

Title: Bananas: the spread of a tropical forest fruit as an agricultural staple
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Abstract: We discuss in this paper the importance of the banana plant in prehistory, its origins and evolution. The use of multidisciplinary approaches has contributed to our understanding of this valuable economic crop though there are still many areas not understood in its entirety. Specifically, the archaeological record has provided limited evidence of *Musa* sp. and identifications to species level are still problematic. There are several archaeobotanical studies that offer reliable identifications and interpretations such as Kuk Swamp in New Guinea and Nkang in Cameroon. It is through the continuous developments in the fields of botany, genetics, linguistics and archaeology that a more comprehensive understanding will be achieved of the history of the world's most important fruit.

Export statistics for 2009 have 70% of the world's banana exports coming from the Americas, specifically Caribbean or Latin American countries (FAOSTAT) and yet, the banana is known to originate from Southeast Asia. A long history of domestication and diffusion by humans has made the banana the most important traded fruit in the world market in volume terms. Total exports for the banana in 2009 reached more than 18 million tonnes with the potato lagging behind at 10 million tonnes. The exported variety is predominantly the 'Cavendish' banana although it represents less than 15% of the total world production. Most of the fruit produced around the world is locally consumed (Table 1).

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It is a fruit of great diversity because of a complex domestication process involving intra-specific & inter-specific hybridisations and somatic mutations with a history that is still being unravelled by botanists, geneticists, linguists and archaeologists (De Langhe et al., 2009). The banana underwent several stages of domestication as it was exploited, cultivated and translocated over the course of several millennia across many distinct geographical and cultural areas. In fact, when domestication began is still unknown but based on multidisciplinary evidence the first stage of domestication is estimated to be more than 4500 years ago (De Langhe et al., 2009; De Langhe and de Maret, 1999). However, cultivation is a precursor to domestication and there is evidence from New Guinea indicating a minimum age of 6500 years ago for cultivation (Perrier et al., 2011).

As it is today, the banana was an important economic plant in prehistory. It belongs to the *Musa* genus which provides many products with economic uses, the most important being the edible fruit eaten raw or cooked. As a food crop bananas are highly productive and require fewer labour inputs than most tropical forests crops, such as yams (Vansina, 1990). However the banana plant may have been valued for uses other than food. Those non-culinary uses may originally have been what attracted humans to exploit and domesticate it and not its food value (De Langhe et al., 2009; Kennedy, 2009a; Vrydaghs et al., 2003). It therefore follows that initial human selection was not necessarily towards the cultivation of seedless bananas but in time, the banana developed parthenocarpy and the seeds were suppressed making the fruit appetising. Parthenocarpy is a domestication trait of the banana, although it may occur in some wild forms of *Musa acuminata* (Simmonds, 1962). Parthenocarpy refers to the

development of fruit without the need for pollination whereas the loss of female fertility renders the fruit seedless. Bananas with seeds are not necessarily wild though the term ‘cultiwild’ is used to define them (De Langhe et al., 2009). Such plants can also be regarded as facultatively parthenocarpic, in which seedless fruits are produced without pollination due to lack of suitable, nearby pollen donors and timing (McKey et al., 2012).

Kennedy (2009a) published an extensive list of products derived from the banana plant (also, McClatchey, 2000). These prominently include cordage such as derived from cultivated *Musa textilis* or Manila hemp, but available from other *Musa* spp. This is highlighted by the fact that the early Chinese term for banana, *jiao*, refers to a fibrous plant, suggesting original familiarity with southern Chinese Musaceae as fibre sources (Fuller and Madella, 2009). Other uses include wrapping material from leaves, wax used in batik cloth production in Indonesia from *Musa acuminata*, medicine, ornamentation and ceremonial offerings. The leaves make useful fodder, and especially in south China and adjacent Southeast Asia leaves of all wild Musaceae are reported as pig fodder. In terms of human consumption there are varied regional traditions, such as pickling of young fruits in Southeast Asia, the use of the pseudostem as a vegetable in India or candied, and the production of dried banana chips and flours in Africa (McClatchey, 2000). In most regions the male flower or bud is also used as a vegetable. Bananas are also ingredients for catsup, and wine in some parts of Southeast Asia and used for beer, prominently in East Africa (Karamura et al., 1998) and occasionally as an additive to cereal-based beers in tribal northeast India (Subbaraya, 2006). A plant with such multiple uses would have surely made humans actively search for the banana in tropical forests and cultivate it, eventually taking it with them when they travelled where further hybridisation would have occurred.

Banana cultivation is normally by vegetative reproduction, required in seedless domesticates. Each banana “tree” is really a tall herbaceous perennial, which normally dies after fruiting, but which is reproduced by clonal suckers produced at the base of the pseudostem near the ground (Figure 1). These suckers normally flower and fruit within a year (9-14 months, sometimes under six months), thus making for annual or semi-annual cropping cycles (Heslop-Harrison and Schwarzacher, 2007; McClatchey, 2000). These can be collected and transplanted, or transported as long as they are not allowed to dry out, aided by trimming off leaves. The banana belongs to the genus *Musa* of the family Musaceae, which also includes the Asian and African genus *Ensete*, and the Yunnan and Vietnamese species of

Musella. Musaceae is a tropical group with most taxa, and most banana cultivation restricted to latitudes below 30 degrees (McClatchey, 2000). The genus *Musa* is subdivided into three, four or five sections depending on which taxonomic treatment one follows (Table 2).

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We will continue to refer to the section *Eumusa* as such and not as *Musa* to avoid further confusion (cf. Kennedy, 2009b). This paper will trace the domestication of bananas of the section *Eumusa* only because this section is responsible for the majority of the domesticated cultivars or what are referred to as common edible bananas, including starchy “plantains” (De Langhe, 2009).

