding, farmers are relying on landraces with good tuber qualities and high yield even though they are late maturing. This study revealed the knowledge of yam landrace diversity, constraints to production and farmers' preferences criteria as a guide for collection and conservation of yam germplasm for yam improvement intervention (Adejumobi *et al*., 2022).

This paper reviews the genetic variability and heritability in yam breeding, genetic improvement of yam for tuber yield and quality traits and related attributes. It assesses the limitations of genetic parameter estimates and the ways of improving genetic gain in yam breeding programs. Utilization of complementary techniques for determination of genetic parameter estimates in yam improvement programs can increase the selection gain and reliable exploitation of the heritable variation in the desired direction (Norman and Tongoona, 2022). Knowledge of the magnitude and pattern of existing genetic variation of traits is a fundamental requirement for its genetic improvement. Breeders often use efficient selection criteria in the large numbers of early generations especially for quantitatively inherited traits. Most of the key economic traits such as specific disease resistance, quality, yield and related traits, are under quantitative genetic control. Effective utilization of genetic variability of crosses depends on the crossing parents and the selection procedures of early generations. Heritability is one of the key genetic estimates often studied. Heritability is the measure of the phenotypic variance due to genetic causes that has a predictive function in plant breeding. In yams, contrasting results have been reported on genetic parameter estimates for various traits in yams. The heritability estimates reported for fresh storage tuber yield in *D. florinbunda* were 12.4 and 58.6%, respectively. In *D. rotundata* (white yam), the broad sense heritability estimates for yam mosaic virus, fresh tuber yield and tuber dry matter contents were 58, 38, 36%, respectively (Norman and Tongoona, 2022). Variability for root shape, color and size of yam species is given in Fig. 5.

The progress achieved in empirical breeding endeavours and the development, status and application of emerging breeding tools and technologies to translate genetic gains in yam improvement have been reviewed. Significant progress has been made in yam genetic improvement over the years which has led to the identification and development of several improved clones and sources of variability for various economically important traits (Darkwa *et al*., 2020). Yam breeding aims at the genetic improvement of genotypes for their resilience and productivity amidst the dynamics of current and future production challenges thereby meeting the demands of various stakeholders in the yam value chain including producers and

Fig. 5. Variability for root shape, color and size of yam spp

consumers. Selection of adequate parents for creation of new genetic variants, and the identification and selection of superior recombinants possessing the desired traits are among the key activities in the plant breeding process. In selecting parents for hybridization and elite progenies with desired superior trait values for targeted end-users, several economic traits are simultaneously considered (Norman and Tongoona, 2022). Fresh tuber yield of yam is influenced by several genetic, biotic and abiotic factors. Some of the key factors affecting tuber yield include maturity, shoot emergence time, tuber initiation time, tuber dormancy period and tuber dry matter content.

BREEDING

Objectives of Yam Plant Breeding: Higher Productivity, Improved Quality, Disease and Insect Resistance, Short Duration Varieties, Non-Staked Varieties, Increasing Shelf-Life, Dormancy, Adaptation to Abiotic Stresses (Otoo, 2017).

Breeding: Yam breeding activities can be illustrated as follows (Otoo, 2017).:

