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REVIEW

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Looking beyond history: tracing the dispersal of the Malaysian complex of crops to Africa

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Abstract

In his 1959 book, *Africa: Its Peoples and Their Culture History*, George P. Murdock suggested that a Malaysian complex of crops dispersed to Africa in ancient times across the Indian Ocean along the Sabaean Lane. The Malaysian complex comprised bananas, sugarcane, taro, three yam species, rice, Polynesian arrowroot, breadfruit, coconut, areca palm, and betel leaf. Except for rice, arrowroot, and potentially taro, most of these crops were domesticated in the Island Southeast Asia-New Guinea region, from where they dispersed to Africa. Our reassessment of agronomic, archaeological, classical, genetic, and historical sources shows that we need to go beneath standard historical narratives to recover a much more ancient and complex history of crop introductions to Africa. Despite considerable uncertainty and fragmented research, we were able to conclude that the Malaysian complex of crops did not arrive in Africa as a complete assemblage at one time or along one route. Multiple lines of evidence suggest that these crops arrived in Africa at different times and followed different pathways of introduction to the continent.

KEYWORDS

archaeobotany, classical antiquity, crop dispersal, crop introduction, G. P. Murdock, Indian Ocean, Malaysian complex, tropical food kit

FOOD PLANTS OF ASIAN ORIGINS THAT PLAYED A ROLE IN AFRICAN CULTURAL HISTORY

Plantain (*Musa* L. cvs.), taro [*Colocasia esculenta* (L.) Schott], and greater yam (*Dioscorea alata* L.), also known as the "tropical food kit" (Blench, 2009), are crops that likely originated in Island Southeast Asian-New Guinea (ISEA-NG) (Table 1) and are now widely cultivated across the wet tropics of Africa. The American anthropologist George Peter Murdock (1959) identified these crops as members of a broader Malaysian complex, comprising four groups: root crops such as Polynesian arrowroot [*Tacca leontopetaloides* (L.) Kuntze], taro [*Colocasia esculenta* (L.) Schott] and three yam species [*Dioscorea alata* L., *Dioscorea bulbifera* L., and *Dioscorea esculenta* (Lour.) Burkill]; fruits and nuts, including bananas and plantains[1] (*Musa* cvs.), breadfruit [*Artocarpus altilis* (Parkinson) Fosberg)] and coconut (*Cocos nucifera* L.); condiments and drugs such as areca palm (*Areca catechu* L.), betel leaf (*Piper betle* L.), and sugarcane (*Saccharum officinarum* L.); and rice (*Oryza sativa* L.) as the sole cereal (Figure 1). Based on his review of linguistic, historical, and ethnographic evidence, Murdock (1959) was seeking to infer the distribution and establishment of traditional plant cultivation before widespread Arabic and European influences. He noted the influence that the Indian Ocean played in the interchange of cultivated plants and concluded that these crops were introduced to Africa through the Sabaean Lane, a trade route that connected southeastern tropical Africa to India since at least the first millennium BC (Murdock, 1959).

Exploiting the monsoon system, merchant vessels were able to sail from the Malabar coast of southwestern India to the Horn of Africa and along East Africa, fueling the development of food production and exchange in the first millennium BC. Murdock (1959) distinguished the so-called Indian complex (cultivated plants of Indian origins that reached East Africa and African plants that reached India), from the Malaysian complex, cultivated crops of Island Southeast Asian origin that were introduced into Africa. He grouped the

[1]Plantains and bananas are referred to as "bananas" here, unless specified differently in a cited source.

TABLE 1 Areas of domestication for each crop of the Malaysian complex (with key references)

Common name	Taxon	Region of domestication	Reference
Banana/Plantain	*Musa* cvs.	Island Southeast Asian-New Guinea (ISEA-NG)	Perrier et al., 2011
Taro	*Colocasia esculenta*	India/Southeast Asia	Matthews et al., 2012; Chaïr et al., 2016; Ahmed et al., 2020
Greater yam	*Dioscorea alata*	ISEA-NG?	Coursey, 1972, 1976; Martin and Rhodes, 1977; Lebot et al., 1998; Lebot, 1999; Malapa et al., 2005; Arnau et al., 2017
Lesser yam	*D. esculenta*	India-SEA?	
Aerial yam	*D. bulbifera*	India-SEA?	
Sugarcane	*Saccharum officinarum*	ISEA-NG	Daniels and Daniels, 1993; Grivet et al., 2004; Moore et al., 2013
Coconut	*Cocos nucifera*	ISEA-NG	Gunn et al., 2011; Geethanjali et al., 2018
Rice	*Oryza sativa* subsp. *japonica*	China	Khush, 1997; Fuller et al., 2009; Choi et al., 2017; Zuo et al., 2017; Gutaker et al., 2020
	Oryza sativa subsp. *indica*	India	Khush, 1997; Fuller et al., 2014; Choi et al., 2017; Gutaker et al., 2020
Breadfruit	*Artocarpus altilis*	New Guinea region	Zerega et al., 2004
Areca palm	*Areca catechu*	ISEA-NG	Heatubun et al., 2012
Betel leaf	*Piper betle*	Unknown	
Arrowroot	*Tacca leontopetaloides*	Pantropic	

FIGURE 1 Images of Malaysian complex crops grown in Africa. (A) Banana tree. (B) Coconuts. (C) Areca palm and nuts. (D) Sugarcane. (E) Breadfruit. (F) Arrowroot. (G) Rice. (H) Taro. (I) Yam. *Image credits*: (A–D, G–I) I. M. Grimaldi; (E) Forest and Kim Starr; (F) Ton Rulkens

Malaysian crops broadly according to geographical distribution: (1) bananas and taro were widely cultivated across equatorial Africa; (2) yams and sugarcane were grown throughout tropical Africa; (3) coconut had a modest distribution along Africa's tropical coasts; (4) breadfruit became established on Madagascar, the Comoro Islands, and Zanzibar; (5) areca palm and betel leaf on Madagascar and the Comoro Islands; and, (6) rice and Polynesian arrowroot on Madagascar. Even though the geographical distributions of cultivation for these crops represent to some degree their biogeographical suitability, they

also are suggestive of overlying sets of historical processes indicating different periods of introduction to the African continent for the various crop species and even cultivars of the same crop, as suggested for banana (De Langhe et al., 2009; Perrier et al., 2011, 2019) and taro (Grimaldi, 2013; Grimaldi et al., 2018).

Some crops only became established on islands off East Africa even though they could be cultivated more broadly on mainland Africa. Breadfruit, for example, now grows in wet tropical environments across Africa, but was restricted to islands off the coast of East Africa until the last hundred years or so (Murdock, 1959), whereas bananas, sugarcane, taro, and yams spread across equatorial Africa. Why did some plants become so extensively cultivated on the African continent, whereas others were geographically limited to islands off the eastern coast?

If the extent of adoption is taken as a guide to time depth, then bananas, sugarcane, taro, and yams were seemingly introduced earlier than the other Malaysian crops because they were incorporated into nascent farming systems across equatorial Africa. The timing of these introductions has been suggested at around 2500–3000 years ago, during the formation and expansion of Bantu cultivation practices in West and Central Africa (Dalziel, 1955; Blench, 2007; Rangan et al., 2015; Power et al., 2019). If this interpretation is correct, these crops were introduced under vegetative forms of cultivation because they are cultivated through clonal propagation, presumably along the African eastern or northern coasts, more than 3000 years ago. Subsequently, they were spread by farmers across the continent (De Langhe, 2007). The archaeobotany of introduction for vegetatively propagated crops to Africa, like anywhere else, is poorly documented and taxonomically imprecise or debatable (Neumann and Hildebrand, 2009; Power et al., 2019; Denham et al., 2020).

