Early Agriculture in Sri Lanka: New Archaeobotanical Analyses and Radiocarbon Dates from the Early Historic Sites of Kirinda and Kantharodai

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Abstract

Archaeobotanical evidence from two Early Historic sites in Sri Lanka, Kantharodai and Kirinda, is reported, providing significant evidence for agricultural diversity beyond the cultivation of rice. These data highlight the potential of systematic archaeobotanical sampling for macro-remains in tropical environments to contribute to the understanding of subsistence history in the tropics. Direct AMS radiocarbon dating confirms both the antiquity of crops and refines site chronologies. Both sites have *Oryza sativa* subsp. *indica* rice and evidence of rice crop-processing and millet farming. In addition, phytolith data provide complementary evidence on the nature of early rice cultivation in Sri Lanka. Both Kantharodai and Kirinda possess rice agriculture and a diverse range of cultivated millets (*Brachiaria ramosa*, *Echinochloa frumentacea*, *Panicum sumatrense*, and *Setaria verticillata*). Pulses of Indian origin were also cultivated, especially *Vigna radiata* and *Macrotyloma uniflorum*. Cotton (*Gossypium* sp.) cultivation is evident from Kirinda. Both sites, but in particular Kirinda, provide evidence for use of the seeds of *Alpinia* sp., in the cardamom/ginger family (Zingiberaceae), a plausible wild spice, while coconuts (*Cocos nucifera*) were also found at Kirinda.

Keywords: Sri Lanka, Rice, Millet, Cotton, Agriculture, Archaeobotany, Phytoliths

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1. Introduction

Sri Lanka possesses an archaeological and historical trajectory that, in many ways, diverges from that of the Indian peninsula, despite sharing many environmental and socio-cultural characteristics with the subcontinent (Coningham and Young 2015; Coningham and Strickland 2008, 791; Coningham and Allchin 1995, 152). Sri Lanka has been connected at various points in time and with varying intensity to broader Indian Ocean maritime trade networks, acting as an *entrepôt* for trade with South Asia and Southeast Asia, and interacting with both the Eastern and Mediterranean worlds (Thapar et al. 1996, 92; Fuller et al. 2011; Coningham, Manuel and Davis 2015; Crowther et al. 2016a; Prickett 1990; Prickett-Fernando 1994; 2003; Bopearachchi 1990; 2006; Perera 1952). Archaeological evidence testifies to an increase in maritime trade by the first millennium BC (Prickett-Fernando 1994, 2003; Bopeachichi 1995; 1996; 1998; Morrison 2016, 17; Muthucumarana et al. 2014, 56), as well as the emergence by this date of urban settlements and internal trade networks. To date, little archaeobotanical research has been undertaken in Sri Lanka, preventing a clear understanding of both the ecological context and subsistence strategies in which increasing urbanisation and trade was enmeshed (Kajale 1989; 1990; 2013; Premathilake et al. 1999; Premathilake 2006; Premathilake and Seneviratne 2015; Adikari 2009). To address this gap, this study adopts a multi-proxy environmental approach involving the examination of both the archaeobotanical seed and phytolith assemblages from the recent excavations of two early historic sites, Kirinda and Kantharodai.

1.1. Current Environment

The environment of modern day Sri Lanka is characterised by rainforests in the Wet Zone of the southwest of the island and drier variants in the Dry Zone in the rest of the country (Deraniyagala 1992, ix; Dassanayake and Fosberg 1983). The terrain of the island is low with the exception of the mountains located in the south-central interior; river systems radiate in multiple directions from this region to the coasts. Modern Sri Lanka is under the influence of a monsoonal climate regime modified by the effects of the mountains in the centre of the island (Gilliland et al. 2013, 1013), with the north-east monsoon lasting from October to March, with its regular rains ending in January and the southwest monsoon lasting from April to September with rain ceasing in June (Parker 1981, 347). Rainfall levels can

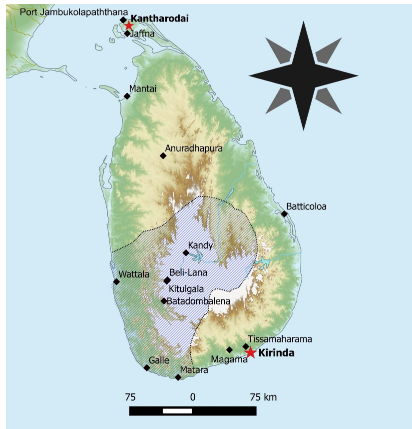

Figure 1: Map of Sri Lanka with labelled archaeological sites including Kirinda and Kantharodai. The hashed area represents the Wet Zone with the rest of the Island covered by the Dry Zone (Map created using QGIS 2.12.3-Lyon 2015

show significant intra- and inter-annual variability depending on the relative strength of the monsoon (Bauer and Morrison 2014, 2208; Premathilake and Risberg 2003; Kulatilake 2016).

1.2. Mesolithic and Early Historic Period: Transitions and Trade

Sri Lanka possesses a different and less well understood trajectory to agriculture than that seen in the neighbouring Indian subcontinent. Archaeologists working in the region have documented no parallel phase with that of the various Neolithic-Chalcolithic cultures of India (Coningham and Allchin 1995, 153; Morrison 2016, 18). Instead, current understanding suggests that hunting/gathering/fishing economies dominated the island until essentially the Late Holocene (Deraniyagala 1992; 2004; Simpson et al. 2008). With no evidence of an intervening Neolithic or Chalcolithic period in Sri Lanka, it would appear that the Stone Age was followed directly by the early Iron Age in the first millennium BC (Deraniyagala 2004; Bandaranayake 1988; Samarathunga 2007, 191). The late Iron Age, which partly overlaps with the Early Historic period, acted as a formative period in Sri Lankan prehistory, with recognizable technologies and institutional structures emerging, including the use of metal, the adoption of new agricultural regimes such as rice and paddy field cultivation, introduction of different varieties of domesticated plants and animals and the appearance of sedentary village settlement, craft production of metal objects, beads and pottery, the construction and expansion of sophisticated systems of water control and the appearance of increasing social inequality (Seneviratne 1984; Karunarathne 2010; Coningham and Allchin 1995, 153; Coningham and Strickland 2008, 791; Morrison 2016, 14; Samarathunga 2007, 191). In general, this trajectory in Sri Lanka appears broadly similar to that seen in parts of the far south of India, including areas of modern Tamil Nadu, where Mesolithic foraging transitioned directly into Iron Age agriculture, crop production and polity formation (see Fuller 2006, 53-55; Fuller 2008a). Along with the introduction of rice agriculture, a diversity of millets were adopted in the historic period, likely from Southern India, as dry farming, transforming the regional landscapes by the end of the First Millennium BC (Bauer and Morrison 2014, 2209-2210; Morrison et al. 2016; Morrison 2015, 11).

2. Kantharodai

Kantharodai, also known as Kadiramalai, is located in the arid zone of the Tropical thorn forest (also called Thorn Forest) ecozone (or ecozone-F by Deraniyagala (2004, Map 1, Figure 2.8)); similar ecozones exist in the Southern thorn forest, in Chitoor and Salem area of Tamil Nadu (Puri 1960; Asouti and Fuller 2008, 18), and the Thorn woodland of Burma (Richards 1964). The dominant physiognomy is shrub, normally comprised of stunted, twisted and gnarled trees with some ground flora. The arid zone temperatures range between 32-36 degrees Celsius. The annual rainfall in this region averages around 1000 mm (Deraniyagala 2004, 2) and the altitude is less than 300 metres (Perera 1975, 192).