DISTRIBUTION AND ECOLOGY

The primary diversity of the genus *Musa* is all of mainland and island Southeast Asia with the northwestern boundaries in the south of China, east India and Sri Lanka and southeastern boundaries encompassing the island of New Guinea, eastern Melanesia and the northern part of Queensland, Australia (De Langhe et al., 2009; Kennedy, 2009a). There exist outliers in Pemba Island, Samoa and Hawaii though these are probably anthropogenic translocations (De Langhe, 2009; Simmonds, 1962). The sections of the genus *Musa* have more delineated distributions but the *Eumusa* section covers the same geographical distribution of the entire genus except eastern Melanesia. Furthermore, the two species largely considered the progenitors of the edible banana (*Musa acuminata* and *Musa balbisiana*) are from the *Eumusa* section and their natural distributions have roughly a north-south divide with an overlapping area for both species found in the north of mainland Southeast Asia (Figure 2). *Musa balbisiana* forms an arch spanning from north Vietnam, Yunnan, north Myanmar and through northeast India to the hills of eastern India (Orissa), with disjunct populations in Sri Lanka (Fuller and Madella, 2009; cf. De Langhe, 2009).

Musa is a genus that thrives in disturbed tropical environments prompting Simmonds (1962) to refer to bananas as ‘jungle weeds.’ It is a pioneering plant that is normally found in man-made habitats because these are the most disturbed surroundings. It does not tolerate very low temperatures and poor drainage but does well in the open sun and moisture-rich areas (Simmonds, 1962). Because it is an understory plant, but only moderately shade-tolerant, it does not fare well with competition from other plants and will give way to trees

that grow to form the forest canopy. The weediness of *Musa* together with their utility lead to human translocation of these taxa, making determining true wild distributions complex. The endemic *Musella lasiocarpa* of Yunnan, for example, may have few, if any, true wild populations left, but it is maintained widely in garden cultivation, as fodder and as part of Buddhist temple gardens by various ethnic groups in Yunnan; its starchy pith is also eaten and fermented (Koshbakht and Hammer, 2009; Liu et al., 2003; Long et al., 2008).

An unresolved issue is the extent *Musa balbisiana* populations are anthropogenic and the result of ancient translocation. For example, De Langhe and de Maret (1999) only allow for true wild *M. balbisiana* from Sikkim/Assam through south China and the northern Philippines. De Langhe (2009) has explicitly hypothesised that *balbisiana* in peninsular India and Sri Lanka represents human translocation, as does that in New Guinea (De Langhe and de Maret, 1999; Perrier et al., 2011). The assessment here, however, accepts true wild status for populations in Orissa (eastern India) and Sri Lanka (Figure 2). This takes into account the habitats in which these plants occur, including those distal from human settlement and obvious human disturbance or encouragement, and comparison with general biogeography of disjunct distributions across many taxa. Patterns of disjunction in moist tropical taxa between Sri Lanka and southwesternmost India and Assam, sometimes with populations in the hills of Orissa, is widespread in plants (see Asouti and Fuller, 2008), including forest dominants such as Dipterocarps (*Dipterocarpus*, *Hopea*, *Shorea*; Asouti and Fuller, 2008). Archaeological evidence is also taken into account for early exploitation (~35,000 BP) of *Musa* in Sri Lanka and the lack of any archaeological suggestion of Pleistocene human dispersals from Southeast Asia/Assam (regions of Hoabhinian technology) to Southern India/Sri Lanka (regions of early microlithic tool traditions). Nevertheless, there are certainly anthropogenic extensions to the range of *M. balbisiana* both in western India and within Assam, where leaves are extensively used, for example as plates (Subbaraya, 2006). Explorations in Southeast Asia suggest that *M. balbisiana* in northern Thailand occurs from entirely anthropogenic habitats (Simmonds, 1956).

The archaeological sites Mafilau and Uripiv Island in Vanuatu illustrate the relationship between anthropogenic disturbance and the banana. *Musa* sp. phytoliths are present in stratigraphic layers following deforestation in these two sites. Presumably, the forest was cleared for horticulture and the existence of *Musa* sp. phytoliths shows it was one of the pioneering plants. The banana phytoliths were found in the post-Lapita layers (2800-

2500 BP) in Mafilau and the Lapita layers (3000-2700 BP) in Uripiv but not in earlier layers representing a human introduction of a previously unknown plant into the Pacific as part of their horticultural economy (Horrocks et al., 2009). A further example where the banana forms part of the forest regrowth is provided by the presence of Musaceae-type phytoliths in layers after ash deposition in the island of Garua, Papua New Guinea (Lentfer and Torrence, 2007).

DOMESTICATION OF *MUSA*

As mentioned above, there are several sections for the genus *Musa*. However, edible bananas only come from sections *Australimusa* with a basic chromosome number of 10 ($2n=20$) and *Eumusa* with a basic chromosome number of 11 ($2n=22$). The distribution of wild *Australimusa*, also known as the Fe'i group, falls within the Pacific region including the Philippines and the island of New Guinea (De Langhe et al., 2009; Sharrock, 2001). The Fe'i cultivar was probably domesticated in the Solomon Islands with the wild progenitor being *Musa maclayi* (De Langhe and de Maret, 1999; Simmonds, 1956). But other authors believe domestication may have occurred in the New Guinea region although are unclear as to the progenitors (MacDaniels, 1947; Sharrock, 2001). Kennedy (2009b) cites that wild species do exist in New Guinea and considers that it may be the original centre of domestication. The modern distribution of Fe'i bananas remains limited to the Pacific extending to Hawaii and Tahiti (Sharrock, 2001).