A second group of crops—minimally comprising areca, betel leaf, breadfruit, rice, and Polynesian arrowroot, new cultivars of earlier introductions—was introduced to the East African islands within the last 1500–1000 years (Rangan et al., 2015; Crowther et al., 2016). By this time, farming practices had already become established along the east coast of the African mainland, yet these mainland cultures did not adopt this second group of crops from adjacent island-based cultures (Crowther et al., 2016). These later introductions were plausibly associated with the early human colonization of Madagascar and other islands by Austronesian language speakers within the last 1000 years, although there is some debate about the presence of earlier colonists on Madagascar (Crowther et al., 2016). Certainly, all crops within the Malaysian complex were known to the coastal communities of Island Southeast Asia, probably including those in Borneo and adjacent islands, who colonized Madagascar (Denham, 2011, 2013).

However, the actual introduction of Malaysian crops to Africa is likely much more complex than this two-wave, historical model suggests. Recent genetic characterizations of banana (Perrier et al., 2011, 2019) and taro varieties (Grimaldi, 2013; Chaïr et al., 2016) suggest multiple introductions of different crops and varieties to Africa. Not only do the Malaysian complex members have different geographical distributions on the African continent (FAOstat, 2020), multidisciplinary evidence suggests that these crops did not arrive together or along the same pathway (e.g., Grimaldi et al., 2018; Perrier et al., 2019). The Malaysian crops followed different routes of introduction around and across the Indian Ocean over the last 3000 years. Furthermore, historical information on these Malaysian crops has never been fully reviewed in the classical literature, except for taro (Grimaldi et al., 2018). The works of early naturalists such as Theophrastus, Dioscorides, and Pliny provide valuable insights on the knowledge of plants in antiquity. References to food culture and agronomic practices were also recorded by ancient lexicographers and geographers such as Megasthenes and Strabo. Here, we examine these classical sources (Appendix S1; abbreviations for citations for these sources are given in the table) with recent genetic, archeological, and linguistic research to re-evaluate Murdock's work and provide a new interpretation of the dispersal of the Malaysian complex crops to Africa.

A deeper look into Murdock's Malaysian crop complex

None of the Malaysian complex of crops was domesticated on Peninsular Malaysia. Murdock was influenced by presuppositions regarding the origins of these crops, such as the compendium on economically useful plants of the Malay Peninsula by Burkill (1935). More recent multidisciplinary evidence enables refinement of the domestication regions for many of the Malaysian crop complex; areca palm, bananas, coconut, breadfruit, sugarcane, taro, and greater yam were domesticated in the Island Southeast Asia-New Guinea region, whereas rice was domesticated in China (Table 1). The regions of initial domestication for these crops have only limited relevance to their subsequent dispersal to Africa because most were already widely distributed within the Southeast Asia-New Guinea region by c. 3000 years ago (Donohue and Denham, 2010; Bellwood, 2011; Denham, 2010, 2013).

Further, although the incorporation of crops into cultural traditions can provide some indication of the relative time since a crop was adopted for cultivation, cultural embeddedness is not necessarily a reliable indicator of antiquity (Rangan et al., 2015). The cultural significance and incorporation of crops into social practices can emerge over a few hundred years, not necessarily over millennia; nonetheless, it can be used to provide a relative indication of antiquity (Denham, 2018). Across much of equatorial Africa, bananas and taro have been important staples and symbolically important for numerous Bantu-speaking communities (Werner, 1968), thus indicating longer-term cultivation than that of recent, yet widely cultivated introductions such as manioc (*Manihot esculenta* Crantz) (Murdock, 1959).

Most Malaysian crops are propagated by tubers, shoots, or cuttings. Notable seed-propagated exceptions are rice and betel palm. Vegetative propagation characterizes many traditional cultivation practices in tropical rainforests (Barton et al., 2012) and predominates across the Pacific, New Guinea, and parts of Southeast Asia (Li, 1970; Yen, 1973; Denham, 2011). Archaeobotanical investigation of vegetatively propagated crops in the tropics requires different techniques from those ordinarily used for cereals, legumes, and tree crops, which heavily rely on the macrobotanical investigation of seeds, nuts, and processing waste (Golson and Ucko, 1994). Although areca nuts and coconut shells, as well as rice grains and spikelets, can be identified using standard macrobotanical techniques (Fuller et al., 2009; van Der Veen and Morales, 2011), crops such as bananas, sugarcane, taro, and yams are primarily detected using microfossil remains of parenchyma, phytoliths, pollen, and starch grains (Hather, 1994; Prebble et al., 2019; Denham et al., 2020). In Africa, the microbotanical techniques required to identify these crops are not regularly applied in archaeological investigations, so these crops have remained largely unnoticed by archaeologists. A more systematic application of microbotanical techniques in the future will undoubtedly clarify the antiquity of vegetatively propagated Malaysian crops in Africa.

FOOD PRODUCTION IN A PREHISTORIC CONTEXT

Banana (*Musa* cvs.)

Musa comprises 82 species (POWO, 2021a), of which edible triploids of sweet banana (AAA) and plantain (AAB) are the most commonly cultivated. Bananas are not indigenous to Africa, although the Musaceae genus *Ensete* Bruce ex Horan is native to East Africa. During the last two decades, considerable progress has been made in reconstructing the domestication history of this complex genus, with several stages of mutation, crossing, and selection occurring across the ISEA-NG region (Perrier et al., 2011). Following the loss of viable seeds, cultivated bananas depend upon humans for colonizing new areas, yet the history of dispersal of edible diploids (AA) and triploids (AAB and AAA) to Africa remains unclear (Perrier et al., 2019). The retrieval of *Musa* phytoliths at the archaeological site of Nkang (Cameroon) provided evidence of banana cultivation in Africa during the first millennium BC (Mbida et al., 2000, 2001). Although questioned by some (Neumann and Hildebrand, 2009), the archaeobotanical evidence has been verified (Perrier et al., 2011), and this early date is tentatively supported by linguistic evidence (Vansina, 1990; Blench, 2009).

Dalziel (1955) hypothesized that bananas were introduced to Africa via Egypt in ancient times, but the crop is generally considered to have been absent from the Mediterranean during classical antiquity. A description of a tree named *pala* with fruits named *ariera* in Pliny's *Natural History* (*NH* 12,24[2]) in the first century AD was interpreted as banana by Bauhin (1623) (Appendix S2). Pliny's text resulted from his conversations with South Indian merchants who were describing jackfruit (*Artocarpus heterophyllus* Lam.), banana (or plantain), and possibly mango (*Mangifera indica* L.) (Smith, 1903; Marr, 1972). *Pala* in Tamil refers to jackfruit, which was abundant around the city of Sydraci in northern India, although Smith (1903) recognized that the leaves, described as 133 × 90 cm large, were those of banana. In support of Smith's interpretation, bananas are not juicy, and they are certainly not big enough to feed four people, unless the interpretation here is of the whole bunch. The description of the fruit coming out of the bark is in accordance with a bunch of bananas hanging from a plant, but at the same time it would fit that of jackfruit as well. Pliny mostly used second-hand information to compile his *Natural History* (as he acknowledged). His account on *pala* was likely based on Theophrastus' *Enquiry into Plants*, written three centuries earlier, in which a plant was described with leaves resembling ostrich wings (*HP* 4,4,5) (Langdon, 1993). Linguistic evidence supports the idea that Pliny was referring to the banana, as the term *pala* resembles the word *palam*, a vernacular name for banana in southern India (Pushpangadan et al., 1989). In the 16th century, Garcia Da Orta (Ficalho, 1891) also recorded *palam* as a name for banana in the Malabar region in southern India. Many interpretations have been proposed for the term *ariera*, which is present only in Pliny's text. It could be a corrupt transcription of *ariti*, a word for banana in Telugu (Kays, 2011) or a name to indicate an unidentified fruit of the Aryan people living between Persia and India, who had been previously cited by Pliny (Perutelli, 1984).