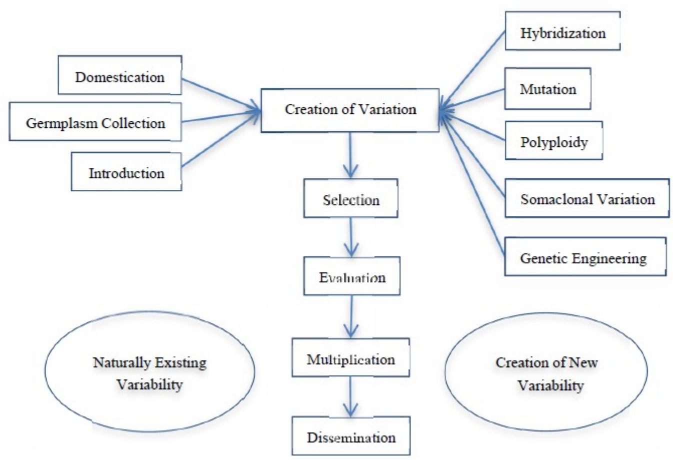

Fig. 1. Graphical illustration of activities involve in yam breeding

Tuber maturity is defined as an increase in the accumulation of citric and malic acids in the tuber, reduction in metabolic activity that supports plant growth, reduction in starch content, dry matter accumulation, and total sugar content. An immature tuber has a poor taste, short shelf-life and more susceptible to diseases. Previously, physiological maturity in yams was noted to occur when the foliage completely senesces or dries. The senescence phase of the aerial organ of yam coincides with the end of suberization of the tuber surface, which begins in proximal region of the tuber at the first stages of growth. However, early or induced senescing or drying of foliage might be due to biotic and abiotic factors such as disease incidence, drought, or other stresses. Recent studies in this aspect utilized alternative indicators with little or no influence by the environment. Traditional farmers also utilized the dramatic change in leaf pigmentation from green to dark green as an indicator of early maturing yams. However, studies have shown non-significant and low correlations between tuber maturity and the colour indices of leaves and tubers. The proximal end or head portion of a yam tuber is also believed to matures earlier than the distal end or tail portion. Thus, uniformity in tuber parenchyma colour may serve as an indicator for tuber maturity, if it occurs during the maturity phase of the crop. Early and late maturing genotypes of yam could be distinguished by time of attainment of uniform parenchyma colour within a tuber, length of tuber dormancy period and time of shoot senescence. Early planting of yams has been noted to increase tuber yield, whereas late planting reduces tuber yield due to shorter growth cycle and reduced effective tuber growth duration. Early field emergence, early tuber initiation, short tuber dormancy duration and low tuber dry matter content have also been implicated to influence tuber yield in yams. The fresh and dry tuber yields of yams differ with genotypes, species and environment (Norman and Tongoona, 2022).

Yam varieties (Darkwa *et al.,* 2020)

- A number of organizations such as IITA and its national partner breeding programmes in Sub-Saharan African (SSA) countries, INRA and CIRAD in Guadeloupe and Vanuatu, CTCRI in India and EIAR (Ethiopian Institute of Agricultural Research) in Ethiopia are involved in yam breeding. These breeding programmes have developed and released more resilient, productive and end-user preferred varieties of the dominant yam species that are used for commercial cultivation. The IITA and its national partner breeding programmes in SSA countries have developed and released improved varieties of the two dominant yam species: white yam (*D. rotundata*) and water/winged yam (*D. alata*). So far, 89 yam varieties have been identified and/or listed for commercial production in Africa of which 25 were IITA bred lines (14 varieties of *D. rotundata* and 11 varieties of *D. alata*) officially released in Ghana and Nigeria. The varieties mentioned for Benin, Togo and Côte d'Ivoire are recommended varieties by breeding programmes after testing for adaptation and suitability for consumption needs.
- Additionally, five farmer varieties with preferred culinary and agronomic features have been recognized and registered for commercial distribution in Nigeria in 2016.
- There are also more candidate improved varieties in the pipeline to be released in Nigeria, Ghana, Benin and Côte d'Ivoire.
- The cultivar testing and release mechanisms are not uniform across countries in West Africa. Ghana and Nigeria have testing and release mechanisms for official release and registration of new varieties, but the other countries in West Africa do not have this for yam. In addition, national programmes in Ethiopia and India also released a number of improved varieties. In India, CTCRI has released 11 improved yam varieties. In Ethiopia, EIAR and its local research institutions have released three yam varieties. The French institutes, INRA and CIRAD have also released improved varieties of *D. alata* and *D. rotundata* in Guadeloupe and Vanuatu.

Currently, various varieties of yams are marketed in different geographic regions. Among the most popular are hawthorn yam *(D. rotundata*), yellow yam (*D. cayennensis*), water yam (*D. alata*), lesser yam (*D. esculenta*), air yam (*D. bulbifera*) and trifoliate yam (*D. dumentorum*). Of these, *D. rotundata, D. alata*, and *D. cayennensis* are the most produced yam varieties, reaching approximately 90 % of the world's production of food yam (Otálora *et al.,* 2024).