The other section *Eumusa* shows a complicated domestication process with two species, *Musa acuminata* (AA genome group) and *Musa balbisiana* (BB genome group), being the main progenitors of common edible bananas. Extensive genetics research has now been conducted and informs some of the finer points regarding wild progeny and stages of domestication (Perrier et al., 2011). As discussed above, the natural distribution of the wild species is extensive though it is generally accepted that the edible banana was originally domesticated in the main centre of diversity, New Guinea, from *Musa acuminata* ssp. *banksii* (De Langhe and de Maret, 1999; Perrier et al., 2011; Vrydaghs et al., 2003). Subspecies *banksii* has been identified as a key contributor to the first stages of domestication, of 'cultiwild' bananas, as it is the wild ancestor of many triploid cultivars including the East African AAA Highland bananas and the AAB West African and Pacific plantains (De Langhe and de Maret, 1999; Perrier et al., 2011).

There were several stages of domestication. The first and key process to domestication was edibility or the transition from wild to edible diploids (Perrier et al., 2011; Simmonds, 1962). The second stage of domestication involved the development of edible triploids from the edible diploids (Perrier et al., 2011). In the first stage of domestication, intra-specific hybridisations occurred between *Musa acuminata* subspecies to develop edible *acuminata* diploids (AA). Perrier et al. (2011) believe this event to have taken place during the Holocene in island Southeast Asia, including New Guinea, and was brought about by human interactions. They further hypothesize three contact areas for the development of domesticated parthenocarpic AA varieties (Figure 2: AxA): 1) the southern contact area with the hybridisation of *banksii* of New Guinea and *zebrina/microcarpa* from Java; 2) the eastern contact area between New Guinea and the Philippine *errans*; and 3) a northern/western contact area with contributions from *malaccensis* or *microcarpa* from Borneo and northern mainland Southeast Asia and *errans* from the Philippines.

As explored by McKey et al. (2012) a distinction needs to be drawn between facultative parthenocarpy, and true parthenocarpy in which flowers are sterile and incapable of seed production. Most diploid *acuminata* seedless bananas are presumably facultatively parthenocarpic, which means that occasional cross-pollination and production of seeds may occur (also, Kennedy, 2009b). This would have played a role in maintaining diverse adaptive potential within *acuminata*. This lead McKey et al. (2012) to question the widespread assumption (e.g. Heslop-Harrison and Schwarzacher, 2007) that cultivated bananas derive entirely from parthenocarpic mutants encountered in the wild. Cross-pollination also provided the pathways to extra adaptability of polyploid (AAA, AAAA) and hybrid genomes (AB, AAB, ABB). There are even rare cultivars that appear to involve hybrids with other species, such as *M. textilis* (AAT, ABBT) and *M. schizocarpa* (AS) (Heslop-Harrison and Schwarzacher, 2007). Favoured varieties of these hybrid parthenocarps could then be clonally propagated, with additional variation arising by somatic mutation. Within Africa, for example, such vegetation mutations and clonal propagation is thought to account for much of the diversity across AAB plantains (De Langhe et al., 1995).

The second stage of domestication was the development of triploidy. The majority of domesticated bananas today are triploids. Edible AA underwent further human selection, producing the AAmLali type and underwent hybridisation with other AA cultivars, resulting in

modern AAA cultivars, including the ‘Cavendish’ (Perrier et al., 2011). Other triploids emerged when *Musa balbisiana* (BB) and cultivated AA bananas came into contact. This probably occurred both by the spread of cultivated AA bananas into regions with wild BB, but also through anthropogenic expansion of BB. Such hybridisations gave rise to AAB and ABB types of bananas. The AAB hybrids include the plantain which flourishes in Africa today and the Maia maoli/Popoulu found all across Polynesia. There were probably multiple centres where hybridisation and somatic mutations occurred and hence allowing for such diversity (Figure 2: AxB). Based on genetic comparisons of viral DNA in cultivated hybrid bananas and *Musa balbisiana* in Thailand, Aung et al. (2010) concluded that some AxB hybridisation likely took place in northern Thailand, although the *M. balbisiana* here probably represented anthropogenic translocation from regions to the North. Subbaraya (2006) has similarly concluded that hybridisations in India are likely, and indeed the high diversity of hybrid types in this region would tend to support this but genetic studies are needed. Sri Lanka has played an important role in caching genetic diversity of several Indian Ocean dispersals, and long traditions of wild *Musa* use bring it into consideration as another region for hybridisation. It has been suggested that AAB ancestors of African plantains arose in an area encompassing the Philippines and New Guinea, while New Guinea to the Bismarck archipelago is the suggested origin for the Polynesian plantain (De Langhe, 2009; De Langhe and de Maret, 1999; Perrier et al., 2011).

The linguistic evidence similarly supports the case for hybridisation by suggesting distinct geographical sources for the two etymologies of banana (Donohue and Denham, 2009). The first one, **muku*, is derived from the New Guinea region. It is in New Guinea that we find the greatest diversity in both banana terminology and in hybrids indicating considerable time depth in Musaceae use. The other one is the Austronesian, **qaRutay*, originated in the Philippines and spreading southwards into the New Guinea region, paralleling the postulated anthropogenic spread of the BB bananas. The historical linguistic reconstruction by Donohue and Denham establishes routes of diffusion of these words similar to those which botanists believe apply to the spread of the banana. From New Guinea, the terms move west and further east. The linguistics evidence in New Guinea indicates pre-Austronesian origins for banana terms in New Guinea even in areas that predominantly have Austronesian languages (Perrier et al., 2011). This implies the survival of banana terms dating from prior to Austronesian dispersal into New Guinea, which carried language and *Musa balbisiana*.