While the classical texts suggest that banana was becoming known there, Pliny's writings cannot be conclusive because it is possible that mixed species were being referred to, where leaves and fruits of different species may have been incorrectly considered a single species. Moreover, the presence of banana in the Mediterranean and North Africa is not strongly supported by archaeological evidence until the 1st millennium AD. A pot containing fermented product made with banana (*Musa*) cellular tissues was reported for an Eighteenth Dynasty burial from Egypt, dating to 1550/1549–1249 BC (Bernsen, 1976). Similarly, dietary proteins of *Musa* have been reported for a burial context on the eastern Mediterranean coast dating to c. 1100–1000 BC (Scott et al., 2021). However, these taxonomic identifications of banana should be considered tentative until corroborating archaeobotanical information and refinement of the phytochemical methods are forthcoming.

In the early 20th century, the Paris Natural History Museum received the grave goods of a mummy and 25 pots containing botanical remains excavated in the Egyptian necropolis of Antinopolis. In one of the pots, a fragment of

[2]Standard citation style for classical sources: abbreviation of the source (see Appendix S1), book number, paragraph number, and line number, when a specific line is cited.

FIGURE 2 Banana in Rauwolf's IVth herbarium. Dried sample of *Musa* × *paradisiaca* collected by Rauwolf in Lebanon during his journey in the Middle East. *Image credit*: Naturalis Biodiversity Center

a banana leaf was found, transversely folded, rolled into a cylinder, and tied with a date palm string (Bonnet, 1905). This leaf fragment suggests banana cultivation in Egypt since at least the 5th century AD. Banana skin fragments occur in an Islamic-period deposit at Quseir al-Qadim in Egypt, dated between 1040–1160 AD (van der Veen and Hamilton, 2011).

Early Arabic botanists documented the banana and indicated that it was grown in East Africa and as far west as Spain. In the 10th century AD, during a journey along the coasts of East Africa, al-Masudi recorded banana as food (Barbier de Meynard and Pavet de Courteille, 1864). In the *Calendar of Córdoba for the year 961*, Arīb ibn Sad mentioned that banana starts growing in September and that, by November, the trees must be covered so that they do not freeze (Dozy, 1961). Avicenna (11th century) included banana in the Canon of the Medicine (Gruner, 1973). In the 16th century, the German botanist Rauwolf collected a sample of banana leaf while traveling in the Middle East (Figure 2).

The multidisciplinary evidence for the long-term history of banana in Africa suggests multiple time periods, likely with different cultural associations, for the introduction of specific cultivar groups to the continent (Perrier et al., 2011, 2019). A consideration of the archaeological evidence in Cameroon, as well as finds from mortuary contexts in Egypt, suggests that AAB plantains, such as those grown in Central and West Africa today, and potentially other banana cultivar groups, were introduced to Africa more than 2000 years ago. Subsequently, triploid AAA and diploid AA banana cultivars were distributed widely across East Africa, North Africa, and into Spain over 1000 years ago by Arabic-speaking peoples and traders. The seedy, wild-type AA bananas of Pemba and Madagascar are of similar or more recent antiquity and were likely introduced from Island Southeast Asia by colonizing Austronesian-speaking populations in the late 1st millennium AD.

Taro [*Colocasia esculenta* (L.) Schott]

Archaeological research in Southeast Asia and Papua New Guinea has demonstrated the use of taro in the Pleistocene, dating to 28,000 years ago (Loy et al., 1992; Barton and Paz, 2007) and its cultivation in the early-to-mid Holocene, from at least 7000–6400 years ago (Denham et al., 2003; Fullagar et al., 2006). The natural range of taro extends from northeastern India to northern Australia and New Guinea (Matthews, 1995), and within this region, it is debated whether taro has undergone multiple domestications (Ahmed et al., 2020).

In his work, Murdock (1959) did not associate taro or any Asian crop to the classical Greco-Roman world; however, historical texts recorded taro as big arum or edible arum, which was present in the Mediterranean by at least the 4th century BC (Grimaldi et al., 2018). In the 2nd century AD, Galen (*Al. Fac.* 3,61) provides the earliest written reference to taro in Africa, writing that the edible arum was shipped to Italy from Cyrene (present-day Libya) "because it can keep for very long time without rotting". Due to abundant water and fertile lands for agriculture, the Greeks occupied the region and established Cyrene in the 7th century BC (Herodotus *Hist.* 4, 158,199), which was subsequently used by the Romans as a commercial hub. Taro is still grown today in the Wadi Darnah, a virtually year-round water source on the northern Libya coast (Ringenbach, 2014).

In the 3rd century AD, taro became known as colocasia, a name previously used in the Greco-Roman world to indicate the roots of the Indian lotus plant (*Nelumbo nucifera* Gaertn.) (Grimaldi et al., 2018). Observations made by early Arab travelers indicate the cultivation of taro in Yemen and along the East African coast during the 10th century AD (Barbier de Meynard and Pavet de Courteille, 1864) and in Mali during the 14th century (Defrémery and Sanguinetti, 1858). The retrieval of desiccated corms of taro at the archaeological site of Quseir al-Qadim confirm that taro was present in Egypt during the 10th–11th century AD (van der Veen and Morales, 2011). The increasing frequency of references to taro as a medicinal and food crop in the Arabic literature highlight the popularity of this crop, which

was rediscovered by European botanists from the 14th century AD onward during the Renaissance (Grimaldi et al., 2018).

Yams (*Dioscorea* spp.)

Dioscorea is a pantropical genus of perennial vines, comprising more than 630 species (POWO, 2021b). Ten species of yam are staple crops, cultivated for their starchy tubers. Additionally, wild yam tubers are consumed as famine foods in many places globally (Coursey, 1975) and were also transplanted by hunter-gatherers (Gallois et al., 2021). The English term "yam", the Portuguese *inhame*, the Spanish *ñame* and French *igname* likely derive from the Mande word *niam* or the Temne *enyame*, which both mean food (Ayensu and Coursey, 1972). In Africa, three yam species are widely cultivated. The most economically significant is greater yam (*D. alata* L.), which was probably domesticated in the New Guinea region (Table 1). The other two economically important species are both West African domesticates: yellow Guinea yam (*D. cayenensis* Lam.), and white Guinea yam [*D. cayenensis* subsp. *rotundata* (Poir.) J. Miège] (Scarcelli et al., 2019). The lesser yam [*D. esculenta* (Lour.) Burkill] and the aerial yam (*D. bulbifera* L.) are less frequently cultivated in Africa, are of unclear geographical origin within a broad region encompassing India and Southeast Asia and are not discussed further here (Burkill and De La Bâthie, 1950; cf. Lebot, 1999).

