Fahien reconsidered: Pleistocene exploitation of wild bananas and Holocene introduction of *Musa* cultivars to Sri Lanka

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Abstract

A recent publication on the phytolith assemblage at Fahien rockshelter, Sri Lanka (Premathilake and Hunt 2018) is argued to represent: the exploitation of wild *M. acuminata* and *M. balbisiana* during the Late Pleistocene; the introduction of edible diploid cultivars from the Southeast Asia-New Guinea region during the early-to-mid Holocene; the generation and cultivation of triploid banana hybrids on Sri Lanka before 6194-5994 cal BP; and, the subsequent spread of derived triploid cultivars to mainland India and westward to Africa. A careful review of the archaeobotanical research presented by Premathilake and Hunt (2018), in the context of broader multidisciplinary evidence (agronomy, archaeobotany, genetics and linguistics) for the domestication and spread of banana cultivars, indicates that three main aspects of their argument are problematic: the lack of clarity in the characterization of banana domestication in the past; the methods used to discriminate phytoliths into banana taxa; and, the promotion of Sri Lanka as a source region rather than a recipient of banana cultivars. Following reconsideration, the Fahien evidence is consistent with previous interpretations for the origins of diploid and significant triploid cultivars outside of Sri Lanka and dispersal to that island.

Introduction

A recent publication on an archaeological investigation at the Fahien rockshelter in Sri Lanka (Premathilake and Hunt 2018) argues for the presence of wild *M. acuminata* and *M. balbisiana* since the Upper Pleistocene. The chronological sequence of *Musa*

phytoliths at the site is also interpreted to represent the appearance of triploid banana hybrids before 6194-5994 cal BP. According to the argument proffered, edible *M. acuminata* diploids were introduced from the Indonesia–PNG region and these subsequently hybridized with *M. balbisiana* to form several AAB and ABB triploids on Sri Lanka. The authors then speculate that the dispersal of some AAB and ABB cultivars occurred "from Sri Lanka northwards to urban Harappan sites during the middle of the fifth millennium BP, and westwards to the east coast of Africa during the first half of the sixth millennium BP" and "may have followed maritime trade networks through the Indian Ocean" (Prematilake and Hunt 2018: 12). They conclude: "The evidence suggests that Sri Lanka's location in the Indian Ocean is important for understanding banana domestication and dispersal" (Prematilake and Hunt 2018: 12).

The reconstruction of the banana domestication process places Sri Lanka as a major diversity center of AAB and ABB cultivars, and the source of traditional triploid banana cultivars in South Asia and Africa. It thus differs considerably from a previous multidisciplinary reconstruction based on agronomic, archaeological, archaeobotanical, genetic and linguistic evidence that locates the origin of the African traditional bananas, i.e. the AAA "Mutika" and the AAB "Plantains", within Island Southeast Asia (Perrier et al. 2011, 2018; also see De Langhe et al. 2015). Furthermore, reconstructions suggest that other AAB/ABB subgroups cultivated in the continental part of South/Southeast Asia may not have originated on Sri Lanka. For example, the popular Indian "AAB Pome" cultivar can be genetically sourced to an edible AA parent, "Mchare" (formerly 'Mlali') which is presumed to have an origin in southeast Indonesia, and a B genome that can be linked to Indian BBs such as Lal Velchi. Although a continental route for Mchare is likely – based on linguistic grounds (Donohue and Denham 2009) – a straight arrival across the Gulf of Bengal can as yet not be excluded (Perrier et al. 2011).

Here, the archaeobotanical evidence presented by Prematilake and Hunt (2018) is carefully reviewed. Three aspects of their argument are found to be problematic: the lack of clarity in their characterization of banana domestication in the past; the use of phytoliths to differentiate banana taxa; and, the promotion of Sri Lanka as a source region rather than a recipient of banana cultivars. In contrast to their proffered conclusion, the Sri Lankan evidence presented by Prematilake and Hunt (2018) is consistent with previous interpretations for the origins of diploid and many triploid cultivars outside of the island.