Kantharodai is possibly the best-known archaeological site on the Jaffna peninsula (Deraniyagala 2004; 1992, x-xi; Ragupathy 1987; 2006, 57, 169), and was the first site the Archaeology Department in Sri Lanka excavated. In 1917, Sir Paul E. Pieris undertook a small-scale exploratory, horizontal excavation of the Buddhist monastic complex (Perera 2013, 62; Ragupathy 2006, 57). In 1970, a joint excavation between the University of Pennsylvania and Sri Lankan Archaeological Department returned and dug three test pits now believed to date to the Early Historic period (Ragupathy 2006, 57). A joint team of archaeologists from the Sri Lankan Archaeological Department and the University of Jaffna worked together on the most recent excavations at Kantharodai in 2012. They attempted to address some of the shortcomings from the previous 1970 excavations, including resolving issues of chronology and a lack of post-excavation analyses (Perera 2013, 63-65). The present excavations at Kantharodai place the archaeological material discussed in this paper firmly within the Historic period (Bohingamuwa 2017; Perera 2013; Deraniygala 2004).

Kantharodai is an inland site with an adjacent ancient sea port called Jambukolapatthana (Figure 1). Kantharodai was an early religious and agricultural settlement situated in the centre of the Jaffna peninsula, and was likely founded in the Proto-historic Early Iron Age and certainly by the beginning of the Early Historic Period (*circa* 450-500 BC), coinciding with the emergence in Sri Lanka of urbanization, literacy and long distance trade, as well as the arrival of Buddhism (Coningham and Strickland 2008, 791). Kantharodai, together with Anuradhapura, and Tissamaharamai, is amongst the largest early historic urban and religious centres in Sri Lanka dating from the Early Historic period. The ancient settlement mound is spread over 25 hectares, making it the largest early archaeological site on the Jaffna Peninsula (Coningham and Allchin 1995, 171; Perera 2013, 62; Ragupathy 2006, 57, 148, 169; Strickland 2017). Indeed, Kantharodai appears to be the only early urbanised central place in Jaffna, with satellite settlements and *entrepôt*s located throughout the Peninsula.

Unsurprisingly, given its proximity to the sea, Jaffna actively participated in both early trans-oceanic trade and the regional trade between south India and Sri Lanka, as evidenced, for example, by the presence of foreign trade items such as coins and pottery dating to Indo-Roman times (Ragupathy 2006, 61, 151, 169). This maritime trade decreased with the decline of the Roman Empire around the 5th century AD (Ragupathy 2006, 61). The later Arab-Chinese trans-oceanic trade focused upon the port site of Mantai, 100 km southwest of Jaffna in the Mannar district of Sri Lanka (Figure 1) (Carswell 2013; Ragupathy 2006, 61, 174; Kingwell-Banham 2015; Bohingamuwa 2017).

Recent pollen work on archaeological grave fills of the Early Historic period (ca. 420 cal BC- cal AD 20) at Galsohon-Kanatta, an Iron Age cemetery in Yapahuwa, north-western Sri Lanka have suggested long-distance trade in plant products, such as perishable flowers (Premathilake and Seneviratne 2015). Amongst the reported pollen identifications are temperate conifers (e.g. *Pinus* sp., *Tsuga* sp.) and floating aquatics, waterlilies and lotus (i.e. *Nymphaea* spp., *Nelumbo* cf. *nucifera*). Based on insecure identifications to northern Eurasian (*Nymphaea* cf. *tertagona*) and Mediterranean (*N.* cf. *alba*, *N.* cf. *lotus*) taxa, Premathilake and Seneviratne (2015) have argued that this indicates trade in cut flowers from Early Egypt to Sri Lanka. However, given the likelihood of indigenous South Asian *Nymphaea* spp. and *Nelumbo*, the claim for maritime trade is probably overstated. Nevertheless, these aquatic taxa may be indicators of increased anthropogenic water environments, such as irrigation tanks that would have been associated with early rice cultivation throughout the dry zone of Sri Lanka.

The importance of artificial irrigation for the Jaffna peninsula is clear. The peninsula possesses no major rivers or lakes and fresh water availability depends on two months of rainfall from the returning monsoon (Ragupathy 2006, 135). This highlights the need for irrigation channels and water storage tanks for flooding for rice cultivation. Kantharodai's location has the most potential for settlement on the peninsula, with its tanks, drainage and paddy field belt. Thus, its advantageous location possesses the capacity to support the necessities of a central place in a region like Jaffna (Ragupathy 2006, 169). However, with the movement towards a hydraulic-based agricultural system, it is likely that Jaffna, with less irrigated land and water resources, was unable to compete with Anuradhapura (Ragupathy 2006, 184). With the shift in power to Anuradhapura, based upon the archaeological evidence to date, it would appear that the settlements in Jaffna during this phase were impoverished compared to the richer settlements in the Dry Zone to the south. It is likely that during this phase, Jaffna came under the hegemony of Anuradhapura and that afterwards the site was abandoned (Ragupathy 2006, 174).

*Table 1: Test pit No. 1 and No. 2 stratigraphy based upon radiocarbon dating, ceramic evidence and archaeological strata from Kantharodai. *See Table 9 for complete AMS dating information*

Test Pit 1	Test Pit 2	Phase	*Lab Number
VIII & IX	VI, VII, VIII	Disturbed Strata	399421
VIII	IV	ca. 170 BC	
VI	V	ca. 200 BC	399420
VII	III	ca. 350-219 BC	399419
IV	II	ca. 400 BC	
II		Sterile	
I	I	Miocene Limestone Bedrock	

The most recent excavation information from Kantharodai is confined to a brief report by the excavator (Perera 2013:63-65) and site stratigraphic details are still unpublished. Trench KTD1 was excavated to a depth of 5.80m from the surface and seven phases have been identified by the excavator. These phases include a lowermost phase, mostly comprised of Miocene bedrock (Phase I) and a succeeding sterile layer (Phase II). KTD 2, the second trench, was excavated to a depth of 6.00m from the surface. Eight phases have been excavated by Perera (Table 1).

Bohingamuwa (2017, 89; Table 2.5; Catalogue 7.1.1.1 and 7.1.1.2), argued that the trenches belong to the same chronological period, based on the striking similarities of the material culture recovered from both trenches, and drew on this to construct continuous site phasing for Kantharodai. The majority of the material remains recovered from both trenches were ceramics (11,011 ceramic sherds, representing 27 different types of wares), followed by beads. Eighty-eight percent (88%) of the ceramics recovered were local wares. Of the imported ceramics, 99% were Indian wares, including Fine Grey Wares and Red Polished Wares. The small proportion (1%) of imported wares, were largely undiagnostic, though some are suspected to be Southeast Asian. The ceramic assemblage does not contain any diagnostic wares that could be identified as being imports from the Middle East or China. Overall, the ceramic assemblage clearly indicates that Kantharodais external interactions were largely focused on India, though possibly with some limited interactions with Southeast Asia (Bohingamuwa 2017). Nearly 84% of the bead assemblage was also local, and the only imported beads were of Indian origin, confirming the above pattern in the ceramic assemblage (Bohingamuwa 2017: 396; Catalogue 7; Table C7.1.12.10).

3. Kirinda

Located in the Dry/Arid Zone (the Eco-zone F in Deraniyagalas classification (1992; 2004:487), the main features of the southern and south-eastern arid lowlands are the lagoons, marshes and sand dunes. The annual rainfall in this region averages between 100-1000mm (Wickramatilleke 1963: 31). Kirinda is in the tropical lowland seasonal rain forest ecozone, which is similar to the Tropical dry evergreen forest, along the Carnatic coast from Tennevalley to Nellore, in Tamil Nadu, India (Puri 1960; Perera 1975, 192; Asouti and Fuller 2008, 52-57). Evergreen trees are usually more abundant, and so the forest retains its overall evergreen character at all times (Perera 1975, 197).