Elsewhere in Asia, linguistic evidence suggests much later establishment of introduced banana cultivation. In China, written sources indicate that banana cultivation was present in southernmost areas (Guangdong) by ca. AD 300 (Fuller and Madella, 2009; Reynolds and Fang, 1940). Dravidian linguistics fit with a similar period for introduction of significant banana cultivation (broadly around 2000 BP), since four root words are found in different sub-groups of Dravidian. This is contrasted by earlier linguistics and archaeobotanical evidence for earlier introduced cultivars, such as African millets, mango, and even sandalwood (Fuller and Madella 2009). In northern India, Prakrit referred to cooking bananas as *kadaṭī* (Hindi *kela*), derived from the Austronesian **qaRutay* (Perrier et al., 2011). Derivatives of *kadaṭī* have been adopted into minority Mundari languages of eastern India, such as in the hills of Orissa. This suggests that despite being Austroasiatic immigrants presumably from the Assam region (Fuller, 2003; van Driem, 2011), they did not bring banana cultivation, nor as far as we can tell anthropogenic *M. balbisiana*, with them. Meanwhile a South Dravidian word series *vārai* and *bālè* is plausibly derived from the **baRat* series of words from the Philippines, Borneo and mainland Southeast Asia (cf. Perrier et al., 2011). Other branches of Dravidian have terms of unknown origin, as is the northern Indian Sanskrit *mōcha*, and related terms (from which derive Arabic *mauz* and our botanical *Musa*), apparently primarily for sweet bananas (Fuller and Madella, 2009). A medieval dispersal of sweet banana cultivars from India into China is suggested by Tang dynasty references to *mao-che* (Schafer 1967).

Some history can be inferred from this mix of banana terms. The presence of a Pali term, implies knowledge of bananas between ca. 500 and 0 BC, as it is not clear how early Pali texts were codified and written down (cf. Salomon, 2006). The Sanskrit term probably suggests roughly a similar date. Reference to *pala* in Pliny (Plin. Nat. 12. 12), written ca. 78 AD but referring to reports from the time of Alexander (ca. 325 BC), also points to cultivation in northern India by the second half of the first millennium BC. This generally points to an earlier establishment of banana cultivation in northern India than in the South. At the same time the arrival of some Southeast Asian introductions, such as *Areca*, coconut and sandalwood into Proto-South Dravidian perhaps as early 1300 BC (Fuller and Madella, 2009), would suggest that bananas were not cultivars that were available or of interest during the earliest phase of translocations across the Bay of Bengal between ca. 1300 and 400 BC (Fuller et al., 2011).

This diversity of banana etyma across India is suggestive of multiple introductions at different times and by different routes. The diversity of banana cultivar genomes in India would fit with numerous introductions, presumably with local hybridisations between diploid AA introductions as well as postulated hybridisation with South Asian BB gene pools. It is even possible that Sri Lankan AA contributed hybrids. Despite considerable genetic advances in recent years, genetic sampling of South Asian wild and cultivated bananas has been extremely limited.

FINDING BANANAS ARCHAEOLOGICALLY

There are various sources of evidence for the existence of *Musa* in archaeological sites: seeds, phytoliths and starch grains. Seeds are generally found in the contexts where wild, or 'cultiwild' and naturalised bananas were being consumed such as in foraging sites. Otherwise, seeds will not be found in contexts where the banana is already domesticated and forms part of a mode of subsistence such as agriculture. This is because of the reduction in seeds once the banana is domesticated. The advantage of finding seeds archaeologically is that they are easier to identify to species level than phytoliths though as seen below seeds in archaeological contexts are scarce. The mode of propagation for domesticated bananas is vegetative and therefore, they do not leave archaeological traces such as seeds or pollen (Vrydaghs et al., 2009), which makes the task of finding edible domesticated bananas in prehistory a very difficult one for archaeobotanists. Accordingly, few sites claim *Musa* remains. It is because of this taphonomic bias that most archaeological reports on bananas are based on phytolith identification (e.g. Bowdery, 1999; Kealhofer, 2003; Mbida et al., 2001). It is generally accepted that the Musaceae family produces distinctive phytoliths and the leaves produce genus-specific morphologies described as volcaniforms, troughs or truncated cones (Ball et al., 2006; Piperno, 2006; Horrocks & Rechtman, 2009). Furthermore, Lentfer has been able to identify seed phytoliths belonging to *Musa acuminata* subsp. *banksii* and those from *Musa ingens* belonging to the section *Ingentimusa* (Piperno, 2006). Trying to narrow down phytolith identifications to wild or domesticated status and to species level is work in progress (Ball et al., 2006; Vrydaghs et al., 2009). However, the use of phytoliths is still not considered reliable generally and in discussions on cultivation, quantitative and distributional analyses are used instead (Kennedy, 2009b; cf. Denham, 2005).

Evidence of domesticated banana outside its natural area of diversity is considered a proxy at the very least for human contact and in some cases for human migration (De Langhe, 2009; Horrocks et al., 2009; Mbida et al., 2001; Perrier et al., 2011; Vrydaghs et al., 2009). The domesticated edible banana is by definition almost devoid of seeds. For this reason finding *Musa* seeds archaeologically in areas where it is indigenous signifies that the find is wild *Musa*. On the other hand, if the seeds are found outside the centre of primary diversity, human beings must have been responsible for their introduction (De Langhe, 2009). However, naturalised *Musa* will also yield seeds and these would be difficult to distinguish from true wild bananas if found in the area of primary diversity. Two sites have reported banana seed remains: Bird's Head in New Guinea (Pasveer, 2003) and the upper levels (12,000-9300 cal. BC) of the later Stone Age/microlithic site Beli-Lena in the wet zone of Sri Lanka (Kajale, 1989). The first site does not provide enough information on the banana finds to warrant interpretation but in Beli-Lena, charred seed remains of both *Musa balbisiana* and *Musa cf. acuminata* were found together with wild breadfruit (*Artocarpus nobilis*) and *Canarium* fragments (Kajale, 1989). The remains of the *Musa* seeds indicate the use of wild fruits by foragers at this early period. Although De Langhe (2009) has hypothesized translocated *Musa* from Assam to account for this evidence, this is more plausibly seen as confirming the true wild status of *Musa* in Sri Lanka. These remains come from the latest levels of a site occupied since at least 35,000 year ago, which shows continuity in lithic technology and occupation (Perera et al., 2011), including geometric microliths which appear to be a cultural innovation of South India and Sri Lanka around 35,000 BP (Petraglia et al., 2009). There is no archaeological case to be made for immigration or trade from Southeast Asia/Northeast India as this remote period.