The domestication of edible diploid and triploid cultivars

A major problem in seeking to disentangle the domestication and dispersal processes proposed by Prematilake and Hunt (2018) is the lack of clarity and consistency in the terminology used throughout the paper. There is terminological slippage, or equivalence, in the usage of cultivated, domesticated and triploid. These terms, though, are not synonymous. Although triploid bananas are cultivated and domesticated, cultivated bananas need not be domesticated or triploid, whereas domesticated bananas are usually cultivated but need not be triploid.

De Langhe et al. (2009) proposed terminology to enable the differentiation of wild and various types of cultivated bananas. This terminology sought to take into account the complex processes involved in the domestication of bananas, including various forms of exploitation and propagation, anthropic targeting of parthenocarpic forms, the development of seed-suppressed and sterile forms, as well as the generation of sterile triploids (Perrier et al. 2011). The terminology sought to incorporate the "continuum of human intervention involving increasing transformation through selection and propagation" (De Langhe et al. 2009: 171). Increasing degrees of transformation are implied by the terminology from wild, cultiwild, basic cultivar to derived cultivar. For clarity in the reconstruction of the past, it is necessary to translate this terminology to the Sri Lankan context.

The only two wild *Musa* species currently growing on the island are *Musa acuminata* and *Musa balbisiana*. Cultiwild refers to morphologically wild plants that may have been clonally propagated on Sri Lanka by people. From an archaeobotanical standpoint, cultiwilds cannot be differentiated from wild plants using plant macro (seeds) or microfossils (phytoliths or starch grains) because the selective pressures exerted upon them by human management are insufficient to lead to directional morphogenetic change. Plausibly cultivation could be inferred from the frequency of banana phytoliths and contextual information relating to agronomic practices and environmental disturbance. Although such an interpretation has been undertaken at Kuk Swamp (Lentfer and Denham 2017), a site of agricultural production, it is not relevant at Fahien rockshelter.

Basic cultivars include edible diploids and triploid populations. Edible diploid cultivars may have been generated through indigenous horticultural experimentation on Sri Lanka, although there is currently no evidence to substantiate that such diploids contributed in any significant way to major triploid cultivar groups, and this is not claimed by Premathilake and Hunt (2018) in any case. Rather, previous archaeobotanical evidence is suggestive of the exploitation of wild, seeded forms on Sri Lanka during the Terminal Pleistocene (e.g., Kajale 1989). Genetics shows that in several major groups of diploid and triploid cultivars – even the AAB/ABB in India- the *Musa acuminata* genome, namely edible AA cultivars, can be traced to sources in the Island Southeast Asian-New Guinea region (Perrier et al. 2011). Consequently, at some point this genetic component was introduced to Sri Lanka either: through the introduction of edible AA cultivars, with an earlier arrival from India of *Musa balbisiana* genotypes (De Langhe 2009), and subsequent *in situ* formation of some triploid cultivars (Premathilake and Hunt 2018); or, through the straight introduction of AA, AAA, and most AAB and ABB cultivars to the island (Perrier et al. 2011).

Premathilake and Hunt (2018: 10) state "edible AA parents were introduced from … the Indonesia–PNG zone" and propose this occurred before 6194-5994 cal BP. However, they do not discuss current diploid cultivars on Sri Lanka and whether these indeed have the requisite genetic lineages of the major AAB and ABB cultivar groups that subsequently dispersed to Africa and India, respectively. Of relevance, Simmonds (1959) mentions only one possible edible AA on Sri Lanka, called 'Navari' and referred to as a

very rare dessert banana; the lack of other AA cultivars today is not necessarily definitive, but it is certainly suggestive of only a minimal role of edible diploids in the history of banana exploitation and cultivation on Sri Lanka.