On the African mainland, yam cultivation is concentrated in areas of high rainfall around the Gulf of Guinea. As rainy seasons become shorter and less intense around 10°N (Ayensu and Coursey, 1972), tuber cultivation is supplanted by an increasing reliance on cereals, with sorghum [*Sorghum bicolor* (L.) Monech] and pearl millet [*Pennisetum glaucum* (L.) R.Br.] as staples. Additionally, other indigenous yams (*D. schimperiana* Hochst. ex Kunth, *D. abyssinica* Hochst. ex Kunth, *D. praehensilis* Benth., and *D. sagittifolia* Pax.) are important crops in the densely populated southern and western parts of Ethiopia (Hildebrand et al., 2002).

African yams were domesticated in the "Yam Zone", from the Ivory Coast to Cameroon, perhaps as early as 7000 years ago (Dumont et al., 2006; Scarcelli et al., 2019), although there is currently no archaeobotanical evidence to support this interpretation. However, multiple lines of inferential evidence suggest that yam cultivation is ancient in this part of the world: the presence of both wild, semi-cultivated and domesticated species and the strong social and spiritual links between people and yams exemplified by the celebrations at the beginning of the yam harvest in the New Yam Festival (Coursey and Coursey, 1971; Gallois et al., 2021).

On Madagascar, there are 32 indigenous *Dioscorea* species and another five that have been introduced (Burkill and De La Bâthie, 1950). *Dioscorea alata* is known locally as *ovy* (with vernacular variants), which means "root", and is similar to the Malayan and Indonesian names used to indicate the same species (Kays, 2011). Early chroniclers of the flora of Madagascar, such as Cauche (1651) and Flacourt (1658), recorded *D. alata* among the most useful plants grown on the island (Appendix S3). *Dioscorea alata* was plausibly introduced to Madagascar during colonization by Austronesian-speaking seafarers in the late first millennium AD. Subsequently, Arab and Swahili-speaking traders could have spread it along the East African coast, although the Portuguese are often accredited with its introduction to West Africa (Burkill and De La Bâthie, 1950).

How and when *D. alata* arrived in Africa is a matter of speculation. Most historical and archaeobotanical sources do not differentiate between the introduced greater yam (*D. alata*) and indigenous *Dioscorea* species. If greater yam was added to traditional cultivation practices that had formerly focused on indigenous yams, then the importance of *D. alata* in culinary traditions and ceremonial life may not be a reliable indicator of antiquity. Murdock (1959) included *D. alata* and *D. esculenta* in the Malaysian complex and proposed that Austronesian speakers brought these tubers from Southeast Asia to Madagascar and East Africa when navigating across the Indian Ocean. The presence of yams on Madagascar and the associated linguistic evidence of a Malayan signature may support Murdock's view, but his theory is less relevant for the African mainland. Although further study is needed, the widespread distribution of *D. alata* across the Old World tropics suggests a much longer chronology for dispersal and cultivation than currently suggested.

MEDICINAL, EXOTIC, AND EXPENSIVE: EARLY TRADE IN CANE AND RICE

Sugarcane (*Saccharum officinarum* L.)

The genus *Saccharum* has a complex evolutionary history (Table 1). A recent genomic analysis (Pompidor et al., 2021) revealed that three founding ancestral genomes were involved in the origin of modern sugarcane cultivars. Brandes (1956) established that *S. officinarum* was domesticated in Papua New Guinea from plants of *S. robustum* E.W. Brandes & Jeswiet ex Grassl that were selected for their high sugar content. Once humans introduced these cultivars into continental Asia, they hybridized or went through allopolyploidization with wild local forms of *S. spontaneum* L., and in addition to autopolyploidy events, they gave rise to cultivars better adapted to subtropical environments (Pompidor et al., 2021).

From India, sugarcane was shipped to the east coast of Africa as recorded in the *Periplus of the Erythrean Sea* in the 1st century AD (Periplus Mare Erythraei, *PME*), where sugarcane is mentioned as "the sweet cane they call sakcari" (*PME* 14,5). The Greek word *sakcharon* is a loanword from the Sanskrit *śarkarā* (TLG, 2014) or *karkara*, which mean

gravel or crystallized sugar. In Prakrit, *karkara* was written as *sakkara* and when Arabic traders introduced sugarcane to Persia, the word became *sakkar* and then *sukkar*, from which the word sugar was ultimately derived (Täckholm and Drar, 1941).

Interpretations of the Hebrew word *kaneh* and *keneh* in the Old Testament have been taken to suggest ancient Jewish communities used sugarcane (Isaiah 43:24, Ezekiel 27:19) (Jensen, 2012). However, this is probably a misinterpretation, and the word more likely indicates hemp (*Cannabis sativa* L.) (Hanuš, 2009). Nonetheless, the "sweet reeds" or "reeds that produce honey" in Greek texts do refer to sugarcane. According to Theophrastus (fr. 190 *apud* Photius *Bibliotheca* 278, 10), there were three types of honey, of which one was made from reeds (Appendix S4). Although such references are insufficient to determine whether the crop was sugarcane or another sweet, stalked cane grass or reed, the references to honey made from reeds increase with time. While describing India, Strabo (*Geogr*. 15,1,20) reported that Nearchus (4^{th}–3^{rd} century BC) and Eratosthenes (3^{rd} century BC) wrote about sweet reeds that produced honey (Appendix S5). Diodorus, a Greek historian and Strabo's contemporary, also mentioned sweet reeds growing in India (*HL* 2,36,5). French (2005) suggested the reeds sent by the king of Maurusians, which were mentioned by Strabo, were sugarcane (Appendix S6). According to Strabo, the Maurusians were people who lived in parts of northern Africa that is now Morocco (*Geogr*. 17,3,2). These historical sources suggest sugarcane was present in North Africa, parts of the Mediterranean, and India around the beginning of the Christian era (Appendix S7).

Scholars have different opinions on whether these texts are referring to sugarcane (Mintz, 1985; Karttunen, 1997; Sato, 2009; Geerligs, 2010). However, in the first century AD, the word *sakcharon* is clearly mentioned by Dioscorides (*MM* 2,104), who explicitly referred to it as a medicinal plant to cure intestinal, stomach, and kidney problems (Appendix S8). Similarly, Pliny (*NH* 12,32) mentioned *saccaron* as a sugar-producing plant that was used medicinally (Appendix S9).

Historical accounts of the presence of sugarcane in Southwest Asia have been recorded since the first millennium AD. Persian-speaking populations were responsible for its spread during the Sasanian Empire (224–651 AD), with subsequent cultivation documented during the Caliphate of Omar in the 7^{th} century AD (Täckholm and Drar, 1941; Watson, 1983). The crop had reached Syria by the end of the 7^{th} century AD and Cyprus, Morocco, and Spain in the 8^{th} century AD (Täckholm and Drar, 1941). From the 9^{th} century AD onward, its range of cultivation was greatly extended, including parts of the African mainland (Watson, 1983).

Watson (1983) proposed an introduction of sugarcane to East Africa and from there to Madagascar. However, linguistic evidence suggests sugarcane was separately introduced from Island Southeast Asia to Madagascar. The Malagasy names for sugarcane are *fisika* and *fary* (Bosser, 1969; Beaujard, 2011); *fary* was the term originally applied to rice and transferred to sugarcane because rice had already been introduced to Madagascar under another name. Following Beaujard (2011), sugarcane was introduced to Madagascar between 1100 and 1400 AD.