CULTIVATION

There are several ways of propagating yams (Andres *et al*., 2017)**:**

- **Tubers-** This is the most important method of propagation in the field. The planting material is called a 'set' and the size of each set should be between 400 and 500 g. The sets are pregerminated in moist sawdust or coconut coir. There are three types of sets that can be obtained from a whole tuber –head sets, middle sets, and tail sets. Head sets are the best to plant because of the presence of eyes, which give rise to the new plants. Whole small tubers can also be planted (Andres *et al*., 2017).
- **Minisets-** Minisets are small pieces of tubers of 25–50 g size that are dipped into a fungicide–insecticide dipping. The cut surfaces are then allowed to dry before planting to produce seed yams (planting material). The miniset technique produces both healthy and high-yielding planting material while reducing costs of seed yam production and improving availability of planting material (Andres *et a*l., 2017).
- **Vine cuttings-** Vine cuttings are another way to produce plants that form healthy minitubers to be used as seed material; 6- to 8-cm-long basal vine cuttings are dipped into a rooting hormone and placed into a propagating bin. If successful, vine cuttings give a high multiplication rate without the use of tubers, which can limit the costs for plantingmaterial. This method is still poorly adopted by farmers. However, with the expected simplification of this technology, farmers could apply it in order to produce healthy seed tubers (Andres *et al*., 2017).

Propagation: Yams are propagated vegetatively from small tubers. Land should be prepared for planting by ploghing and harrowing. Tubers should be planted in trenches to a depth of 15 cm allowing at least 30 cm between individual plants and 1.5 m between rows. The soil is often mounded around plants or ridged to aid drainage. It is common practice to stake plants with a 2–4 m support to allow them to climb and ensure that all parts of the plant receive adequate sunlight (Plantvillage, 2024). Yams are propagated from cuttings of the tuber. Because the plants climb, they are provided with poles or trellises for support. It generally takes seven to 10 months before the tubers can be harvested, and this must be done by hand because mechanical harvesters tend to damage the tubers. Yams store better than most tropical tuber crops and this is one reason why they are widely grown (Science, 2024).

Planting Methods: When cultivating as monocrop, yam is planted in rows keeping an interrow spacing of 100 cm and row to row spacing of 50–100 cm. However, yams are often intercropped with maize, sweet potatoes, cassava, etc. In intercrops, the distance between yam plants is determined by the number and types of associated crops. Farmers cultivating on soils with a high water holding capacity (adequate residual moisture during the dry season) commonly plant nonsprouted tubers in the dry season. These tubers will remain dormant in the ground until they sprout. With seed yam production using minisets, yam cultivation under lowland conditions can be shifted to the dry season, which helps to avoid flood damage to the crop. The minisets are planted at the end of the rains and harvested at the beginning of the next rainy season. Yams are planted using four main methods, namely (1) ridges, and mounds, (2) holes, and flats (Andres *et al*., 2017).

Planting on ridges and mounds- Ridges of 25–40 cm height are formed at a spacing of 100 cm. Well-decomposed organic materials are applied before planting yam sets. Planting on mounds is done by forming small heaps of soil, and well-decomposed organic materials are also applied before planting (Andres *et al.,* 2017).

Planting in holes and on the flat- Yams can be planted in holesmeasuring 45 cm x 45 cm x 45 cm. After preparing the planting holes, one part of well decomposed organicmaterials ismixedwithtwo parts of sand and applied to the holes. A yam set is then planted in each hole.When planting on flats, the sets are also planted in holes and the vines are grown without staking on the ground (Andres *et al.,* 2017).

Staking: Staking of yam is necessary to optimally expose the leaves to the sunlight throughout its growth, especially in the 'climbing' yams. The larger the surface area of the plant exposed to sunlight, the higher are the yields that are obtained. Nonstaked cultivation is also practiced. It suppresses weeds better, but gives lower yields. Yam plants are usually staked soon after emergence. Different methods of staking include (1) individual staking (one stake per plant), (2) pyramidal staking (tops of several stakes are slanted to form a peak), and (3) trellising (string wire between two strong posts) (Andres *et al*., 2017).