Using phytoliths to discriminate between banana species, subspecies and cultivars

Previous studies have documented the existence of wild bananas, including *Musa acuminata* and *Musa balbisiana* in archaeobotanical assemblages from Pleistocene-aged contexts on Sri Lanka (from Kajale 1989 onwards). Sri Lanka is potentially within the natural range for both species, as are parts of India (Fuller and Madella 2009). Thus, the use of leaf and seed phytoliths to identify wild bananas during the Pleistocene and Holocene on Sri Lanka is unproblematic.

Premathilake and Hunt (2018) present detailed supporting materials regarding the morphometrics and morphotypology (i.e. form variants) for modern wild and cultivated bananas on Sri Lanka, which are near-exclusively drawn from Perera (2017). Their intention is to differentiate among wild bananas, as well as the latter from triploids cultivated on Sri Lanka today. However, the presented criteria (Premathilake and Hunt 2018: Tables 3, *S1, S7-S11*) are insufficient for unequivocal discrimination of phytoliths in archaeological contexts. For instance, although a drawing of a typical volcaniform leaf phytolith and its variants is provided (Premathilake and Hunt 2018: Figs. *S1-S2*), comparable drawings for seed phytoliths are missing. As a result, it is not possible to interpret and assess the photomicrograph and descriptions of seed phytoliths from archaeological contexts.

A clear-cut distinction between the phytoliths of the two relevant species, *Musa acuminata* and *Musa balbisiana,* is heavily compromised by the overlap in the morphometric ranges for Base Length (BL) and Crater Length (CL) in seed and leaf phytoliths for both species, as well as the lack of metric data for the groove lengths on seed phytoliths (Premathilake and Hunt 2018: Table *S1*). The data for CL are questionable for *Musa acuminata* when compared with Vrydaghs et al. (2009: Table 2), and previous studies have suggested that BL is an unreliable measure given the fragility of base edges and propensity to break (Vrydaghs et al. 2009).

The presented morphotypological criteria are highly subjective interpretations. For example, seed phytoliths are discriminated based on “Rectangle and square base with few verrucae” (*M. acuminata*) and “Variable base with more verrucae” (*M. balbisiana*) (Premathilake and Hunt 2018: Table *S1*). There are also inconsistencies in the use of phytolith-form variants to discriminate the species based on leaf phytoliths. For instance, *Musa balbisiana* is reported to have Variants 4 and 8, which are missing in *Musa acuminata*, whereas previous studies report Variants 4 and 8 are present in *Musa acuminata*, while Variant 8 is missing in *Musa balbisiana* (Ball et al. 2006; Vrydaghs et al. 2009). In the light of previous methodological studies on banana phytoliths, the criteria used by Premathilake and Hunt (2018) are unreliable to discriminate the phytoliths of *Musa acuminata* and *Musa balbisiana*.

The differentiation of wild and domesticated in the Sri Lanka data, where a BL threshold > 21.24 μm is used, is inconsistent with previous studies (e.g., Ball et al. 2006). The unreliability of this criterion for discrimination is confirmed by Premathilake and Hunt's own data (2018: Tables *S10-S11*), with overlaps in BL and CL measurement ranges for wild and domesticated bananas, even in the same wet zone. Similarly, the morphotypological criteria used (Premathilake and Hunt 2018: Table 3) are equivocal and subjective. For example "Protuberances rarely occur on V3" in wild bananas, while they "commonly occur" in domesticates; further, "Psilate to granulate is commonly found" in wild bananas, while "Granulate to verrucate pattern is found in moderate level" in domesticates. Only the examination of large numbers of phytoliths (n >100, as proposed by Ball et al. 2016 and Vrydaghs et al. 2009) could raise the probability of matching the actual diversity of the archaeological banana phytoliths within a sediment sample. Unfortunately absolute numbers of banana phytoliths are not provided; the frequencies are relative and expressed graphically as percentages (Premathilake and Hunt 2018: Fig 3).