Desiccated fragments of sugarcane, including diagnostic nodes and roots, were found at the archaeological site of Quseir al-Qadim and dated to 1120–1210 AD (van der Veen and Morales, 2011). These are the only macrobotanical remains of this crop found in Africa. However, historical texts suggest a much greater time depth for the introduction of sugarcane to Africa, potentially extending over the last 2000 years.

Rice (*Oryza sativa* L.)

The evolutionary history of rice is a complex matter that has been subject of numerous studies and different theories have been proposed to reconstruct its domestication history (Table 1). Recent genetic, archaeological, and archaeobotanical evidence suggest that rice originated multiple times in South and East Asia but that it was initially domesticated in the lower and middle reaches of the Yangtze River valley in China c. 9000–6000 years ago (*Oryza sativa* subsp. *japonica*) (Choi et al., 2017). Following climatic changes, rice (subsp. *japonica*) moved to India along early trade routes and hybridized with wild local populations (*O. rufipogon* Griff. or a cultivated proto-*indica*) that resulted in the origin of Indian rice (subsp. *indica*) c. 4000 years ago (Choi et al., 2017; Gutaker et al., 2020). In India, rice was grown on the flood plains as a summer crop, which complemented the cultivation of barley and wheat during the winter (Sallares, 1991). Although ancient texts do not discriminate between domesticated subspecies, early Greek writers (from the 5^{th} century BC on) report rice cultivation in Mesopotamia, Pakistan, and India, although neither the Greeks nor the Romans adopted it in the Mediterranean. For example, the *Periplus of the Erythraean Sea* (c. 60 AD) records rice as a crop in Pakistan (*PME* 37,7) and India (*PME* 41,5), and traded to Somalia (*PME* 14,4) and Socotra (*PME* 31,4). Although the cultivation of rice was confined to Asia, its trade to Africa, most likely as an exotic and expensive food, is confirmed by the rice grains retrieved at two Roman ports in Egypt, Berenike (also known as Berenice) and Myos Hormos (latterly Quseir al-Qadim during the Islamic period) (Cappers, 1999; van der Veen and Morales, 2011, 2015; Spengler et al., 2021). Both ports were active during the early centuries AD and were well known in the classical world, including to Strabo and Pliny, as well as in the *Periplus of the Erythraen Sea*, for trade eastward around the Indian Ocean to India, Sri Lanka, and potentially beyond. Although a trade item, rice is not known to have been cultivated on the African mainland at this time.

The ancient Greek word for rice is *oryza*, a term borrowed from the Old Persian *virinza*, and Sanskrit *vrīhi*, which were themselves derived from Dravidian terms for rice (Krishnamurti, 2003). The term *orinde*, attested in Persian as *birinj*, is considered by historical linguists to be cognate with *oryza*, with the implication that these words derive from the same language and were adopted at different times with different phonetic results (Marinone, 1992). In Greek literature, both words are first reported in a fragment of Sophocles (5th century BC) (*Fr*. 609 *apud* Athenaeus 3.110e) as "orindes bread, a kind of bread made of rice, a seed that grows in Ethiopia and resembles sesame". Here Sophocles is referring to the "Ethiopians of Asia", people who formerly lived in the Indus region (*Hist*. 3,94).

Sophocles' record indicates that by the 5th century BC, rice was known in the Mediterranean. Herodotus also potentially referred to rice as something similar to millet that was eaten by Indians (*Hist*. 3,100) (Marinone, 1992). Megasthenes (4th–3rd century BC), on describing his visits to India, mentioned that rice was eaten to accompany meat (in *Diodorus HL* II,36). Strabo (*Geogr*. 15,1,13) wrote that rice was cultivated in India during the rainy season together with flax, millet, sesame, and the cereal bosporum (a type of millet), and he cited Aristobulus (*Geogr*. 15,1,18), who provided the earliest account of rice cultivation in a Greek text in the 1st century BC (Appendix S10). Several other authors recorded rice cultivation in India (from the 3rd century BC on): Theophrastus (*HP* 4,4,10), Dioscorides (*MM* 1,95), Pliny (*NH* 18,71), and Galen (*Al. Fac*. 12,92,5) (Appendix S11).

Most classical references to rice are as a medicinal plant, rather than as food (Marinone, 1992). The Greek authors give the impression that rice was an exotic and expensive crop, used only on specific occasions (Marinone, 1992). Greco-Roman texts leave no doubt that rice was known during classical antiquity. Interestingly, a single grain of rice was retrieved from the archaeological site of Mycenaean Tiryns in the Peloponnese dated to the 12th century BC (Kroll, 1982), which Sallares (1991) interpreted to represent long-distance trade between Asia and the Mediterranean. Akkadian texts of the 12th century BC indicate rice cultivation of comparable antiquity on the flood plains of modern Syria (Muthukumaran, 2014). Thus, rice was plausibly traded between Syria and the eastern Mediterranean at that time, even though neither the Greeks nor Romans adopted it as a food crop (Sallares, 1991).

According to Murdock (1959), rice only became established in Madagascar under dry cultivation, while wet cultivation arrived much later on the island and the African continent. This assertion is supported by linguistic studies (Beaujard, 2011) since the Malagasy word *vary* for rice is related to the Kalimantan term *bari*, which was possibly borrowed from Dravidian. Genetic analysis of rice in Madagascar revealed that the *japonica* subspecies of *O. sativa* is found primarily in the east coast lowlands and clearly has a Malay signature, whereas the *indica* subspecies is predominant in the central uplands and associated with agricultural techniques of Indian/Malay origin (Mather et al., 2010).

Oryza sativa along with mung bean [*Vigna radiata* (L.) R. Wilczek] and cotton (*Gossypium arboreum* L.)—was introduced to Pemba and Zanzibar around 700-1000 AD, the Comoros around 750–1000 AD (including both *indica*- and *japonica*-derived cultivars), and to Madagascar by 1000–1200 AD (Boivin et al., 2013; Crowther et al., 2016). Arab and Portuguese traders subsequently brought Asian rice to East and West Africa, where it gradually replaced the indigenous African rice (*O. glaberrima* Steud.), which had been cultivated in West Africa for millennia (Wang et al., 2014).

Rice (*O. sativa*) has a complex history of introduction and adoption in Africa. It was initially known as a trade item in the eastern Mediterranean, as far back as the second millennium BC. Knowledge of rice persisted through the Greek and Roman eras, and subsequently Arab traders distributed rice along Africa's east coast and offshore islands. However, rice was probably not cultivated as a crop on the continental mainland until the last thousand years or so.

INDO-PACIFIC NUTS IN AFRICA

Coconut (*Cocos nucifera* L.)

The coconut fragments dating to the early centuries AD at the Roman Egyptian archaeological sites of Berenike (Cappers, 1999; 2006) and Myos Hormos (van der Veen and Morales, 2011; 2015), as well as references to coconut oil in early translations and commentaries of the *Periplus of the Eythrean Sea* (Schoff, 1912; Mauny, 1968; Casson, 1989), provide firm multidisciplinary evidence for its use during Roman times. In the *Periplus*, the translation of coconut palm or oil is *nauplios*, subsequently interpreted as *nargilios* for its tentative resemblance to an Indo-Aryan form (Hoogervorst, 2013). Yet, there is no mention of coconut in early Roman and Greek texts and recipes, so it was not an ingredient in Roman cuisine (van der Veen and Morales, 2011). Only *Cosmas Indicopleustes* attests its presence in the Greek literature in the 6th century AD (Cappers, 2006). Cosmas noted that coconut was known as *argellia* in India (*CT* 11.13), a name probably derived from the Sanskrit *narikela* (Faller, 2011) (Appendix S12).