Kirinda is a historic coastal site situated in the Hambantota district of the Southern Province, on the southern coast of Sri Lanka (Figure 1). Kirinda sits within the Lower Kirindioya basin. It is located about 10 km southeast of Tissamaharama, the capital of the ancient Ruhuna kingdom, founded in the 3rd century BC according to both historical sources and archaeological remains (Weisshaar et al. 2001, 61). The modern day Kirinda fisheries harbour is located adjacent to the ancient Kirinda Vihara, dating to the 2nd century BC based upon inscriptions.

Previous research at Kirinda surveyed and excavated a habitation mound (referred to as KR01) (Bohingamuwa 2017; Somadeva 2006). Previous dating attempts have been problematic with significant reversals in the stratigraphic sequence between the uppermost deposit (dated to 1410-1700AD) and an overlying horizon (dating to 260-30BC). This is one of the reasons that the authors decided to analyze samples from disturbed contexts. However, the majority of dates from the site correspond to the Historic period *circa* 550-900AD. Nevertheless, the site has been interpreted as having long-term occupation from 260BC to 1400AD, overlapping with early urban activity across the Lower Kirindioya basin (Somadeva 2006; cf. Bohingamuwa 2017).

The renewed study of Kirinda in 2013 was undertaken as part of a collaborative project between the Central Cultural Fund of Sri Lanka, the Post Graduate Institute of Archaeology of Colombo, and the Universities of Oxford, Bristol, Institute of Archaeology, UCL and Ruhuna. In addition to the recovery of samples for archaeobotanical investigation, these excavations were conducted to resolve problems surrounding the dating of the archaeological sequence at Kirinda (see Tables 2 &3, & S4). Excavations were conducted in two locations, both of which reached culturally sterile beach deposits. The first trench (KR02) was excavated as four adjacent 1m quadrants at the edge of modern beach deposits. A shallow sequence of occupation horizons including minor cut and fill activity was identified and formed eight discrete horizons (Table 2). Phases 1, 3 and 5 were identified as discrete occupation horizons that likely reflect small-scale domestic activity at the site (Table 2).

*Table 2: Description of stratigraphic phases identified in excavations of Trench 2, Kirinda (KR02). Note that the number of the phases begins at the lowest phase. Additional soil descriptions provided in Supplementary S4. * See Table 9 for full AMS radiocarbon dating data.*

Phase	Description	AMS Lab No*
Phase 8	Modern topsoil	
Phase 7	Recent occupation deposits	
Phase 6	Mixed occupation deposits	
Phase 5	Occupation horizon	
Phase 4	Low intensity occupation deposits, small circular pit present	376484 376483
Phase 3	Occupation horizon rich in artefacts	
Phase 2	Lack clear occupation characteristics	376485
Phase 1	Oval pit cut including post-hole	

A second larger trench (KR03) was excavated as a single 4m x 2m trench into habitation mound deposits.Twelve distinct phases of activity were identified in the 2m deep sediment sequence (Table 3). Initial cultural activity at the site was evident in the form of hearth refuse deposits and a collection of small postholes in Phase 1, sealed by a mixed ashy loam in Phase 2, suggestive of small-scale habitation. More significant structural activity is evident in Phase 3a, with a linear alignment of large postholes spanning the length of the trench, and likely extending beyond. Phase 3b marks the end of the life of the structure, with large pits cut around the post holes, potentially to aid robbing large posts for use elsewhere. The overlying deposits predominately comprise numerous discrete or mixed dump deposits, with little clear indication of occupation within the bounds of the trench spanning Phases 4-12.

*Table 3: Description of stratigraphic phases identified in excavations of Trench 3, Kirinda (KR03). Note that the number of the phases begins at the lowest phase. Additional soil descriptions provided in Supplementary S4. *See Table 9 for full AMS radiocarbon dating data.*

Phase	Description	AMS Lab code No*
Phase 12	Disturbed topsoil	
Phase 11	Pale grey ashy, silty sands	
Phase 10	Broken ceramics present, potentially a discrete dump	
Phase 9	Mixed occupation dump deposits	
Phase 8	Mottled horizon comprising shell rich dump horizons	
Phase 7	Shell rich dump horizons	
Phase 6	Discrete dump horizons	
Phase 5	Thick deposit with sparse charcoal inclusions	
Phase 4	Distinct clayey horizon, potentially stabilise ground surface	
Phase 3a	Linear alignment of large post-holes	
Phase 3b	Robbing post-holes and cutting of large pits	
Phase 2	Ashy mottled silty sands	378859
Phase 1	Initial occupation with small scale structural activity	399418 (S401556 & S402885), 376487

The overall sequence represented at Kirinda, based upon the radiocarbon dates and limited quantity of Chinese and Middle Eastern ceramic wares as well as datable local wares, appears to date from ca. late 3rd/4th century AD to the early/mid-8th or 9th century AD (Bohingamuwa 2017; 98; Table 2.6). The material culture recovered from the two trenches at Kirinda is strikingly similar, with assemblages dominated by ceramics, with beads constituting the next most common class of material culture recovered. The paucity of imported materials highlights the role of Kirinda as a regional fisheries harbour that only occasionally participated in external trade. Of the ceramics recovered from KR3, for example, 93% appear to be local wares while 1.5% are classed as India-Sri Lanka wares, non-diagnostic coarse wares that could have originated from either India or Sri Lanka. Very limited quantities of ceramics from India, South-east Asia, China and the Middle East were identified (Bohingamuwa 2017, 478 and Table 7.2.1.2). The bead assemblage recovered from Kirinda also confirms this pattern. Ninety-three percent (93%) of the 447 beads recovered from KR3 were locally made (Bohingamuwa 2017; 478-488 and Table 7.2.2.11), while only a small quantity of imported beads, produced in India, the Mediterranean and South-east Asia, were recovered. Some or all of these imported artefacts may have arrived in Kirinda via Tissamaharama, the main urban centre in the region (Figure 1) (Bohingamuwa 2017).

4. Materials and Methods

Flotation samples of bulk sediment were collected during excavation at Kirinda and processed near the site by means of washover method bucket flotation (Pearsall 2000, 84). This method has proved reliable over a wide range of field conditions in the tropics (e.g., Fuller et al. 2004; Castillo et al. 2016a,b; Crowther et al. 2016b). Flots were captured in bags with 250 μ mesh, which is sufficiently small to assure good recovery of rice chaff (spikelet bases) and small weed seeds, notably of aquatics such as *Cyperus* or *Typha*. All archaeological stratigraphic layers, i.e. fills, as well as those associated with recognizable cultural features were targeted. At the site of Kirinda, flotation was supervised by Charlene Murphy (CM) and H. Horton; the majority of flotation samples measured 40 litres (Table 4, S2). Heavy fractions were sorted in the field for other categories of archaeological evidence. At the site of Kantharodai, 20 litre archaeobotanical samples were taken and floated by Wijerathne Bohingamuwa (WB) and colleagues (Table 4, S2). All additional environmental remains recovered from heavy fractions, such as artefacts, faunal remains, and snails and other shells were sorted, labeled and catalogued.

All light fraction flotation samples were run through 2, 1 and 0.5 mm geological sieves before sorting. Sorting for Kantharodai was carried out by Patrick Austin, a research assistant at UCL and CM; identifications were made by CM and Dorian Q Fuller (DF). Sorting for Kirinda was carried out by CM and identifications were made by CM and DF. Dried flots from both sites were sorted in London under a low power binocular microscope for the separation of seeds and wood charcoal, with identification carried out with consultation of the UCL archaeobotanical reference collection, various seed atlases, and reference to previous experience with tropical Asian assemblages (e.g. Fuller 1999; Fuller et al. 2004; Castillo et al. 2016a). Discussion of some key identification criteria is included in the Discussion section. All radiocarbon dates were sent to Beta Analytic, UK and carried out on charred archaeobotanical remains using standard pre-treatment methods (acid/alkaline washes). (Table 9, S1).