In an archaeological context, one would expect to find a decrease in seeds in the stratigraphic layers as one moves to later periods meaning banana domestication was en route and selection for seed suppression was happening (De Langhe, 2009). However, we should also bear in mind that there are species of *Musa* exploited for non-food uses which were probably reasons for the manipulation and cultivation of bananas containing seeds. The early sites Batadomba-lena and Kot Diji, discussed below, both suggest the use of *Musa* for non-culinary purposes.

The earliest recorded anthropic use of *Musa* sp. comes from phytoliths found in the Batadomba-lena rockshelter, Sri Lanka (Perera et al., 2011) during the Late Pleistocene. *Musa*

sp. phytoliths show up as soon as human use of the rockshelter is recorded corresponding to a date of 36,300-34,600 cal. BP. This adds further weight to inference of true wild *Musa* populations in the Sri Lanka (against the anthropogenic hypothesis of De Langhe, 2009). Interestingly, it is present together with breadfruit/jackfruit-type (*Artocarpus* sp.) phytoliths, which is suggestive of a food use, especially when considered in light of the later macroremains from nearby Beli-Lena. However, the *Musa* phytoliths themselves comes from leaves and co-occur with numerous palm frond (Arecaceae) phytoliths, which likely entered the site as raw materials for mats, baskets, etc. It is possible that *Musa* sp. in this rockshelter was being consumed as food but, alternately, it is also probable that like the palm remains found in this same site, it had other uses, such as wrappers made from the banana leaf. A hypothesis suggesting an ulterior use of *Musa* sp. has previously been proposed by Fuller and Madella (2009) regarding the *Musa* leaf phytoliths found in Kot Diji, Pakistan dating to 1900-2000 BC or earlier (the Harappan period). It is suggested by them that Musaceae plants, either *Musa* or *Ensete*, were cultivated during the Harappan period as a source of fibre or raw materials (e.g. paper, wrappers, etc). However, the presence of edible *Musa* cannot be entirely discounted in the site of Kot Diji and this could point to a very early introduction of the domesticated banana from island Southeast Asia (Fuller and Madella, 2001; Lejju et al., 2006).

The oldest evidence for cultivation of banana plants lies in New Guinea, the region where AA diploids were domesticated. The excavations at Kuk Swamp in the Highlands of Papua New Guinea yielded *Musa* phytoliths in several phases. The phase prior to ca. 10200 cal. BP probably signifies wild banana. The phytoliths corresponding to the period between 10200-9910 cal. BP to 6950-6440 cal. BP have been interpreted as belonging to a mixed cultivation regime involving swidden (Denham, 2005). Finally, in Phase II (6950-6440 cal. BP) Musaceae phytoliths occur in higher frequencies than the previous phases and has been interpreted as indicative of banana cultivation (Denham, 2005; Perrier et al., 2011). The banana seeds found in Sri Lanka may be older but they suggest consumption of the fruit but not manipulation of the plant, and therefore not cultivation. Phytoliths matching seed and leaf phytoliths of *Musa acuminata* spp. *banksii* were also found in the early Holocene layers of Kuk Swamp which indicate that this diploid has a long history of anthropic manipulation which was ultimately brought into domestication. *Musa* starch grains have also been found in Kuk Swamp (Denham, 2005). These finds in New Guinea predate any known contact with Southeast Asia and is an important reaffirmation on the origins of domesticated banana and that any possible inter-specific hybridisation with *Musa balbisiana* via Austronesian speakers

would have happened at a much later period circa 1350 cal. BC (Denham et al., 2004). The sites Yuku and Reber-Rakival are two other sites in Papua New Guinea which yielded *Musa* sp. phytoliths. The banana evidence in Yuku dating to ca. 3200 cal. BC is interpreted as part of a subsistence regime including other plants such as yam whereas in Reber-Rakival dating to 450 BC to AD 600 is presumed to be cultivated (Horrocks et al., 2008; Lentfer & Green, 2004).

Although it is hypothesised by some authors that the BB group was introduced into New Guinea via the Austronesian expansion from Taiwan into the Philippines and eastern Indonesia and onward to New Guinea (De Langhe and de Maret, 1999; Perrier et al., 2011), there is still no hard archaeological evidence to prove this. This may be because of a general lack of archaeobotanical enterprise rather than nonexistent *Musa* sp. in Southeast Asian prehistoric sites (Castillo and Fuller, 2010). There are only a few sites in Southeast Asia where phytolith analysis has been conducted and in some of these, *Musa* sp. phytoliths have been found. The situation in China for the evidence of *Musa* is even more difficult to interpret because even though there have been more phytolith studies conducted in China than in the whole of Southeast Asia, the focus is on rice and millet cultivation in regions well north of traditional banana cultivation (Fuller and Madella, 2009). In fact, there is only one known Chinese site with *Musa*-type phytoliths, the mid to late Holocene Poyang Lake (Zhao and Piperno, 2000). The phytolith study forms part of an environmental reconstruction, and the *Musa*-type phytoliths presumably pertain to wild Musaceae that grow in the upper river catchments to the south of the lake.