A combination of linguistic evidence and increasing references by early Arabian pharmacologists such as Serapion, Thābit Ibn Qurra, Maimonides, and Ibn al-Bayṭār (Täckholm and Drar, 1941) suggests that coconuts were a commodity for Arab traders. Significant quantities of coconut fragments are present in Arabic deposits of Quseir al-Qadim, Egypt (van der Veen and Morales, 2011). The Arab introduction of this palm to Egypt and across the Arabic world is further supported by the Egyptian and Persian name *nárgíl* for the coconut, similar to the Sanskrit *nárikeli* or *naríkera* (Täckholm and Drar, 1941).

The level of genetic admixture, combined with historical and linguistic evidence, indicates that the Indian Ocean

could have represented the point of eastward and westward dispersal of coconut (Geethanjali et al., 2018), with multiple human dispersals to Madagascar (Gunn et al., 2011). Apart from Arab traders, Austronesian-speakers also moved coconuts across the Indian Ocean. The Malagasy name for coconut *voaniho* derives from the Malay *nihu* (Beaujard, 2011) or *buahniu* (Allibert, 2008), suggesting introduction by Austronesian speakers from ISEA.

Despite the antiquity of coconut in the Mediterranean and North/East Africa, the Portuguese are often accredited with its introduction to West Africa (Alpern, 1992). However, the multidisciplinary evidence from classical and Arabic texts together with archaeological and linguistic findings, suggests there were several waves of introduction that account for the complex genetic diversity of modern coconut populations in and around Africa. Moreover, coconuts could have naturally dispersed by floating, possibly adding another element to the complex picture of its introduction to Africa.

Breadfruit [*Artocarpus altilis* (L.) Kuntze]

Of all Malaysian crops, breadfruit is probably the best represented in historical accounts, but the least discussed by Murdock (1959), who mentioned it growing in the Comoros, Zanzibar, and Madagascar. Breadfruit belongs to the genus *Artocarpus* which includes 57 species (POWO, 2021c) distributed from South Asia, east through Southeast Asia and into Oceania (Lincoln et al. 2018). Domesticated in the circum-New Guinea region (Table 1), breadfruit is now found in West and Central Africa, as well as on the western islands of the Indian Ocean (Omobuwajo, 2007). This tree is widely planted in southern India and Sri Lanka, where it was potentially introduced by the Portuguese (Medagoda and Kumari Chandrarathna, 2007).

Historically, the earliest account is by Pedro Fernandez de Quiros, who in 1595 wrote about it after his travels to the Marquesas Islands and referred to it as "a fruit which reaches the size of a boy's head". The German botanist Rumphius (1750) documented it in the Moluccas, where he named it *Soccus lanosus*, based on the local name *soccun* and its silky flesh, *lanosus*. Following the description made by Quiros, Rumphius reported also the local name of *Soccus capa* referring to the similarity of the fruit to a head, and noted that the plant cannot be propagated by seed but by cuttings (1750). The rapid loss of viability of breadfruit seeds and the poor survival rate of seedlings during long-distance voyages encouraged the use of vegetatively propagated material for transporting breadfruit over long journeys (Ragone, 1997). The story of the introduction of breadfruit to Mauritius is instructive. Sometime after 1797, Félix Delahaye, a gardener employed by the French government, successfully managed to introduce to Mauritius breadfruit seedlings collected in Java after losing many of them in the South Pacific (Mulvaney, 2007). The introduction of a seeded related species in the western Indian Ocean is recorded in the *Voyage à la nouvelle Guinée*, where it

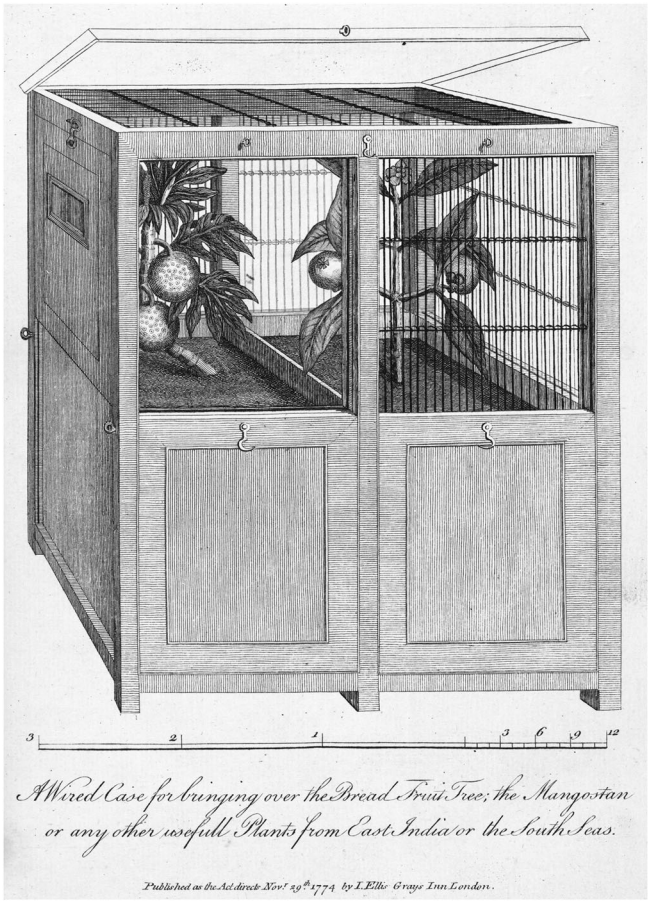

FIGURE 3 Breadfruit transported to the East Indies and South Seas. From Ellis (1775)

was allegedly transported from Luzon (Philippines) to Mauritius and La Réunion in the second half of the 18th century (Sonnerat, 1776; Sims, 1828). However, this latter episode refers to seeded *Artocarpus camansi* Blanco—breadnut—that together with *A. mariannensis* Trécul is considered a wild relative of *A. altilis* (Zerega et al., 2015).

Finally, it is with the 18th century British overseas explorations that breadfruit reached its fame in the western world, when Captain William Bligh was ordered to command a breadfruit gathering expedition to Tahiti because it was considered a nutritious food for slaves working on sugar plantations (Ellis, 1775). The notorious mutiny of the *HMS Bounty* is the story of the first attempt of transporting breadfruit from Tahiti to the West Indies, which failed after part of the crew mutinied and took over the ship (Bligh, 1790). Subsequently, breadfruit was successfully introduced to Royal Botanic Gardens in St Vincent in 1793 with the second expedition on the *HMS Providence* led again by Bligh (Sagot, 1872) (Figure 3), while the Portuguese brought it to Brazil (Dean, 1991).

Historical records suggest that breadfruit was introduced to East Africa from Mauritius. Its appearance in Madagascar and the rest of the African continent may have only occurred during the 20th century (Chevalier, 1940). One reason for its

limited popularity in Africa could be the widespread cultivation of African breadfruit (*Treculia africana* Decne), which bears a similar crop.