Table 4: Kantharodai and Kirinda Flotation and Archaeobotany Summary

	Kantharodai		Kirinda	
	Trench 1	Trench 2	Trench 2	Trench 3
Average Flotation Sample Volume (L)	20	20	40	40
Total Flotation Volume (L)	380	520	1060	2785
No. of Light Fraction Samples	19	26	28	44
Total Volume of Light Fraction Samples (L)	1	3.2	1.5	9.2
Total Count of Archaeobotanical Remains	1614	974	1054	2484
Total Taxa	16	27	5	11

4.1. Phytoliths

Small sediment samples of up to approximately 5 grams of unprocessed soil were collected from each archaeological context at both sites for phytolith analysis. Fourteen phytolith samples in total were analysed. Five samples from Kirinda and 9 samples from Kantharodai were analysed. Methods of phytolith extraction (removal of organics by loss on ignition in a furnace, removal of carbonates by HCL acid, and heavy liquid flotation with sodium polytungstate) followed established protocols in the UCL Archaeobotany Laboratory. Subsequent systematic analysis of slides by AW recorded at least 300 single cell morphotypes and 100 multi-celled silica skeletons, following, in the first instance, the international code for phytolith nomenclature (Madella et al. 2005) and beyond that utilising the phytolith reference collection at UCL and published references (Metcalfe, 1960, Kealhofer and Piperno, 1988, Chen et al., 2013, Weisskopf, 2014, de Albuquerque et al., 2015) (S3).

5. Results

Preserved macrobotanical remains were recovered from both Kantarodai and Kirinda. Many of the seed remains recovered are taxa that have been found across numerous archaeological sites in South Asia and for which there are established identification criteria. The most ubiquitous crop on both sites was rice, including grains and rice spikelet bases; spikelet bases could be classified following the scheme of Fuller et al. (2009). Millets were also recovered, and identified following Fuller (1999; 2006), while pulse identification criteria follow Fuller and Harvey (2006). Cotton (*Gossypium* sp.) could be identified based on testa fragments and funicular caps (Fuller 2008b; Crowther et al. 2016b). Weedy taxa and other wild remains were assigned to the most probable family where known matches in reference material or seed atlases could not be made. Key criteria used for some challenging taxa are summarized here, including millets, *Spermacoce*, and *Alpinia*.

Table 5: List of Specimens Present in Trench 1 from Kantharodai by Phase

Taxa	**ix**	**viii**	**vii**	**vi**	**v**	**iv**	**iii**	**ii**	**i**
Rice		X	X	X	X	X			
Rice Spikelet bases	X	X	X	X	X	X	X		
Zingiberaceae		X			X				
Genus Alpinia									
Cotton	X	X	X						
Pulses	X	X	X						
Millets	X	X	X						
Weed Seeds	X	X	X						

Table 6: List of Specimens Present in Trench 2 from Kantharodai by Phase

Table 7: List of Specimens Present in Trench 2 from Kirinda by Phase

Taxa	vii	vi	v	iv	iii	ii
Rice	X		X	X	X	X
Rice Spikelet bases	X	X	X	X	X	X
Zingiberaceae						
Genus Alpinia		X			X	
Cotton			X		X	
Pulses	X	X	X	X	X	
Millets	X	X	X	X	X	
Weed Seeds	X			X		

Taxa	Tsunami	Post-hole Building Fill	Fill	Upper House	Fill	Lower House	Fill	Oval House	Natural
Rice			X	X	X	X	X	X	
Rice Spikelet bases			X			X		X	
Zingiberaceae	X	X	X	X	X	X	X	X	
Pulses			X	X		X		X	
Millets				X			X		
Portulaca			X	X			X	X	
Coconut				X			X		
Nutshell				X	X		X	X	
Weed Seeds					X	X			
Fruit Mesocarp				X					
Exocarp			X			X			

Table 8: List of Specimens Present in Trench 3 from Kirinda by Phase

Taxa	Phase i	Phase ii	Phase iii
Rice	X	X	X
Rice Spikelet bases	X	X	X
Zingiberaceae			X
Genus Alpinia			
Pulses	X	X	X
Millets	X	X	X
Portulaca	X	X	X
Coconut		X	X
Nutshell	X	X	X
Weed Seeds	X	X	X
Fruit Mesocarp	X		X
Exocarp	X		
Cotton	X	X	X

5.1. AMS Dates and Chronology

Table 9: List of Specimens Radiocarbon Dated from Kirinda and Kantharodai. *All radiocarbon dates were sent to Beta Analtyic, UK. Standard pre-treatment methods were used (acid/alkaline washes). OxCal. v.4.3.2 and IntCal14 Bayesian sequence model used.

6. Discussion

6.1. Archaeobotanical Assemblages

6.1.1. Kantharodai

The archaeobotanical assemblage from Kantharodai was composed primarily of pulses, millets, rice and rice crop-processing waste (Table 5 & 6). Figure 9 shows that each phase is dominated by rice spikelet bases which

Lab ID*	Sample ID	Site	Material	Delta^{13}C age (BP)	Radiocarbon (95% confidence)	Calibration Date
378857 & Supplement 376483	KR02-31-5	Kirinda	Charred Rice (*Oryza sativa*)	-25.50/00	1430±30	AD 575 to 655
376484	KR02-35-4	Kirinda	Charred Rice (*Oryza sativa*)	-25.50/00	1490±30	AD 540 to 640
376485	KR02-48-6	Kirinda	Charred Rice (*Oryza sativa*)	-22.30/00	1620±30	AD 385 to 475 AD 485 to 535
399418 Supplements 401556 & 402885	KR03-64	Kirinda	Charred Rice (*Oryza sativa*)	NA	1420±20	AD 595 to 660
378859	KR03-36	Kirinda	Charred Rice (*Oryza sativa*)	-25.40/00	1210±30	AD 715 to 745 AD 765 to 890
376487	KR03-41D-1	Kirinda	Charred Rice (*Oryza sativa*)	-25.60/00	1290±30	AD 660 to 770
399419	KTD02-32	Kantharodia	Charred Kodo millet (*Paspalum scrobiculatum*)	NA	2140±30	350 to 305 BC 210 to 90 BC 65 to 60 BC
399420	KTD02-37	Kantharodai	Charred Rice (*Oryza sativa*)	-25.60/00	2220±30	BC 380 to 200
399421	KTD02-15	Kantharodai	Charred Kodo millet (*Paspalum scrobiculatum*) & Rice (*Oryza sativa*)	-18.30/00	2080±30	180 to 40 BC 5 BC to AD 0

decrease slightly through time. Very low numbers of rice caryopses, millet and pulses were recovered from the rest of the assemblage. There is evidence of *Alpinia* cf. *zerumbet* (Zingiberaceae), as at Kirinda, but in very low numbers (S2). Rice caryopses comprised a low percentage of the total assemblage, 1% of the total assemblage from Trench 1 and 4% from Trench 2; a typical pattern seen with rice crop-processing at archaeological sites (S2). This domesticated crop assemblage is complimented by the recent faunal analysis which has identified food debris, comprised notably of domestic cattle, pigs, and goats along with fish and wild pig remains suggesting that the inhabitants were using both domesticated and wild animals in their subsistence strategy (Perera 2013, 62).

6.1.2. Kirinda

The archaeobotanical assemblage from Trench 2 was dominated by *Alpinia* cf. *zerumbet*, with fruits and nuts representing the next largest category. *Alpinia* cf. *zerumbet* are present in most phases of Trench 2, raising the possibility that it is more than a contaminant from the surface level/2005 Tsunami level. Also, as it is charred this would suggest anthropogenic use. Low counts of rice, rice spikelet bases and pulses, millets and other weed seeds were recovered (S2).

From Trench 3, rice is the largest component of the assemblage recovered.