The earliest find in mainland Southeast Asia is at Gua Chawas, a rockshelter located in the Malay Peninsula where phytoliths were found in layers belonging to the Hoabinhian, Neolithic and Orang Asli periods (Bowdery, 1999). Like the cave sites from South Asia, the *Musa* found in the lowest levels at Gua Chawas, dating to the Hoabinhian period circa 10,000 BP, are in all likelihood, wild bananas. At what point, the bananas in this site are the domesticated variety is difficult to establish. The phytolith study at another site situated in the Thai-Malay Peninsula, Nong Thalee Song Hong, dating to 5000 BP indicates a mix of economic plants including *Musa* sp., *Oryza* and the palms *Areca* and *Cocos* (Kealhofer, 2003). The case of Nong Thalee Song Hong suggests forest management through periodic burnings and disturbance (Kealhofer, 2003). And although the presence of *Musa* phytoliths may sometimes be indicative of human exploitation if properly quantified and qualified, it

definitely does not suggest domestication. Like in Nong Thalee Song Hong, palm phytoliths were also found in the same layers as banana phytoliths in the two Laotian open sites, Lao Pako and Ban Ang, prompting one to question whether these plants were occurring together in the wild as opposed to being the result of direct human management. Both bananas and many palm taxa thrive in disturbed soils. Lao Pako in the Mekong floodplain and Ban Ang (The Plain of Jars) are two Iron Age sites in Laos dating to approximately 300 BC to AD 300 (Bowdery, 1999). Though it is inferred that rice agriculture was taking place in both sites, there is no indication that the *Musa* sp. phytoliths were domesticated even if it would seem likely that at such a late period there was already cultivation and management of economic plants in the mainland other than rice.

BANANAS OUTSIDE THE AREA OF PRIMARY DIVERSITY

If banana phytoliths are found within the area of primary diversity, it is difficult to know whether the plant was wild or domesticated, and whether humans played a role at all in its location. However, the inverse holds true. When *Musa* has been discovered in areas where it is not endemic, it is through human interaction that we find the banana translocated and so is directly associated with agriculture (Perrier et al., 2011). The evidence of *Musa* sp. in the two sites Mafilau (800-400 BC) and Uripiv Island (1000-700 BC) in Vanuatu show the dispersal of the banana east of New Guinea through human movements (Horrocks et al., 2009). Humans travelled even further east and by 1300 AD *Musa* together with another introduced crop, the sweet potato (*Ipomoea batatas*), were under intensive cultivation in the Kona Field System of Hawaii (Horrocks & Rechtman, 2009). The *Musa* phytoliths and sweet potato starch grains were found in high concentration numbers in the archaeological contexts suggesting intensive cultivation.

Wild *Musa* do not occur in Africa or the Americas and it can therefore be inferred that the banana arrived in both these continents in its domesticated form. The most widely discussed evidence of *Musa* outside its area of origin comes from Africa (Figure 3). The modern distribution suggests three waves of bananas, including highly diversified African Plantains (AAB) in west and central African rainforest regions, later a highland adapted AAA banana around the Great lakes of Africa up to Ethiopia, and a diverse range of genomes around the southeast coastal regions and Madagascar, designated the “Indian Ocean Complex” (De Langhe et al., 1995). The diversity of AAB plantains has led to the hypothesis

of an early introduction, perhaps as early as 3000 BP, to allow for diversification (De Langhe et al., 1995). It has even been suggested that the arrival of plantains in west-central Africa caused an agricultural and demographic revolution which drove the expansion of speakers of Bantu-languages (Blench, 2009; Murdock, 1960). The linguistics evidence, however, does not appear to be a straight case of dispersal of crops with a single term but displacement of one regional term by another (Vansina, 1990). Bananas are often seen as part of the Southeast Asian trio, including Asian yams and taro (Blench, 2009; Fuller et al., 2011). Other authors, however, have pointed to later introductions to Africa, such as related to the Austronesian settlement of Madagascar ca. 500 AD (e.g. Simmonds, 1962), and Islamic era trade (e.g. Watson, 1983). However, given the modern distribution of genome types, it seems more likely that the Arab/Swahili era trade, and Madagascar-connected Malay trade (after 600 AD) should be linked with the “Indian Ocean complex” and a similarly diverse range of banana types found in the Arab world in Oman and Egypt. Still a mystery is whether the AAA highland types evolved from some of these introductions within Africa or have precursors somewhere in tropical Asia. Dessicated peel remains of banana dating to the Arab trading ear have been recovered from Qesir al-Qadim on the Red Sea coast (van der Veen, 2011).

One archaeological site has produced evidence to support this early dispersal. At the site of Nkang in Cameroon phytoliths of *Musa* were found in two archaeological pitfall contexts dated by radiocarbon on other materials to the mid-first millenium BC (Mbida et al., 2001). The proper identification of phytoliths to the genus *Musa* was done using qualitative morphological studies on modern reference material of the African indigene *Ensete* and the introduced cultivar *Musa*, which allows separation of the volcaniform phytoliths (Figure 1). This evidence ostensibly provides evidence of human contact via the Indian Ocean at a very early date as well as cultivation of bananas in Africa as early as 2500 years ago (Mbida et al., 2001). Furthermore, it is still not completely understood how the spread of bananas to west Africa actually took place. It is likely to have taken place via the Indian Ocean corridor with one hypothesis suggesting a trans-African route from the east coast of Africa into west Africa and another suggesting circumnavigation (Blench, 2009; De Langhe, 2007; Fuller et al., 2011). Nevertheless, systematic sampling for phytoliths at two contemporary or later sites in southern Cameroun, which have produced evidence for pearl millet macro-remains, has failed to turn up bananas. On the basis of this negative evidence and ecological arguments for the region the Nkang evidence has been questioned (Neumann et al., 2012). Indeed, the phytoliths themselves are not directly dated, and the possibility of intrusive material from later periods is

difficult to exclude. Ideally additional sites of this period are needed to reaffirm the Nkang evidence.