Areca nut (*Areca catechu* L.) and betel leaf (*Piper betle* L.)

Areca catechu is a slender palm native to Southeast Asia (Bharath et al., 2015), cultivated for its nuts, which are used as stimulants and narcotics. The nuts are usually combined with betel leaf (*Piper betle* L.), slaked lime and spices, to be chewed as refreshment after meals and in traditional ceremonies (Chandak et al., 2013). In Africa, the zone of betel palm cultivation is primarily Kenya, the Arab Peninsula, the Horn of Africa, Zanzibar, Madagascar, and La Réunion (FAOstat, 2020).

Areca nut, or betel nut, appears in southern Asian literature from the second millennium BC (Prabhakaran Nair, 2010). From its natural range in Southeast Asia, betel nut was initially introduced to India, from where it was transported to the Arabian Peninsula and the Horn of Africa (Purseglove, 1972). Chewing betel leaves after meals was common in India from the 1st century AD (Lingappa, 2011).

Early classical references, though, are not definitive. A potential reference to areca palm in Herodotus' *Histories* (Hill, 1952), probably refers to date palm, which was plentiful in Assyria and used to make wine and honey (Forster, 1942). Similarly, Desfontaines (1830) recognized areca nut in Pliny's work (*NH* 24,165) (Appendix S13), but Pliny's names are not definitive and could describe other recreational plants.

A single areca nut was found in the Islamic deposit of Qusier al-Qadim, the earliest archaeological specimen known from Africa, although it is absent from Roman deposits at this site (van der Veen and Morales, 2011). While Greek and Roman authors do not clearly reference betel nut, by the time of Ibn Battuta (14th century AD), betel chewing was widespread in East Africa (Defrémery and Sanguinetti, 1877). Taking the archaeological and historical lines of evidence together, areca nut and betel leaf were likely introduced to East Africa through Arab trade networks during the late first millennium AD.

AN ONLY CHILD: POLYNESIAN ARROWROOT [*TACCA LEONTOPETALOIDES* (L.) KUNTZE]

The primary regions of cultivation of *T. leontopetaloides* are Southeast Asia and the Pacific, although it also includes Senegal and Madagascar to the west (Drenth, 1976) and extends to Hawai'i in the east, where it was introduced by Polynesians in the last millennium (Krauss, 1979). It was likely dispersed by sea, human agency (Drenth, 1976), and animals (Saw, 1993). Arrowroot is possibly an ancient crop in many regions, because of its embeddedness in traditional ceremonies and ancestor worship (Burkill, 1985; Borokini et al., 2011).

Today, Polynesian arrowroot is only a minor crop, probably because it has been replaced by other crops. The corms are eaten, especially during periods of famine, and other uses include a milk substitute, alcoholic drink, and use of the inflorescence in musical instruments and toys (Burkill, 1985). Burkill (1985) also observed widespread use as an antidote against venom stings and bites and as a cure for stomach disorders, dropsy, and liver and genital infections. Currently, there is very limited information to infer the antiquity of Polynesian arrowroot in Africa.

POTENTIAL PATHWAYS OF INTRODUCTION

The taxonomic identification of species of the Malaysian crop complex in classical, literary, and historical sources is often problematic. Furthermore, the absence of plants from ancient texts does not mean the crop was not present. While historical sources may suggest the relatively recent introduction of some crops to Africa, especially to West Africa, written records for sub-Saharan Africa are extremely scarce before Arab and European explorations. Most problematic is the lack of taxonomic specificity of descriptions in ancient texts.

All Malaysian crops were cultivated in various parts of the ISEA-NG region within at least the last 2000 years. Not all of them were staples, but they were widely grown on Borneo and neighboring islands of ISEA, the homeland of the Austronesian-speakers who colonized Madagascar (Denham, 2013). Consequently, if we rely on Madagascan introduction, we are necessarily constrained to the last 1000–1250 years. However, new lines of genetic and archaeological evidence point to deeper histories for the dispersal of most Malaysian crops to the African mainland, most notably those widely grown in the West and Central African rainforests—such as bananas, taro, and sugarcane and, by association, greater yam (Power et al., 2019). Historical traces of these dispersals are now largely circumstantial, such as varietal and linguistic diversity (Blench, 2007). Significantly, recent multidisciplinary research on bananas alludes to a much older history of introduction. The domestication history for AAB plantains currently grown in West Africa starts in New Guinea at least 7000–6400 years ago and seemingly extends to Nkang in Cameroon around 2750–2300 years ago (Denham et al., 2003; Perrier et al., 2011). The complex journey through which bananas, and other putatively early Malaysian crops (greater yam, sugarcane, and taro) were introduced to Africa remains a mystery.

Furthermore, these vegetatively propagated crops require different archaeobotanical techniques to those ordinarily used to identify cereals, legumes, and tree crops (see Hather, 1994; Denham et al., 2020). Bananas, sugarcane,

taro, and yam are primarily traced using a combination of archaeological parenchyma, phytolith, and starch grain analyses. In Africa, as elsewhere, these microbotanical techniques are not regularly applied in archaeological investigations, so these plants have remained largely invisible. The systematic application of these microfossil techniques is needed to clarify the antiquity of the vegetative component of the Malaysian crop complex in Africa.

For the last 4000 years, Africa was not isolated from neighboring regions around the Indian Ocean (Rangan et al., 2012). Several African domesticates, including pearl millet (*Pennisetum glaucum* R.Br.) and sorghum [*Sorghum bicolor* (L.) Moench], were introduced to India before 3000 cal BP[3] (Fuller, 2007; Boivin and Fuller, 2009). Around this time, plants also moved westward from the ISEA-NG region to the Indian subcontinent: most notably sandalwood (*Santalum* sp. L.), first found in India at c. 3350–3250 cal BP (Asouti and Fuller, 2008). Furthermore, multiple lines of evidence suggest connections within the ISEA-NG region, as well as with mainland Southeast Asia and East Asia that enabled the movement of domesticated animals and plants from c. 4000–3000 years ago (Donohue and Denham, 2010; Denham, 2013).

Although limited, archaeological traces clearly show interaction within ISEA-NG, between ISEA and mainland SEA, between India and ISEA, and between India and Africa before 2000 years ago. The disparate lines of evidence indicate the transfer of plants or plant materials in short steps around the Indian Ocean, and the existence of social connections that could have enabled the net transfer of many plants from the ISEA-NG region to Africa. Although the specific pathways remain unknown, they likely included numerous local exchanges, long-distance voyaging routes, and a mix of maritime and terrestrial exchange networks. Plants, together with the knowledge of how to grow and use them, moved through these networks sometimes individually and other times together as part of an agronomic package.

CONCLUSIONS

Although the identity of many plants in classical texts is open to interpretation, our findings regarding the antiquity of Malaysian crops introduced to Africa are inferred from a combination of literary sources, phytogeography, and fragmentary archaeological and linguistic data. The precise timings for the introduction to Africa of most crop plants within the Malaysian crop complex are unknown, yet a generalized sequence of introductions can be hypothesized based on the fragmentary multidisciplinary evidence (Figure 4).