The Zingeribeceae family is also present. Rice and rice spikelet bases, pulses and millets were recovered in slightly larger numbers, when compared with Trench 2, along with some cotton fragments (*Gossypium* cf. *arboreum*)(S2, Table 7). Looking at the results from Trench 3 by phase it is clear that rice dominated the assemblage in phases i and ii and there was a shift in phase iii with rice spikelet bases dominating the assemblage. Small amounts of coconut shell, fruit mesocarp, and vascular tissue were also recovered from all three phases along with cotton (*Gossypium* sp.) and a few different millets including *Echinochloa* cf. *frumentacea* (millet) and *Brachiaria ramosa* (browntop millet) (S2, Table 3).

6.2. Millets

Small millet grains were recovered in limited quantities from both sites (4-21% of seeds in selected samples), including a diversity of morphotypes at Kantharodai (S1). Identifications of millets was done using criteria that had been developed from a fairly extensive reference collection at UCL and extensive experience with archaeological millets across South and East Asia (e.g. Fuller 2003; Fuller et al. 2004; Deng et al. 2015). Representative specimens are illustrated in Figures 2 and 3. Three of the millets types have long embryos, i.e. with embryo length of around 60% grain length or more, as characteristic of *Brachiaria*, *Echinochloa* and *Setaria*.

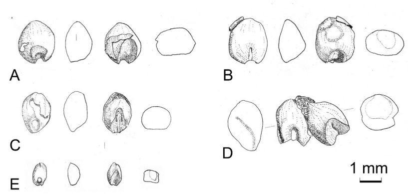

Figure 2: A. *Echinochloa* cf. *frumentacea*, from KTD Pit 2 Flot 37; B. *Paspalum* sp., from KTD Pit 2 Flot 32; C. *Brachiaria ramosa*, from KR03, Flot 44l D. *Panicum sumatrense*, two adhering grains, from KTD Pit 1, Flot 50; E. *Setaria* cf. *verticillata*, from KTD Pit 1 Flot 10 (Drawn by DQF).

Among these, *Echinochloa* (Figures 3A and 4E) is recognizable by having its maximum breadth displaced towards the embryo end while tapering towards its apex. Other millets have their maximum breadth towards the middle of the grain. *Echinochloa* also has a hilum that is wider than it is long

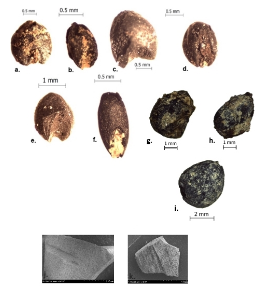

Figure 3: Millets recovered from Kirinda and Kantharodai a. *Paspalum* sp., b. *Setaria* cf. *verticillata* c. *Panicum sumatrense* d. *Brachiaria ramosa* e. *Echinochloa* cf. *frumentacea* f. *Digitaria* sp., Carbonised Cotton (*Gossypium*) from trench 3 from Kirinda g. KR03-41 h. KR03-33 i. KR03-15, j. & k. SEM image of Coconut shell fragment from Kirinda.

(hL/wW < 1). While it not strictly possible to distinguish *Echinochloa* to species, domesticated taxa (*E. utilis*, *E. frumentacea*) are closer to round (the L/W ratio in modern *E. frumentacea* averages 1.07), while wild taxa, such as *E. colonum* averages more than 1.2. This specimen, of *Echinochloa*, is most likely to be cultivated sawa millet of Indian origin (De Wet et al. 1983a), and is therefore assigned to *Echinochloa* cf. *frumentacea*. The prehistory of this crop is poorly known, although there is some evidence that it was cultivated in parts of the Harappan world as suggested by recent finds (Bates et al. 2016). *Echinochloa* recovered from South Indian Neolithic (Fuller et al. 2004) suggest it was an occasional crop from ca. 1500 BC onwards in southern India, and it is known from Iron Age/Early Historic contexts in Tamil Nadu (Cooke et al. 2005), from whence it likely came to Sri Lanka as reported here.

The other large long embryo millet is *Brachiaria ramosa*, which is similar in general to *Setaria italica*, but is generally more dorso-ventrally compressed (L/T around 0.5), with a somewhat larger hilum (hL/L averages 0.25 compared 0.2 in modern *S. italica*). *Brachiaria ramosa* was the staple millet of South India throughout the Neolithic (Fuller et al. 2004; Kingwell-Banham and Fuller 2014), and remained an important crop into the Early Historic era as indicated by evidence from Paithan in Maharashtra (Fuller, n.d.) and sites in Tamil Nadu (Cooke et al. 2005). In the Southern Neolithic, *Setaria verticillata* was a recurrent companion species to *Brachiaria ramosa*, interpreted as a grain crop (Fuller et al. 2004), and thus the identification of a small *Setaria* cf. *verticillata* type from Kantharodai is perhaps to be expected.

A shorter embryo millet is represented by *Panicum sumatrense*, with an embryo length/length ratio of just under 0.5., which also has a characteristic acute apex. This Indian little millet was an occasional crop in South India during the Neolithic and Iron Age to Early Historic periods (see Cooke and Fuller 2015), but was a much more prominent crop in Gujarat and elsewhere in the Harappan world of northwestern India (Weber and Kashyap 2016; Pokharia et al. 2014).

Much shorter embryo ratios are found in a few grasses, including the rather round *Paspalum* sp. and the small, elongate *Digitaria* sp.. *Digitaria* spp. are widespread weeds, both of rice and millet cultivation (Chen et al. 2017; Moody 1989). While kodo millet (*Paspalum scorbiculatum*) was an important cultivar in Iron Age and Early Historic southern India (Cooke and Fuller 2015). Domesticated kodo millet tends to have much more circular (L/W= 1.0) and thicker grains. *Paspalum scrobiculatum* is a widespread weed of rice cultivation (Moody 1989). Rice weed surveys in Sri Lanka have found the closely related *P. commersonii* and *P. conjugatum* are frequently encountered weeds (Chandrasena 1989), and these have more elongated grains than *P. scrobiculatum*, although further comparative work is needed to separate the charred grains of various wild *Paspalum* spp. The only complete specimen recovered is fairly elongate (L/W: 1.5) and has a compressed shape. This suggests that the *Paspalum* recovered here may have been a wild form.

6.3. Zingiberaceae: Alpinia cf. zerumbet type

From the archaeobotanical assemblage from Kirinda, quite a few specimens of an ovate-conical to slightly trigonous seed were recovered. These have a strong resemblance to taxa in the Zingiberaceae family, and identification as such is favoured not only by overall shape, but by the presence of an interior tubular embryo and an irregularly patterned or rippled surface (Figure 4). Preservation of internal morphology was limited however, as interiors were often highly porous in broken specimens, a taphonomic outcome that might be expected with Zingiberaceae as a result of their endosperms essential oil content. Zingiberaceae is a family of flowering plants made up of more than 1,300 species of aromatic perennial herbs, which are divided into approximately 52 genera found throughout tropical Africa, Asia, and the Americas, with particularly high diversity found within tropical Asia. The most diverse group is the tribe Alpinoideae, including the genus *Alpinia*

(Kress et al. 2005; Mabberley 2008). This family includes a larger number of economic species, cultivated and collected for either their seeds (various forms of cardamom, grains of paradise) and/or their rhizomes (gingers, turmeric, galangal). Published studies of seed morphology and anatomy are available (Liao and Wu 2000; Benedict et al. 2015), although none are comprehensive and no seeds were available as reference material in our collections. Nevertheless, general seed shape and surface patterns resemble those illustrated from *Alpinia*. A few broken specimens preserve what appear to be two parallel embryo compartments about one third of the distance along the seed length (Figure 4b). This suggests a forked embryo, regarded as characteristic of the *Alpinia* ki clade in Benedict et al. (2015), which includes the shell ginger, *A. zerumbet*, known to be cultivated for its rhizomes in India and Sri Lanka (Ibrahim 2001). The large quantities of remains of this type in our material suggests the use of the seed, probably as a cardamom-like spice. Given that both of our sites lie in the dry zone of Sri Lanka, whereas *Alpinia* can be expected to grow mainly in the Sri Lanka wet zone, we infer that these were either traded to these sites as spices or were cultivated.