Another site with problematic reported early banana is the Munsa swamp, where a pollen core also reported banana phytoliths (Lejju et al., 2006). Banana phytoliths were reported from both lower strata and upper strata in the core, with dates associated with the lower strata of 3600 and 4500 BP. One of difficulties in interpreting this evidence, however, is a hiatus in sedimentation, in which radiocarbon dates jump from 3600 BP to 900 BP over the depth of around 20cms, and in which there is no pollen and almost no phytoliths. This implies that the swamp may well have dried out and sediment mixing is highly likely. Therefore lowermost phytoliths can only be unambiguously dated to before 900 BP. Over the past 900 years the core also includes micro-charcoal suggesting use of fire in landscape management. This indicates that banana cultivation was established in Uganda since at least 1100 AD. However, some of the published banana phytolith images from this site have also been critiqued so even amongst the earliest examples there is room for some doubt (Neumann and Hildebrand, 2009). Awaiting more sites with evidence, these data suggest that at least over the past 500 years (the uppermost levels) and perhaps for more 1000 years banana cultivation was carried out near Munsa, to the northwest of Lake Victoria.

In West Africa, the Portuguese would have first encountered the banana in the 15th century, and they introduced it to the Canary Islands, where there was a nascent sugar industry worked by enslaved Africa populations (Carney and Rosomoff, 2009). From here the banana was introduced to Santo Domingo in the Caribbean in 1516. It was in this period that Portuguese borrowed the word *banana* from a West African language. The establishment of bananas in New World agriculture can be seen as part of a larger process of the translocation of African crops, often accompanying slave ships containing African populations familiar with their cultivation (Carney and Rosomoff, 2009).

Bananas found in tropical America are mostly AAB African plantains suggesting that most arrived by this trans-Atlantic route (Vrydaghs et al., 2003). However, the AAB Maia maoli/Popoulu type is found in the west of South America possibly signifying some translocations from Polynesia, but it is not clear if these are pre-Columbian or relatively late in time (Vrydahs et al., 2003; Simmonds, 1962). While Langdon (1993) suggested that the banana reached Latin America in Pre-Columbian times, from Polynesia more than 2000 years

ago, this remains unconfirmed. There is as yet no archaeological evidence relating the arrival of bananas in the New World.

On the whole evidence for bananas outside of tropical Asia is sketchy. There are a number of lines of evidence that point to prehistoric introductions to Africa more than 2000 years ago as well as historic era introductions during the early Islamic era. Evidence in Asia is little better, and while the New Guinea origins of AA cultivars seems clear, most of the dispersal through Asia (China and India) is framed only by minimal ages of around 2000 years ago, provided by historical sources. As one of the world's most important crops, and with potential to identify bananas archaeologically, there is a gap that can be filled in by further archaeological research.

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Region	Total Production Quantity in tonnes (2009)	Total Export Quantity in tonnes (2009)
Africa	11,213,336	570,611
Americas	26,604,039	13,114,652
Asia	56,077,267	2,161,101
Europe	392,914	2,475,570
Oceania	1,529,071	209
WORLD	95,816,627	18,322,143

Table 1: Total production and export quantities of bananas by region. Oceania includes Australia, New Zealand, Melanesia, Micronesia and Polynesia. (Source: FAOSTAT).

Kennedy 2009b	De Langhe et al. 2009 Sharrock 2001 Denham et al. 2011	Argent 1976	Simmonds 1960, 1962
<i>Musa</i>	<i>Eumusa</i>	<i>Eumusa</i>	<i>Eumusa</i> (or <i>Musa</i>)
	<i>Rhodochlamys</i>	<i>Rhodochlamys</i>	<i>Rhodochlamys</i>
<i>Callimusa</i>	<i>Callimusa</i>	<i>Callimusa</i>	<i>Callimusa</i>
	<i>Australimusa</i>	<i>Australimusa</i>	<i>Australimusa</i>
<i>Ingentimusa</i>		<i>Ingentimusa</i>	undetermined (but includes <i>M. ingens</i> , <i>M. lasiocarpa</i> & <i>M. beccarii</i>)