Cultivation: The tubers of most species of yam are poisonous to humans. A few are edible and some others can be made edible by various methods including soaking, boiling, and drying. People started to cultivate yams, rather than digging up wild ones, as long as 10,000 years ago in both Africa and Asia, and some time later in the New World. The cultivation of most yams is very labor intensive. Cultivated yams generally do not produce seeds and so tubers or pieces of tuber must be planted in prepared soil, most often in mounds, to grow new plants. Some kind of framework or trellis must be provided to support the vines, unless they are grown next to trees or in fields previously planted with corn so that the old stalks can provide support. At the beginning of the dry season, the vines die away and the tubers are ready to be harvested. Most species must be dug out by hand very carefully; if they are damaged they could spoil soon. In the late 1900s, wars and famines in parts of Africa contributed to the loss of some cultivated yam varieties. Work is now going on to restore them and also to develop new varieties. Yams are a nutritious food, providing carbohydrates, some protein, and minerals like phosphorus and potassium. The tubers of many varieties can be stored as long as six months without refrigeration. For hundreds of years, yams were the most important food in many parts of Africa and the Pacific islands. There are many traditions associated with yams including ceremonies and festivals, which show their importance in traditional society. Today, West Africa produces over 90 percent of the world's yam crop, with Nigeria the largest grower. South America, the West Indies, the Pacific islands, and some parts of Asia also produce yams, though most are grown for local consumption. There is also a small international trade and some are grown for medicinal and other uses (NEW, 2024). Yams are cultivated for the consumption of their starchy tubers in many temperate and tropical regions, especially in West Africa, South America and the Caribbean, Asia, and Oceania. About 95% of yam crops are grown in Africa. A yam crop begins when whole seed tubers or tuber portions are planted into mounds or ridges, at the beginning of the rainy season. The crop yield depends on how and where the sets are planted, sizes of mounds, interplant spacing, provision of stakes for the resultant plants, yam species, and tuber sizes desired at harvest. Small-scale farmers in West and Central Africa often intercrop yams with cereals and vegetables. The seed yams are perishable and bulky to transport. Farmers who do not buy new seed yams usually set aside up to 30% of their harvest for planting the next year. Yam crops face pressure from a range of insect pests and fungal and viral diseases, as well as nematodes. Their growth and dormant phases correspond respectively to the wet season and the dry season. For maximum yield, the yams require a humid tropical environment, with an annual rainfall over 1,500 millimetres distributed uniformly throughout the growing season. White, yellow, and water yams typically produce a single large tuber per year, generally weighing 5 to 10 kilograms. Yams suffer from relatively few pests and diseases. There is an anthracnose caused by *Colletotrichum gloeosporioides* which is widely distributed around the world's growing regions. Winch *et al.*, 1984 finds *C. gloeosporioides* afflicts a large number of *Dioscorea* spp. Despite the high labor requirements and production costs, consumer demand for yam is high in certain subregions of Africa, making yam cultivation quite profitable to certain farmers (Wikipedia, 2024).

Cultivation

Seeding yam: Obtaining high-quality yam tubers requires a series of well-established steps carried out to guarantee the optimal cultivation of the yam plant. Initially, adequate soil preparation, seed selection, and subsequent seeding must be carried out (Otálora *et al.,* 2024).

Seeding material: The propagation of the yam plant is carried out utilizing whole tubers, pieces of these, or aerial bulbils, which are called "seeds". It is essential to select a good seed to obtain high yields. This is done from tubers that come from healthy, vigorous plants, free of diseases, and with excellent weights. In many cases where the tuber has considerable weight, it is divided into three sections of approximately 150 to 300 g: head or proximal part, the tail or distal part, and the center. Fig. 6 illustrates a diagram of the above. The parts obtained after cutting are cured with ashes. This methodology is called "mini-set" propagation, which considerably reduces the volume of tuber used as seed and allows the marketing of yam seeds, but does not provide homogeneity of sprout in the crop (Otálora *et al.,* 2024).