Most problematically, no quantitative information is presented on how archaeological phytoliths conform to morphometric and morphotypological criteria derived from modern reference samples, which themselves are highly problematic. Thus, it is not possible to undertake a systematic comparison of the data for ancient phytoliths. Furthermore, Premathilake and Hunt fail to address methodological issues identified in previous research that have found the differentiation of wild bananas, cultivated diploids and cultivated triploids extremely difficult using morphometric or morphological criteria (Ball et al. 2006; Lentfer 2009; Vrydaghs et al. 2009; Lentfer and Denham 2017). Given these methodological uncertainties, there is no robust basis for discriminating wild and domesticated bananas in the phytolith assemblage at Fahien.

Despite uncertainty, the general chronology of phytolith frequencies at the site warrants consideration (Premathilake and Hunt 2018: Fig 3). Foremost, there is a major reduction in the frequency of banana leaf and seed phytoliths after c. 8019-7817 cal BP (Premathilake and Hunt 2018: Fig 3). From this time up to the late Holocene, the frequencies of all *Musa* phytoliths, leaf and seed, as well as those identified as 'wild' and 'domesticated' are relatively low until the increase at c. 3986-3844 cal BP. The interpretation of these findings is complicated by the apparent reworking of the stratigraphy from 5547-5475 cal BP onwards, as noted by the authors.

The marked drop-off in the frequency of banana phytoliths, especially those derived from seeds, to a relative paucity of banana leaf phytoliths after 8581-8423 cal BP could be attributed to multiple factors. It may represent a switch in land use and occupation practices, namely, a lower frequency of rockshelter use by people and possibly other fauna; alternatively, it could represent a shift in the local ecology. However, there is little substantive evidence to suggest that such a marked reduction in seed phytoliths corresponds to the introduction, adoption and cultivation of edible diploids with the subsequent generation and cultivation of triploid cultivars from at least 6194-5994 cal BP. Although Premathilake and Hunt (2018: 12) claim: "Edible diploid (AA) bananas may have been introduced from elsewhere … before 5994–6194 cal BP", such an early

date is not directly defended in the rest of the text. As the authors admit, phytoliths of edible AA cannot be distinguished from those of wild AA (Premathilake and Hunt 2018: 10) and hence any statements regarding the timing of the introduction of edible AA diploid cultivars are pure supposition and unnecessary.

Rather, the frequencies of leaf and seed phytoliths indicate that bananas became less prevalent, hence less significant contributors to local diet, until the marked peak in cultivated leaf forms at 3986-3844 cal BP, which potentially corresponds to the appearance of triploid cultivars. Only at 3986-3844 cal BP is there a fundamental switch in respective phytolith frequencies, whereby leaf phytoliths of 'domesticated' (i.e. triploid)-morphotype predominate over seed phytoliths. A reduction in the frequency of seed phytoliths towards the present plausibly represents the predominance of seed-suppressed cultivars (cf. Lentfer and Denham 2017).

Something different is clearly happening at 3986-3844 cal BP, with a peak in "domesticated banana leaf" types. Although still muted in comparison to the peaks in wild banana seed phytolith frequencies during the Pleistocene, it is suggestive of something different occurring in the landscape. The character of these phytoliths is not transparent to the reader based on the information presented. However, this later date range is more plausible for the introduction of cultivated diploids and/or triploids to Sri Lanka; indeed it is slightly later than the introduction of cultivated bananas to Kot Diji in Pakistan at 4450-3850 cal BP (Fuller and Madella 2009). However, there is no reliable evidence for the introduction of bananas further westward to Africa until 2750-2300 cal BP at Nkang, Cameroon (Mbida et al. 2001), given major uncertainties regarding claims for pre-5000 cal BP banana at Munsa in Uganda (Lejju et al. 2006; see Neumann and Hildebrand 2009). Hence, there is no archaeological context for inferring the earlier development of triploid bananas on Sri Lanka and their dispersal to Africa.