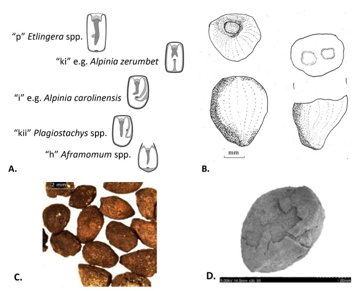

Figure 4: A. Selected schematic cross-sections on internal anatomy of *Alpinia* spp. and close relatives grouped into the clades (h, p, Ki, etc.) after Benedict et al. (2015) (drawings by DQF). B. Drawings of two examples of charred *Alpinia* seeds from Kirinda, a complete seed at left and a broken seed, at right, showing the cavities from split embryo like that in the ki clade (drawings by DQF). C. Carbonised *Alpinia* seeds from Kirinda D. SEM of carbonised *Alpinia* seed from Kirinda.

6.4. Weeds

Mericarp fruit segments, which appear to be from a Rubiaceae, *Spermacoce* (syn. *Borreria*), were identified in the Sri Lankan assemblages. These

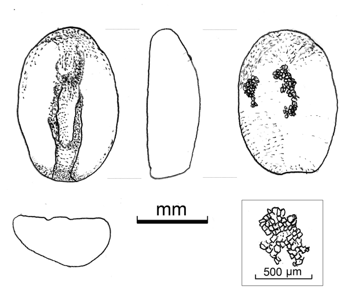

Figure 5: Drawing of *Spermococe* cf. *hispida* from Kirinda, Trench 3 (Drawings by DQF)

are semi-conical in shape with a round ridge or tongue running down the middle of the flat side (Figure 5). *Spermacoce* is a genus of many weeds found in arable fields throughout the tropics (Sivarajan et al. 1987). Amongst original species in the Old World are taxa that have apparently been human dispersed from Africa to Asia and from Asia to Africa (Fuller and Boivin 2009). The Sri Lankan material here has a pitted surface, which on closer inspection has a finely reticulate testae pattern, with five-sided, fairly equilateral, and straight (not sinuous), cell walls. The seed (mericarp) has a broadly ellipsoid shape. Based on a comparative study of ten species (Chaw and Sivarajan 1989), we found similarity with *S. alata* (usually considered as South American in origin), although now widespread in Sri Lankan rice (Moody 1989; Chandrasena 1989), and *S. hispida*, regarded as native to South Asia (Fuller and Boivin 2009), and frequent on rice field bunds in Sri Lanka (Chandrasena 1989). Its native habitat is sandy soils, and it is common in coastal regions (Panda 1996; Sivarajan et al. 1987); thus it could be native to the region around Kirinda, growing around rice fields or in millet fields. Previously, a *Spermacoce* sp. has been found in South Indian Neolithic sites as a probable weed of millets like *B. ramosa* (Fuller 1999), and these finds were also probably *S. hispida* type.

6.5. Coconuts

Fruits and nuts were recovered in relatively small quantities from both sites. Some of these could not be accurately identified. One recognisable taxon was coconut, preserved as fragments of shell (i.e., endocarp of *Cocos nucifera*). The SEM images show that coconut nutshell has a consistent thickness, with indented impressions of fibrous hairs often running through the surface of the shell fragments (Figure 3i & 3j) (Walshaw 2010). Vascular strands are also visible as hollows in the cross section.

Aside from the identification of a few coconut shells, there is limited evidence of any sort of wild fruit and/or plant resource used at either Kirinda or Kantharodai. Although quite a few fragments of the category vascular tissue and probable exocarp tissue were recovered, these were not identifiable to species level.

Coconut is an important traditional cultivar in Sri Lanka, especially in coastal regions, as it is elsewhere in India and Southeast Asia. Recent genetic research suggests two main groups of coconuts, one associated with the Indian Ocean and one with Island Southeast Asia and the Pacific (Gunn et al. 2011), although most earlier commentators have pointed to a single Malaysian origin (e.g. Burkill 1966; Simoons 1991). Possible wild coconuts are suggested to be found in the Seychelles, Sri Lanka and parts of coastal Southeast Asia, but the early history of cultivation and translocation of these trees remains obscure, although dispersal throughout the Pacific and westwards to mainland Africa and Madagascar has been traced through a combination of linguistic and archaeological evidence (Boivin et al. 2013; Crowther et al. 2016b; Gunn et al. 2011). In South India, Dravidian linguistic reconstructions suggest that coconuts were added to the plant repertoire at the Proto-South Dravidian stage, at around the same time as Citrus fruits, cotton and iron metallurgy, placed broadly in the first millennium BC or later second millennium BC (Fuller 2007).

6.6. Phytoliths from Kirinda and Kanthoradai

Both sites produced phytoliths, Kirinda more than Kanthoradai, despite fewer samples (5) being analysed, probably because despite being in the dry zone, Kirinda is situated in a tropical lowland seasonal rainforest environment where abundant evapotranspiration is to be expected, whereas Kanthoradai, located in the arid zone, has less access to water outside the monsoon which is reflected in both the composition of the samples and the production of fewer phytoliths overall.

As can be seen from multivariate correspondence analysis (Figure 6), while along axis 1 the samples from both sites all fall within the same range, the sites separate along axis 2. This is because Kanthoradai has a greater variation in morphotypes and greater variation in the proportions of morphotypes. The samples containing the millets are separate on the right side of the chart. These samples contain higher proportions of Panicoids but also some rice and phytoliths from hydrophilic plants, suggesting both millet and rice crop-processing waste in the same sample.

Although there are bilobate single cells from Panicoids, there were no millet or Panicoid multicells at Kirinda. One sample contained scant Setaria type bilobate single cells (1.6%). At Kantharodai, however, five samples contain either Setaria type bilobes, millet, Panicoid multicells which fits with the macrobotanical results and the site's location in the arid zone. The majority of phytoliths cannot be identified to species. Taphonomically, millet husk phytoliths are less robust than rice phytoliths, in part because rice takes up copious amounts of silica and the cells used to identify rice husk are hairs (double peaked glumes) which are commonly very strong, while millet husks are identified using long dendritic cells from the lemma and palea which are generally thinner and more fragile. However, this alone does not account for the paucity of millets at Kanthoradai. It would seem that even though rice farming requires considerably more labour than millet, especially in the arid zone where there are few natural water sources, it was considered the more important crop.

Despite having different proportions of constituents in the samples overall, as would be expected given the different environmental zones, rice phytoliths are ubiquitous at both sites. At Kirinda, 100% of the samples produced rice husk phytoliths (double peaked glumes or distinctive husk multi cells) and silica bodies from rice leaves. While fewer rice phytoliths were found at Kanthoradai they are still common with husk occurring in 56% of the samples and a higher proportion of phytoliths from leaves (67%) suggesting crop processing was taking place at both sites. There are relatively large proportions of phytoliths from hydrophilic plants, for example Phragmites, as well as abundant Cyperaceae, both leaves and nutlets, at both sites. Cyperaceae is a common wetland plant rice weed (Moody 1989). Cyperaceae also has numerous economic uses such as weaving mats and basketry and some subfamilies include many edible species (Balick 1990; Johnson 1998). There are large proportions at both sites. This would be a little unusual in an arid zone such as Kanthoradai if the rice agricultural system was rainfed so the presence of such high proportions points to irrigated rice. Both leaves and nutlets could be part of the rice crop processing waste. Leaves could also be from discarded woven goods or matting.