Soil preparation and seeding process: Soil preparation is one of the steps that require the most time and input in the yam growing process. Yam plants are light-loving and shade-sensitive, so they require places where there is a good amount of light available for their growth. Another important point is to plant the yam seed in light, well-drained, and friable soil, since, compared to cassava and sweet potatoes, yam penetrates the soil while expanding. Thus, compacted soils would not allow adequate growth of the tubers and could generate deformations. Likewise, the depth of the soil should be approximately half a meter to guarantee the adequate growth of the tubers. With this in mind, soil preparation generally consists of a prior process of cleaning, cutting, and even burning. Subsequently, the soil is prepared for planting in two conformations: individual mound system or ridge system (Fig. 7, 8) (Otálora *et al.,* 2024). The individual mound system consists of lifting mounds 20 to 30 cm high above the ground surface with wooden tools used manually. The yield of tubers has been reported to increase in larger mounds, however, there is a dependency on the type of soil. This system is recommended in steep terrain, where the mechanization process is complicated to do. Pits or "beds" 10-15 cm deep are made in the mounds, in which the seed is deposited and covered with grass, mulch, or soil mixed with organic matter. The depth of the pits can vary depending on the species, for example, *D. esculenta* requires shallower pits than species with longer tubers such as *D. alata*. This arrangement allows better use of runoff water, avoids possible slipping of the seed and controls or prevents problems caused by erosion. Additionally, stakes or support are included at one end of the mound to allow the development of the plant. The support allows the plant to receive a greater amount of light and thus enhances its photosynthetic process, avoids contact of the plant with the soil in times of excessive heating, and facilitates the cleaning of possible weeds in the crop (Otálora *et al.,* 2024). On the other hand, the ridges system is recommended when machinery for soil preparation is available. Also, it is recommended in areas with minimal slopes and when the land has excess humidity. Because of this, the ridges system is less common than the mound system. For this system, ridges from 1 to 1.5 m wide and 0.5 m high are made, with a plow 30 to 40 cm deep, one to two times (Otálora *et al*., 2024).

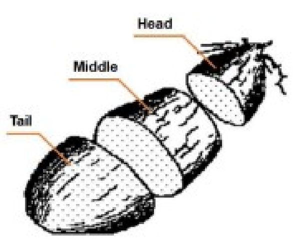

Fig. 6. Mini-set propagation technique

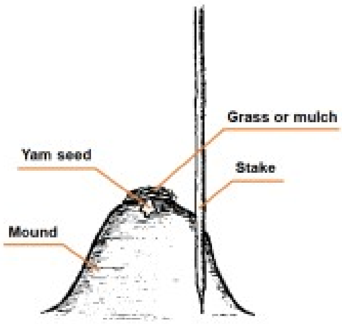

Fig. 7. Mound system

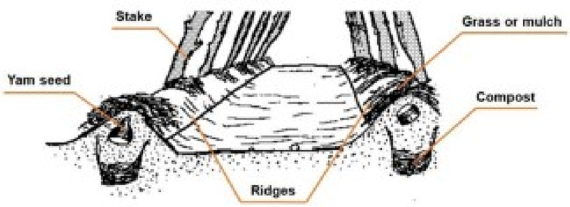

Fig. 8. Ridge system

In terms of seeding, 10,000, 15,000, and 20,000 plants per hectare can be cultivated, depending on the type of planting system. Up to 10,000 plants per hectare can be planted in mounds, while 20,000 plants per hectare can be reached in ridges (Lebot, 2009). In the case of 15,000 plants per hectare, distances of 1.0 m by 0.7 m can be used between plants. For 20,000 plants per hectare, distances of 1.0 m by 0.5 m are reached (Otálora *et al.,* 2024).

Harvesting, Curing, and Storage: Yams mature 7–9 months after planting, indicated by the yellowing of the leaves and natural dieback of the vines. In order to maximize yield, harvesting must be done when the yam reaches full maturity and before the soil becomes too dry. After removing the vines, hand tools are used to carefully dig out the tubers taking care to damage them as little as possible. After harvesting, the yams with bruises must be cured, and may be dipped in wood ash, in order to avoid fungal rot. All tubers should be cured for a few days before storing them. Yams could be stored at ambient temperature for relatively longer time (up to 6 months) than other tropical fresh produce, and the multitude of species with different maturity periods may ensure an extended period of availability of yam tubers in homes and markets. Moreover, the long storability enables producers to sell at high prices in periods of peak demand and low supply. Consequently, yam is an essential source of income and dietary calories in rural areas of West Africa during the annual period of food shortage (August–October). However, despite the good storability, tubers are often damaged during and after harvest, which can lead to postharvest losses. Good storage is best achieved in shaded, cool conditions (29–32 ^{0}C) with relative humidity of 90–95%. The tubers should be stored in a well-ventilated place that is kept dry. Traditionally, yam is stored in barns of vertically arranged wooden poles and palm leaf midribs. Another method is to bury the tubers in a ditch covered with soil and shaded by, for example, coconut leaves. Stored tubers have to be checked regularly. Barns or storage areas must be securely fenced, and traps and/or baits should be used to prevent rodents and other pest from attacking the tubers. The tubers remain dormant for a period of some 3–4 months after harvest and may start to resprout while in storage (Andres *et al*., 2017).