Vegetatively propagated crops that are widely distributed in wet equatorial regions of Africa, are deeply embedded in the local cultures—like plantain, sugarcane, taro, and greater yam—and were plausibly dispersed earlier than other food plants. Although degrees of cultural embeddedness, as well as extent of cultivation, are unreliable guides to antiquity, these crops were likely introduced to

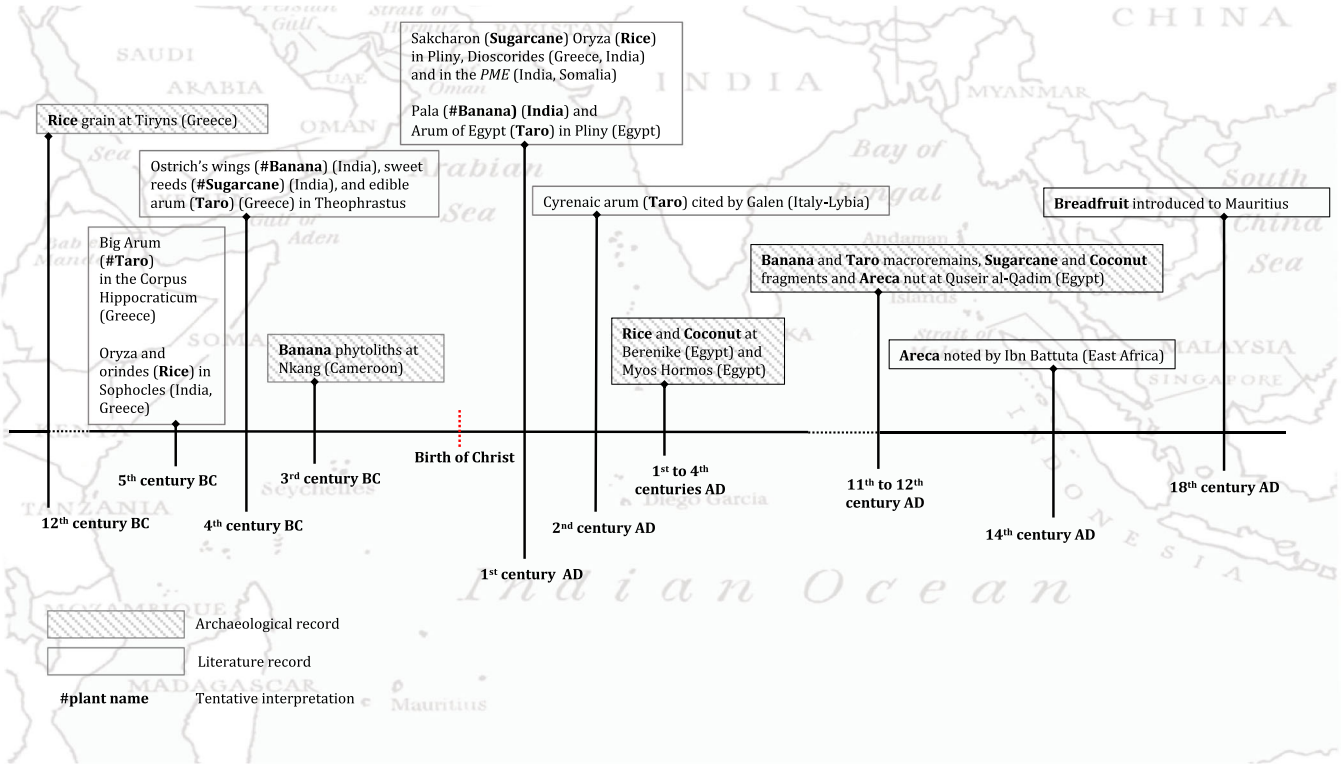

FIGURE 4 Timeline for crop introductions to Africa derived from literary and archaeological sources

Africa before 2000 years ago. Foremost, these crops were widely distributed around the Indian Ocean at this time, with known spheres of cultural interaction extending around this vast region. Additionally, although the precise timings of introduction to Africa are uncertain, archaeobotanical evidence for bananas from Cameroon and Egypt, as well as historical sources for banana, taro, and sugarcane indicate over 2000 years of time depth. Currently, the historical processes and cultural associations through which these tropical crops, initially domesticated in the ISEA-NG region, were introduced to Africa are unknown.

By contrast, a series of discrete periods marks the sequential introduction of crops that are more localized to the East African coast and offshore islands. Rice and coconut were known in the Roman world and traded to Red Sea ports around 2000 years ago, with later introductions and cultivation of the crop along the East African coast and on Madagascar from c. 1000–1200 AD. Areca palm, presumably with betel leaf, was likely introduced within this latter timeframe to East Africa and adjacent islands, such as it was widely known by the time of Ibn Battuta in the 14th century AD. Plants with a putatively more limited distribution to Madagascar—such as Polynesian arrowroot—were plausibly introduced by Austronesian-speaking colonizers from Island Southeast Asia within the last 1000 years, who also brought with them more recent cultivars of crops that had been introduced to Africa in earlier times. Subsequently, breadfruit was introduced by the Portuguese to Mauritius in the western Indian Ocean in the 1790s.

Currently, the multidisciplinary lines of evidence for Murdock's Malaysian crop complex in Africa suggest a multilayered history of introductions. Our chronological interpretation of initial introductions requires archaeobotanical validation and refinement, but provides greater temporal depth for plant introductions to Africa than most current assessments envisage. For most species, new groups of cultivars were introduced during later periods of cultural interaction between Eurasia and Africa, as well as around the Indian Ocean.

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[3]Dates determined using radiocarbon dating are expressed as calibrated "cal" when the raw dates have been converted to calendar dates by means of association with internationally agreed calibration curves obtained through other independent methodologies such as dendrochronology.

AUTHOR CONTRIBUTIONS

T.D. and I.M.G. designed the research, collected the data, and wrote the manuscript; T.R.vA. collected data; I.M.G. and T.R.vA. secured funding; all authors contributed to the final version of the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

Appendix S1. Classical, Byzantine, and Arabic sources consulted in parallel with Thesaurus Linguae Grecae (TLG) and Thesaurus Linguae Latinae (TLL) (2014). Translations and commentaries of texts are in the reference list.

Appendix S2. Tentative description of banana in Pliny's *Natural History* (*NH* 12,24).

Appendix S3. Description of yams in Madagascar by E. de Flacourt in *Histoire de la Grande Isle Madagascar*, Chez Alexandre Lesselin, Paris, 1658.

Appendix S4. Tentative description of sugarcane in Theophrastus (Theophrastus fr. 190 Wimmer [*apud* Photius *Bibliotheca* 278, 10]).

Appendix S5. Erathostenes and Nearchus tentative description of sugarcane in the *Geography* by Strabo (*Geogr*. 15,1,20).

Appendix S6. Strabo's tentative mention of sugarcane in Africa in the *Geography* (*Geogr*. 17,3,5).

Appendix S7. Tentative mention of sugarcane in Diodorus of Sicily's *Historical Library* (*HL* 2,36).

Appendix S8. Dioscorides' description of sugar extracted from reeds in India and Arabia in *Materia Medica* (*MM* 2,104).

Appendix S9. Pliny's description of sugar extracted from reeds in the *Natural History* (*NH* 12,32).

Appendix S10. Rice cultivation in India, Pakistan, Western Asia reported in the *Geography* by Strabo (*Geogr*. 15,1,18).

Appendix S11. Rice in Dioscorides' *Materia Medica* (*MM* 1,95).

Appendix S12. Cosmas description of coconut in *Christian Topography* (*CT* 11.13).

Appendix S13. Pliny's description of a plant sometimes interpreted as areca nut (*NH* 24,165).

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