Rugulose spheroids from Arecaceae leaves are present in all samples at Kanthoradai and all except two at Kirinda. Palms are a useful economic plant. They can provide shelter, construction material, thatch, matting, and food and drink. Zingiberaceae type phytoliths are also present at both sites, as well as possible Marantaceae leaves (Piperno, 2006), as are a very few folded spheres (found in some Anacardiaceae) and scalloped forms possibly from Curcurbitaceae rind. There are numerous cultivated and wild cucurbits in South Asia (see e.g. Decker-Walters 1999; Dassanayake and Fosberg 1983). No banana phytoliths were in evidence at either site.

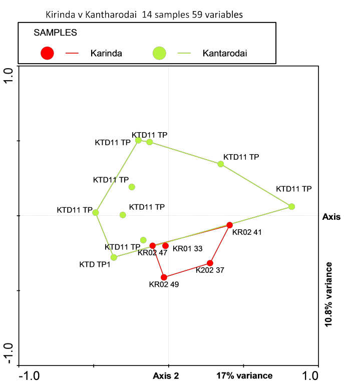

Figure 6: Correspondence analysis of Kirinda v Kantharodai on 14 samples with 59 variables. Kantharodai (KTD), Kirinda (KR)

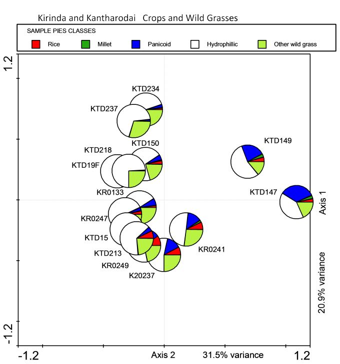

Figure 7: Correspondence analysis of Kirinda v Kantharodai for Crop and Wild grasses on 14 samples with 33 variables. Kantharodai (KTD), Kirinda (KR)

6.7. Rice

Rice spikelet bases were examined and recovered from both sites. The rice spikelet bases were identified as either wild-type with a smooth scar, or

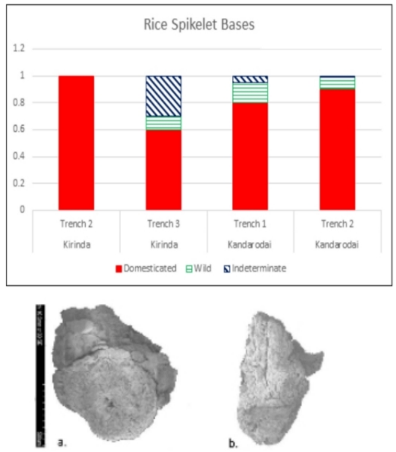

Figure 8: Frequency of rice spikelet bases from Kirinda and Kantharodai. The image in the top right-hand corner shows rice identifications from Kirinda a. Wild-type carbonised rice spikelet base b. Domesticated carbonised rice spikelet base

domesticated with a deep indentation and jagged, irregular scar based upon the criteria of rice spikelet bases established by Fuller et al. (2009) (Figure 8). Taken together, the presence of rice spikelet bases provides firm evidence of rice crop-processing taking place on site. Based upon recent genetic and morphometric work on South and Southeast Asian rice by Castillo et al. (2016a), a similar methodology was employed on rice grains from the sites of Kirinda and Kantharodai. Using the Length/Width ratio for rice the Sri Lankan sites were compared with the two South Asian sites and three Southeast Asian sites studied by Castillo et al. (2016a) to classify archaeological rice as either more likely to have been *Oryza* subspecies *japonica* or *Oryza* subspecies *indica*. The results are presented below and revealed a mixed population with the majority of rice ratios falling within the greater than 2 category for Kirinda and thus more than half were likely *O. sativa* subspecies *indica*. A similar pattern is seen at the site of Kantharodai [n=3] in which 2 of the rice ratios were greater than 2 and one was less than 2. Thus, two of the rice grains were probably *O. sativa* subspecies *indica* and one was *O. sativa* subspecies *japonica*.

Figure 8 shows that the majority of rice spikelet bases recovered from both sites over 50% at Kirinda and over 75% at Kantharodai were domesticated; these occur alongside a few wild and indeterminate rice spikelet bases. No immature types with protruding vascular strands were found. Wild

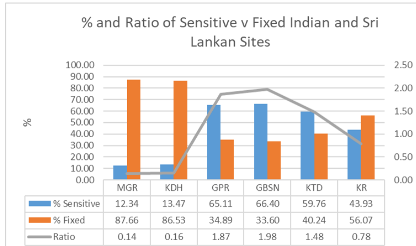

Figure 9: Percentage and Ratio of Sensitive versus Fixed phytolith types from Indian and Sri Lankan sites. Mahagara (MGR), Koldihwa (KDH), Gopalpur (GPR), Golbai Sassan (GBSN), Kantharodai (KTD), Kirinda (KR) (Weisskopf et al. 2014)

rice species such as *O. rhizomatis* and *O. rufipogon* are known in Sri Lanka (Vaughan 1990) and weedy varieties or crop-wild hybrids can be expected. Rice grain measurements were taken and analysed following morphometric work on South and Southeast Asian rice by Castillo et al. (2016a). The results suggest a mixed population, with both wild and domesticated rice spikelet bases, with somewhat greater dominance of *O. sativa* subsp. *indica*. It is possibly a mixed population in which some subspecies *indica* were also present, as were found at Early Historic sites in Gujarat and Maharashtra, India (Castillo et al. 2016a). A similar pattern is seen at the site of Kantharodai, with a very small sample size [n=3], in which 2 of the rice ratios were greater than 2 and one was less than 2. Thus, two of the rice grains were probably *O. sativa* subsp. *indica* and one was *O. sativa* subsp. *japonica*. There is no currently available comparable rice morphometric measurements recorded from other Sri Lankan sites. Environmental recovery was undertaken at the Early Historic site of Anuradhapura (Coningham and Gunawardhana 2013, 423) and rice grains and husk were recovered but it pre-dated the methodology employed here for improving the recovery and recognition of rice spikelet bases. There may have also been issues with the recovery of smaller seeds, i.e. millets, at Anuradhapura due to use of a coarse (1mm) mesh size.

Using the sensitive vs. fixed model (Madella et al. 2009, Jenkins et al. 2010, Weisskopf et al. 2015, Fuller et al. 2016) where sensitive represents wet rice agriculture and fixed dry or rainfed arable systems, Kanthorodai and Kirinda were compared to the phytoliths from sites in Uttar Pradesh and Odisha, India analysed by Harvey et al. (2006); Harvey and Fuller (2005). The Indian samples were collected from Koldihwa (Neolithic to Iron Age 1900-500 BC) and Mahagara (Neolithic 1700-1400BC) in the Belan Valley, Uttar Pradesh and Golbai Sasssan and Gopalpur, lowland settlement mounds on the coastal plain of Odisha. The samples analysed here characterise the agricultural economy at the transition from the Neolithic (Chalcolithic) to the Iron Age, 1300 1000BC at Golbai Sassan and 1400-1000BC at Gopalpur (Harvey et al. 2006). The chart shows a sharp contrast between the higher northern sites to those on the coastal plain and further south (Figure 9). The ratios of sensitive to fixed suggest rainfed rice in the higher and drier Belan Valley, while the lowland Odisha sites are clearly irrigated, as is Kanthoradai. Kirinda has a lower ratio. Kirinda is in the far southeast next to the beach so the sandy soils, easily draining, could have an effect. Thus, based upon both the macrobotanical and phytolith data presented in the present paper by ca. 300 BC, raising questions over whether a shift took place at the end of the Iron Age locally, or whether this represents the spread of already established wet rice traditions. The drier reconstructed at Kirinda, further indicates, variability in the degree of intensification of rice production across Sri Lanka over time.