The last step in the development of yam cultivation is its harvest, which is carried out mainly manually, as well as its seeding. This process is performed after the senescence stage of the plant foliage has finished and when the plant is inactive since the tuber bulking has stopped. This translates to a harvesting process of 7 to 10 months after planting and is generally after the rainy season. The process consists of the initial removal of stems and foliage with a machete, then the tuber is removed from the ground. For species that produce large numbers of small, compact tubers, such as *D. esculenta* and *D. trifida*, a fork with flat blades is placed under the tubercles and then lifted by pressing it with a foot. For larger tubers, the soil is gently removed, starting from the base of the stem and down to the distal end of the tuber, which is removed when it is free. To avoid the premature harvesting of tubers, many farmers remove some of them to observe their size and color at their distal end to determine if their harvest is adequate. On the other hand, the use of machinery has been highlighted in some countries, such as India, Ivory Coast, and New Caicedonia. However, these types of harvesters have been limited to species that produce small tubers from small seeds, in addition to requiring the removal of stacking systems to avoid interference with machinery (Otálora *et al*., 2024).

Yams in West Africa are typically harvested by hand, using sticks, spades, or diggers. Wood-based tools are preferred to metallic tools as they are less likely to damage the fragile tubers; however, wood tools need frequent replacement. Yam harvesting is labor-intensive and physically demanding. Tuber harvesting involves standing, bending, squatting, and sometimes sitting on the ground depending on the size of mound, size of tuber, or depth of tuber penetration. Care must be taken to avoid damage to the tuber, because damaged tubers do not store well and spoil rapidly. Some farmers use staking and mixed cropping, a practice that complicates harvesting in some cases. In forested areas, tubers grow in areas where other tree roots are present. Harvesting the tuber then involves the additional step of freeing them from other roots. This often causes tuber damage. Aerial tubers or bulbils are harvested by manual plucking from the vine. Yields may improve and cost of yam production be lower if mechanization were to be developed and adopted. However, current crop production practices and species used pose considerable hurdles to successful mechanization of yam production, particularly for small-scale rural farmers. Extensive changes in traditional cultivation practices, such as mixed cropping, may be required. Modification of current tuber harvesting equipment is necessary given yam tuber architecture and its different physical properties (Wikipedia, 2024). Yam is harvested 10-12 months after planting, in November, December, or January. Subsequently, the yam is sold by farmers to local distributors, who market the yam locally or use it for export processes (Otálora *et al*., 2024).

Production systems:

Mono cropping- When cultivating as a mono-crop, yam is planted in rows, keeping an interrow and intercrop spacing depending on the farmer's desires, and it is planted without mixing it with another crop. Regarding spacing, if the farmer wants to have big-sized tubers at harvest time, the spacing should be increased, but if the farmer wants to have smaller-sized tubers, then the space should be reduced (Malichi, 2024).

Intercropping- In an intercropping system, yam is cultivated in association with other crops. It is essential that the farmer selects crops that will be beneficial to the yam, such as leguminous plants, and the number and types of associated crops determine the distance between them (Malichi, 2024).

Agroforestry System- In an agroforestry system, Yam is cultivated in association with trees that act as living stakes for the yam stems that need to be staked. In addition to staking, trees can also help fix nitrogen in the soil, depending on the type of tree used. In this system, it is crucial to start by planting the trees before the Yam or having the trees in place before the yam because as soon as Yam stems start growing, they need to be staked. The trees used must be compatible with Yam (Malichi, 2024).