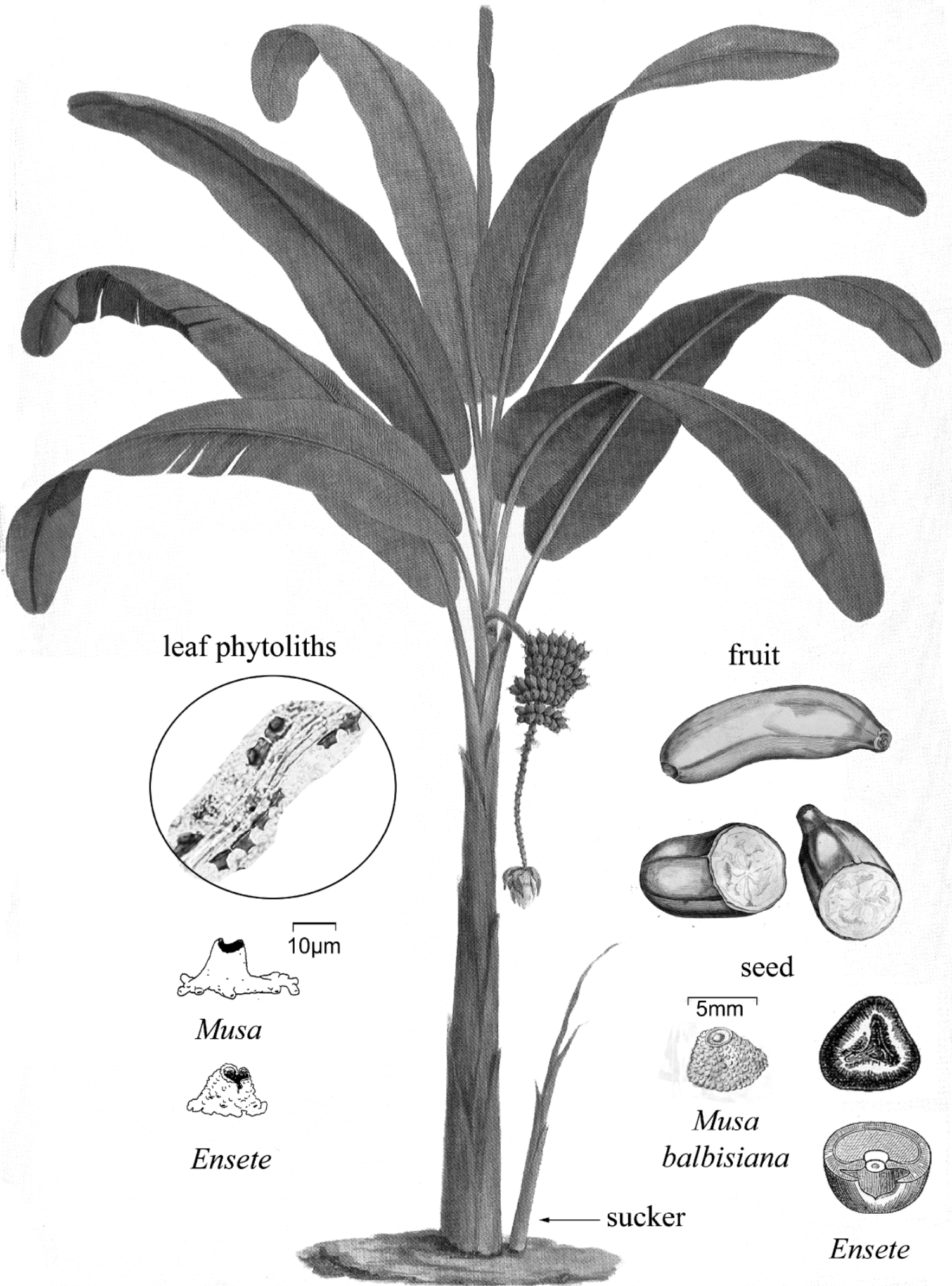
Table 2: Examples of authored papers dividing the genus *Musa* into sections.

Figure Legends

Figure 1. A banana plant and some of its archaeologically recoverable parts (seeds and phytoliths), with *Ensete* types for comparison. Main plant image is after Luigi Balugani in James Bruce's (1790) *Travels to Discover the Source of the Nile*, fruit is after Rheede's (1963) *Hortus Malabaricus*; *Ensete* seed is from La Maout and De Caisne (1873) *A General System of Botany, Descriptive and Analytical*, while *Musa* seed was sketched by DQF. Phytoliths *in situ* is from a photograph of UCL reference collection (courtesy of Alison Weisskopf); detailed phytolith morphotypes are after Mbida et al. (2001).

Figure 2. Map of early Asian bananas, indicating the distribution of selected wild taxa, and maximal northern and western limits of wild Musaceae taxa in Asia. The core area of *Musa acuminata* ssp. *banksii* is indicated within the greater range of *M. acuminata*. Probable distribution of true wild *M. balbaisana* is differentiated from anthropogenic extensions of *M. balbisiana* range (BBant). Plausible regions of hybridization between different AA genomes (AxA) and AA and BB genomes (AxB) are indicated. Selected archaeological and palaeoenvironmental sites, mentioned in the text, are numbered: 1. Kot Diji; 2. Beli Lena; 3. Batadomba Lena; 4. Gua Chawas; 5. Nong Thalee Song Hong; 6. Lao Pako; 7. Ban Ang/ Plain of Jars; 8. Poyang Lake; 9. Yuku; 10. Kuk Swamp; 11. Island of Garua; 12. Reber-Rakival, Watom Island. Distribution in South Asia from Fuller and Madella 2009. Distribution in China through Taiwan from Wu and Cress 2000; Chiu et al. 2011. For Thailand see Simmonds 1956; Elsewhere, after Perrier et al. 2011; De Langhe and de Maret 1999.

Figure 3. A map of banana cultivation in Africa and Arabia, indicating the broad geographic genomic divisions. Archaeological sites mentioned in the text are numbered: 1. Nkang, 2. Bwanbe-Sommet 3. Abang Minko'o; 4. Munsa; 5. Qesir al-Qadim. Areas of staple crop and important crop status are from Murdock (1960), while outlier cultivation has been augmented from Westphal 1975; Watson 1983; De Langhe 2001; Karamura et al. 2008; Cavendish production in Sudan is reported by Lescot and Ganry (2010). Genomic banana types follow De Langhe et al. 1995; Karamura et al. 1998; AAMLali is after Perrier et al. (2011).



leaf phytoliths

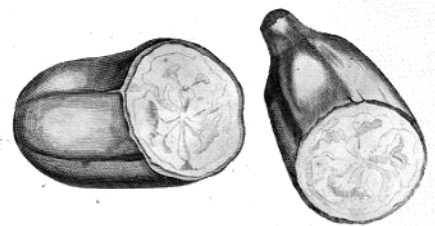


Musa



Ensete

fruit



seed



*Musa
balbisiana*



Ensete

sucker