To recap, although Premathilake and Hunt (2018) present detailed information on modern banana morphometrics and descriptive morphological criteria for Sri Lanka, there is a lack of methodological transparency in how these criteria were applied to the phytolith assemblage at Fahien. Transparency is essential to enable the validity of the derived classifications to be assessed. Without such methodological rigour, claims for the generation of triploid bananas by 6195-5994 cal BP on Sri Lanka are without foundation.

Sri Lanka as likely recipient rather than source region of triploid cultivars

Regarding the commonly cultivated bananas in Sri Lanka, the now controversial suggestion that "triploid banana cultivars may have been generated as a direct consequence of the local geographical configuration of hybridization and dispersal during the Holocene" (Premathilake and Hunt 2018: 10) is unrealistic. It implies that Sri Lanka is a center of triploid banana generation, rather than considering India as the more likely proximal origin of AAB and ABB cultivars. The triploid cultivars considered to be generated on Sri Lanka are all popular in India as well; for instance, *Ambul* = Mysore, *Kolikuttu*= Rasthali (i.e.Silk), *Suwandel* = Pisang kelat, *Puwalu* = Pome/Nadan (Table 1;

compare to Prematilake and Hunt 2018: Tables *S2*-*S5*). The simultaneous presence of many popular cultivars in both countries indicates a cultural link, which could mean either the introduction from India to Sri Lanka or the reverse. The occurrence of the term "kesel/kehel" in several Sri Lankan cultivar names is highly suggestive of an Indian origin. The lack of synonyms in India for some less abundant cultivars in Sri Lanka may be due to incomplete comparative identification in both countries, or it could indeed indicate *ad hoc* generation of some triploids on Sri Lanka. However, since such cultivars are not known to be grown elsewhere, their dispersal from Sri Lanka is at least questionable. Of note is also the probable absence of traditional AAA triploids in Sri Lanka (Table 1), which negates the idea that *ad hoc* generation of AAA triploids could have taken place.

Although the Indian origin of at least one ascertained AAB triploid ("Pome") after the arrival of an edible AA via mainland Southeast Asia (after Perrier et al. 2011) is mentioned, an alternative origin from Sri Lanka is advanced by Prematilake and Hunt without any explanation for the necessity of such an optic. The alternative is introduced as "From our results …", yet *ad hoc* triploid generation on Sri Lanka is undemonstrated from the phytolith data, which is not able to discriminate triploid cultivar groupings, and would be highly controversial on botanical grounds. Further, the cultural argument, that the purported introduction to India from Sri Lanka occurred in the middle of the fifth millennium BP as a result of maritime networks associated with the Harappan urban period (see Fuller and Madella 2009), equally leaves open the possibility that cultivars could have dispersed from India to Sri Lanka.

Following the above, argumentation for a Sri Lankan origin of the African traditional cultivars, the AAB Plantain and AAA Highland cooking bananas, is misconceived and based on insufficient information. Firstly, the cited references (Perrier et al. 2009, 2011) exclude the controversial Munsa phytolith finding from Uganda in the development of their multidisciplinary reconstruction of banana domestication; hence the timeframe for the dispersal of bananas to Africa is limited to the last 3000 years (after Mbida et al. 2001), rather than extending back over 5000 years (after Lejju et al. 2006). Secondly, the possibility of an Arabian civilization involvement in the introduction of non-traditional AAB and ABB cultivars to the east coast of Africa was previously suggested by De Langhe et al. (1994-5), but for a much later period. Most tellingly, however, there is no diversity in AAB Plantain and AAA Highland cultivars on Sri Lanka today, which does not support an interpretation for the island as their center of origin.