Global production: Yam cultivation has had continuous growth since the beginning of this century, reaching an average value close to 2 % per year. This growth is due to the investment of different countries in yam, allocating more land for its cultivation and harvest. A general increase is appreciated from 2000, when production of approximately 40 million tons of yam was reached, in the year 2018, with a production of 72 million tons. This growth has been associated with the increased exploitation of yams as food and as a source of compounds with medicinal value. Likewise, the yield has been kept in a narrow range with an oscillating value between 8 and 11 tons of yam per hectare (Otálora *et al.,* 2024). Since then, crop production has gradually increased and Africa has participated with most of the world yam production. In 2018, Africa produced about 70 million tons of yam, this was 97 % of world production in that year, and the growth of the crop reached a value of 2 % per year. Likewise, countries within Africa are the largest producers worldwide, such as Nigeria, Ghana, Ivory Coast, Benin, and Ethiopia. While yam production in Latin American, Caribbean, and Asian countries has been much less, however, with the same importance of cultivation at the local level. Thus, Haiti, Colombia, and Brazil have had relevance in yam production in America and the Caribbean, with productions exceeding 200,000 tons in 2018 (Otálora *et al*., 2024). In 2020, world production of yams was 75 million metric tons led by Nigeria with 67% of the total (Wikipedia, 2024). Despite the productive development of yams worldwide, its market has been limited locally with a low quantity of export and import of the product compared to the market for other crops, such as cassava and potatoes. Thus, in 2018 the amount of yam exported did not exceed thousands of tons. However, the participation of Colombia and Costa Rica in yam exports to the United States, Puerto Rico, and countries of the European Union has been highlighted. The international market for yams is limited and smaller compared to other crops, such as cassava or potatoes. This does not exceed thousands of tons exported annually (Otálora *et al*., 2024). Likewise, *D. rotundata* and *D. alata* have had worldwide production and marketing, including Africa, Asia, and LAC. Other species have had greater production in specific regions, such as *D. trifida* or yam cush-cush, which is produced and marketed in the Colombian Caribbean. It is important to highlight that the difference between the cultivated varieties lies in the physical and chemical aspects of their tubers, which may present different consistency and flavor for the consumer. Thus, *D. alata* produces tubers with light brown to dark brown coloration and cream-colored pulp. While, *D. rotundata* has tubers with a white pulp, and *D. cayannensis* has tubers with a yellow pulp (Otálora *et al*., 2024). Currently, various varieties of yams are marketed in different geographic regions. Among the most popular are *D. rotundata, D.cayennensis*, and *D. alata*. Also, lesser yam or *D. esculenta*, air yam or *D. bulbifera*, and trifoliate yam or *D. dumentorum*. Of these, *D. rotundata, D. alata*, and *D. cayennensis* are the most produced yam varieties, reaching approximately 90 % of the world's production of food yam. Likewise, *D. rotundata* and *D. alata* have had worldwide production and marketing, including Africa, Asia, and LAC. Other species have had greater production in specific regions, such as *D. trifida* or yam cush-cush, which is produced and marketed in the Colombian Caribbean (Otálora *et a*l., 2024).

Nutrition: Nutritionally, the yams are equivalent to the common potato, containing 80-90% carbohydrates, 5-8% protein, and about 3.5% minerals. Yam production is now declining because cassava (*Manihot utilissima*) and sweet potatoes (*Ipomea batatas*)—sources of starch that are easier to cultivate—are increasingly being used. Yams are not fed to livestock because they are more expensive than other kinds of animal feed (Science, 2024).

Eating: Before eating, yams are usually peeled and then either boiled, roasted, or fried. In Africa yams are usually prepared as *fufu* or *four-fou*, made from peeling, cutting, and boiling the tuber, and then pounding it into a gelatinous dough. It is served with soups or stews or cooked raw in palm oil. Likewise, appreciable concentrations of steroidal saponins and derivatives have been detected, which are precursors of hormones with different properties within the body, including antitumor, anticancer, and antiviral properties. This fact has allowed its application in the pharmaceutical and cosmetic industry (Otálora *et al*., 2024).

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