6.8. Cotton

Gossypium arboreum, commonly known as tree cotton, is a woody shrubby plant, native to India and Pakistan. Tree cotton possesses a natural distribution across tropical and subtropical warm regions. However, the current distribution may not represent the primary wild habitat, as feral varieties may have spread and introgressed with early cultivars (Fuller 2008b). Cotton was likely grown in ancient India as a perennial fruit crop, similar to grapes or tree fruits such as dates. Cotton has been documented as a cultivar in the Indus region dating to pre-Harappan times (Fuller and Madella 2001) and had spread to the South Deccan by the Early Iron Age (Fuller 2008b). Old World cotton, which includes tree cotton, is now considered a relic crop, having been replaced by New World cotton (Zohary, Hopf, Weiss 2012). New World cotton is now grown throughout much of India, aside from the eastern part of the country, due to the subcontinents long rainy season (Fuller 2008b). The other Old World cotton, *G. herbaceum*, originated in Africa and is known to have been grown in northern Sudan from the early centuries AD (Clapham and Rowley-Conwy 2009; Fuller 2015). While this species became important in parts of northern India, it seems less likely to have been present in ancient Sri Lanka. Annual forms of tree cotton probably only became available in Sri Lanka and other parts of the world during Medieval times (from 9th or 10th c. AD), after which annual forms of tree cotton spread to regions with cold winters like Central Asia and China (Hutchinson 1959); thus we expect that the cotton identified here was a perennial, tree cotton, managed in small groves, or hedges. Management of tree cotton in hedges is described from the rice growing areas of Southeast Asia in the 19th century (Thorel 1873). This was perhaps similar to the cotton found sites in Madagascar and East Africa from the 8th c. AD (Crowther et al. 2016b), which is inferred to be a perennial *G. aboreum* var. *indicum* based on colonial era distributions (Hutchinson and Ghose 1937; Hutchinson 1959).

6.9. Dating

6.9.1. Kantharodai

Settlement at Kantharodai has been dated to the 5th century BC, continuing to at least the 1st century BC, as surmised from excavations conducted in 1970 (Deraniyagala 1992, 730). Previous radiocarbon dates from Kantharodai fall in the range 500-100 BC (Ragupathy 2006, 57). The newest radiocarbon dates (Beta 399421, Beta 399420, and Beta 399419) on rice caryopses from Kantharodai shows a date range of roughly 300 BC to 200 AD; which fits with the historically accepted date and occupation of the site (S1).

6.9.2. Kirinda

We ran six radiocarbon dates on charred rice (*Oryza sativa*) grains from Kirinda, placing the start of trench 2 at c. AD 500 and the start of Trench 3, c. AD 600, both firmly within the Historic period (S1). These results support the bulk of dates previously reported from KR01 (Somadeva 2006).

6.10. Broader Picture

These new Sri Lankan archaeobotanical finds indicate the movements of native South Asian millets as well as rice southward through the subcontinent and into Sri Lanka. Although present in the North and South Deccan in the Iron Age, the native millets move into Tamil Nadu and Sri Lanka by the Early Historic period and are fully adopted along with a few African millets (Cooke, Fuller and Rajan 2005).

Similarly, South Asian native and African pulses are present at an earlier date in the North and South Deccan, move southwards to Tamil Nadu and Sri Lanka by the Early Historic period (Fuller et al. 2004). Few of the Near Eastern crops are present in Tamil Nadu and Sri Lanka until quite a bit later, for example during the Medieval period at the port site of Mantai (Kingwell-Banham 2015). As summer crops (kharif), pulses and millets, are often intercropped and formed the core of peninsular Indian and Sri Lankan farmers repertoires and staple foods of the majority of the inhabitants for over 3,000 years (Petrie and Bates 2017; Morrison 2015, 13). This form of dry cultivation was likely supported by rainfall and traditional water-harvesting facilities such as runoff-fed reservoirs capturing seasonal rains from the monsoon (Morrison 2015, 13-14). Both archaeobotanical assemblages from Kirinda and Kantharodai show close similarities to sites in Southern India (Tamil Nadu) with their consistent presence of rice, millets and pulses which dominate the Southern India site assemblages. As in Southern India, hunting and gathering likely co-existed with alternative subsistence strategies including pastoralism, extensive and intensive agricultural practices, fishing and collecting of marine resources, and trade on Sri Lanka. Thus, there was likely a complex mosaic of interconnected communities and economic strategies in Sri Lanka during the Early Historic period (Morrison 2016, 18).

Recent work by Morrison et al. (2016) has argued for a major agricultural transition from a predominantly dry-farming agro-pastoral regime in the Southern Neolithic and most of the Iron Age in Southern India to a more complex and diversified productive landscape during the later periods. From the later Iron Age and beginning of the Early Historic period irrigated rice (wet rice or paddy) assumes a greater role and intensive farming in irrigated zones, built in favourable areas (Kingwell-Banham 2015; Krishna and Morrison 2009; Morrison et al. 2016; 1996). Bauer and Morrison (2014, 2210) argue that the proliferation of larger reservoirs constructed for the purposes of agricultural intensification in Sri Lanka was most concentrated during the Early Middle Period/Early Historic Period (500-1300 AD) based upon archaeological as well textual references and inscriptional evidence. Bauer and Morrison (2014, 2213) posit that it was during the transition from the Iron Age and Early Historic Period that a shift occurred from a reliance on rainfed agriculture to reservoir irrigation which would have produced radical changes to the landscape (Bauer and Morrison 2014, 2213). As well, Bauer and Morrison (2014, 2213) argue that changes in irrigation infrastructure were accompanied by the adoption of these new cultigens and the cultural values associated with this new cuisine (cf. Fuller and Rowlands 2011).

7. Conclusions

This study offers new insights into Sri Lankas agrarian and ecological past in the Early Historic period and attempts to situate these results within the wider context of South Asian archaeology. Kantharodai, as one of Sri Lanka's four most important historic sites, appears to have a similar, parallel economic and urbanized development to other early south Indian and Sri Lankan urban centres such as Anuradhapura and Magama at the end of the Protohistoric period (Perera 2013, 53; Ragupathy 2006, 61, 169). During the Early Historic period, Sri Lanka was connected with the wider Indian Ocean with archaeological evidence of regular trade relations with the rest of South Asia, Southeast Asia and the Mediterranean world. The archaeobotanical assemblage recovered from Kirinda and Kantharodai does not demonstrate specific trade organization but does suggest connectivity between Southern India and Sri Lanka as they possess a similar crop package. The phytolith evidence from Kantharodai suggests the presence of both millet and rice crop-processing waste. Whereas Kirinda has evidence of rice and rice crop-processing waste but no evidence of millets. The ratio of sensitive to fixed phytolith morphotypes (as defined by Weisskopf et al. 2015, Weisskopf, 2017) suggests that Kantharodai possessed irrigated rice while Kirinda may have been rainfed. Phytoliths from palms were common at both sites and could include those from coconut, as several charred fragments of coconut shell were recovered from Kirinda from the macrobotanical assemblage. Thus, both Kirinda and Kantharodai conform to our current, if patchy, understanding of Early Historic sites in Sri Lanka and Southern India. The archaeobotanical and phytolith assemblages from both sites, although located at opposite ends of the island, possessed similar signatures which would suggest that irrigated rice agriculture and millets were firmly established at both sites in the Early Historic period. In Southern India and Sri Lanka during the Early Historic period we see a trend towards greater diversification with a wide range of millets and pulses adopted as cultigens along with evidence of rice, both Kirinda and Kantharodai fit within this broader pattern. Thus, there is now empirical environmental data to extend this trend to Sri Lanka for the first time.

Conflicts of Interest

Authors declare no conflicts of interest.

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Figure 2. A. *Echinochloa* cf. *frumentacea*, from KTD Pit 2 Flot 37; B. *Paspalum* sp., from KTD Pit 2 Flot 32; C. *Brachiaria ramosa*, from KR03, Flot 44l D. *Panicum sumatrense*, two adhering grains, from KTD Pit 1, Flot 50; E. *Setaria* cf. *verticillata*, from KTD Pit 1 Flot 10 (Drawn by DQF)

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Supplement 3: Phytolith Data from Kantharodai and Kirinda

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