An overview of the phytogeography of banana triploids militates against Sri Lanka as a region of origin and dispersal. Although some triploid diversity exists on the island, the greatest diversity in major triploid groupings exists outside Sri Lanka. It is more likely that major triploid groupings were generated across a vast Indo-Pacific region extending from India, across Southeast Asia to the New Guinea region (Li 1970). A selection of triploid cultivars was then introduced to Sri Lanka at various times and followed various dispersal pathways from India, as well as around the Indian Ocean. The Fahien evidence suggests that triploid bananas were cultivated on Sri Lanka around 3988-3844 cal BP, although a majority of them were probably introduced as triploids rather than generated

from diploids on the island. Hence, there are no grounds to suppose that triploids dispersed from Sri Lanka "[to India] during the middle of the fifth millennium BP", and "westwards to the east coast of Africa during the first half of the sixth millennium BP" (Premathilake and Hunt 2018: 12).

The Significance of Fahien

The Fahien rockshelter provides robust evidence for the presence of wild bananas extending back to over 40,000 years on Sri Lanka. However, there is no evidence to indicate that the exploitation of wild and cultiwild diploid bananas on Sri Lanka led to *in situ* domestication on the island.

Foremost, there is no archaeobotanical data presented for edible AA diploids at the site. It is acknowledged that the discrimination of phytoliths between wild and cultivated diploids is not possible. Consequently, the idea that edible AA cultivars were introduced to the island from the Island Southeast Asia- New Guinea region before 6194-5994 cal BP seems to be a narrative device. Such an introduction is invoked to drive an argument for the presence of edible AA, with the requisite genetic lineages, to then enable *in situ* triploid cultivar development on Sri Lanka.

Following the above, major triploid cultivar groups were more plausibly all introduced to the island, rather than generated on it, since insufficient information is presented on the discrimination of ancient phytoliths to ascertain how they compare to modern reference samples in terms of morphometrics and morphotypological (variant descriptive) criteria. Phytogeography and linguistics certainly suggest Sri Lanka as a recipient rather than originator of major triploid groups, with many cognate triploid cultivars on the Indian subcontinent.

Nonetheless, the findings at the Fahien rockshelter are significant. If consumption of wild bananas during the Late Pleistocene in Sri Lanka were to be confirmed, it would extend to a considerable degree the primary region of anthropic exploitation of wild bananas, from Sri Lanka in the west to the circum-New Guinea region in the east. Although early-to-mid Holocene claims are problematic, phytoliths plausibly indicate cultivation of bananas at 3985-3845 cal BP, although these results will need to be confirmed at other archaeological sites. Thus, the phytolith assemblage at Fahien rockshelter stimulates debate regarding the origin and dispersal of banana cultivars around the Indian Ocean, and will hopefully spur new investigations across this vast maritime landscape.

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Table 1. Indian synonyms of reported Sri Lankan cultivars

Genome type	Sri Lanka	India (Note 1)	Identity. Remarks (Note 2)
AAA	Amban		Introduced ‘ *Pisang Ambon”*?
AAA	Anamalu		*Gros Michel*
AAA	Bin-kesel		*Dwarf Cavendish*
AAA	Cavandish		*Cavendish*
AAA	William Hyb		*Introduced Cavendish hybrid*
AAB	Ambul	Mysore	Other name in S.L. = Honderawala
AAB	Kolikuttu	Rasthali	Standard name = Silk
AAB	Muwanathi-kesel		“kesel” → introduced from N. India (Note 3)
AAB	Puwalu	Vannan	Standard name = Pome
AAB	Suwandel	Thiruvannantapuram	Standard name = Pisang kelat
AAB	Neithrapalam		
AAB	Udakombu		
ABB	Alamburu		
ABB	Alu-kesel	Pey kunnan	Standard name = Pisang awak
ABB	Seeni-kesel		Close if not P.awak
ABB	Mondan	Monthan	
AAAA	IC2		Introduced Gros-Michel hybrid
AAAB	Kandula		
AABB	Pulasthi		

Notes
1. Several regional synonyms are used in India
2. In italics: relatively recent introductions
3. “Kesel/kehel” : “banana” in Sri Lanka, and “kela/keli” in North India.