Plant use in southern Africa's Middle Iron Age: thearchaeobotany of Mutamba

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Abstract

Mutamba is a thirteenth-century settlement located on the Soutpansberg Mountains in northern South Africa with links to the regionally important Mapungubwe polity. This paper provides a detailed report of the range and utilisation of archaeobotanical taxa found at Mutamba. This research provides base-line evidence on the little understood, but significant role of plants in southern African Iron Age society. The analysis of 100 randomly selected samples from domestic features yielded 11 identifiable species and two genera. The results provide evidence for a potential crop package made up of finger millet (Eleusine coracana), sorghum (Sorghum bicolor), pearl millet (Pennisetum glaucum), cowpeas (Vigna unguiculata) and mung beans (Vigna radiata). Mutamba also contains the first documented example of Vigna radiata as a crop component in South Africa, the first tangible indication for the occurrence of malted grains used in beer brewing and the first archaeological links between Gossypium herbaceum and cotton spinning, previously based only on ethnographic data.

KEYWORDS
archaeobotany; South Africa; Mutamba; agriculture; plant use; Middle Iron Age; Mapungubwe

Introduction

The tenth to thirteenth centuries AD were a time of social and political intensification in present-day northern South Africa, southeastern Botswana and southwestern Zimbabwe (Huffman 2007). This period, sometimes referred to as the Middle Iron Age (MIA), saw the development of the first socially complex society in the region, with its apex at the thirteenth-century regional capital of Mapungubwe. Mapungubwe society was characterised by stratified social classes, with a ruling élite who had a monopoly over important community-wide ritual activities such as initiation rites and rainmaking (Schoeman 2006), as well as preferential access to local and long-distance trade and control over production of metal and other crafts (Calabrese 2000, 2007; Huffman 2000). The development of social complexity in the region is closely associated with the expansion of long-distance trade between communities in the interior and the wider Indian Ocean World System from the ninth century onwards. Through entry points on the coast, objects of Asian manufacture such as glass beads, porcelain and cloth were imported to Africa. In turn, goods such as metals (gold, tin, copper, iron), animal products (especially ivory, but also feathers, shells, hides and horns) and slaves were exported from the African interior.

Despite sweeping social changes, MIA communities remained predominantly agrarian. Livestock — cattle, sheep and goats — were important, not only as dietary contributors, but also (especially in the form of cattle) in social contracts such as bridewealth (Huffman 2000). Agriculture helped MIA populations to grow and maintain themselves, to the point where sites like Mapungubwe may have been home to as many as 5000 people — a significant increase from earlier capitals in the region with estimated populations of 500 people only 250 years earlier (Huffman 2000: 23). Agricultural intensification linked to this population increase is seen in the rapid increase of settlements on better-suited agricultural lands along the floodplain of the Limpopo River and associated wetlands in the vicinity of Mapungubwe (Du Piesanie 2008). However, despite the important role of plants and agriculture in subsistence strategies and the rise in social complexity, they have rarely featured as research topics in the region. Indeed, no baseline data exist for the range of domesticated species cultivated, nor for any of the wild species exploited for food, fodder, construction, crafts or other purposes in the MIA. When botanical remains are mentioned, it is typically limited to the identification of well-preserved chance finds rather than part of a systematic sampling strategy or study of plant remains. It is only within recent years that archaeobotany has received consideration in southern African Iron Age archaeological research (Greenfield *et al.* 2005; Scott 2005; Schoeman 2006; Antonites and Antonites 2014; Raath 2014). This does not mean that archaeologists have previously been unaware of human-plant interactions. Indeed, botanical remains have been noted at numerous southern African Iron Age sites (e.g. Fouché 1937; Gardner 1968; Eloff 1979; Klapwijk and Huffman 1996; Reid and Young 2000; Schoeman 2006; Raath 2014). However, our understanding of plant use in the MIA of the region under consideration here is limited to remains listed in the appendixes of excavation reports from large capitals such as K2 and Mapungubwe (Fouché 1937; Gardner 1968; Eloff 1979). These, for example, note the presence of sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), cowpeas (*Vigna unguiculata*), marula (*Sclerocarya birrea*), baobab (*Adansonia digitata*), nyala berry (*Xanthoceris zambesiaca*), African medlar (*Vangueria infausta*), watermelon (*Citrullus lanatus*) and water berry

(*Syzygium cordatum*) on sites, but little else. However, these examples typically represent chance finds of preserved remains recovered in the general excavation process.

The lack of a primary understanding of plant use is due to the fact that archaeobotany has not yet been incorporated into general southern African archaeological practice (Antonites and Antonites 2014). In contrast, other parts of the African continent (East and West Africa, in particular) do have established archaeobotanical traditions where research has yielded detailed information on topics such as early cultivation traditions (e.g. Kahlheber *et al.* 2009), plant exploitation as a part of metal production (e.g. Iles 2009) and plant exploitation and landscape evolution (e.g. Mercuri 2008).

When the Mapungubwe period site known as Mutamba was excavated in 2010 and 2011 a dedicated archaeobotanical recovery process was integrated into the research methodology applied there. This paper presents results from the analysis of macrobotanical materials from that site and represents the first set of baseline data for plant exploitation, subsistence and crafting during the MIA, as well as one of the few carpological studies in southern Africa. Methodologically, this research is also significant since it is the first time that an analysis following the methodologies set out by Antolin and Buxó (2011) has been used for southern African material. Furthermore, it highlights the methodological importance of incorporating archaeobotanical techniques into Iron Age contexts.

Background to Mutamba

Mutamba was initially identified and excavated by Loubser (1988, 1991) in the 1980s and later re-excavated by Antonites in 2010 and 2011. The excavations by Loubser took place in a 3 × 3 m unit in the central area of the site. Subsequent research by Antonites (2012) investigated the site as an example of a small community in the hinterland of the Mapungubwe polity. The site is located approximately 80 km southeast of Mapungubwe (Figure 1), but despite this distance, its small size and its seemingly commoner status the community at Mutamba had access to an array of traded goods such as wound and drawn glass beads (Antonites 2014), ocean shells and objects made from iron, copper alloys and gold (Antonites 2019a). At the same time, the community produced shell beads, worked metals and potentially also hunted for ivory. In addition, large numbers (N = 187) of spindle whorls from the site point to a likely intensive cotton spinning industry (Antonites 2019b). It is likely that its strategic geographic position on the southern margins of Mapungubwe's area of influence meant that it had access to resources in demand by the political centre (such as gold, cotton and ivory). At the same time, this gave Mutamba's inhabitants access to objects typically restricted in their circulation to élite sites in the Mapungubwe heartland (such as metals, beads and shells). Mutamba is therefore an expression of the expansion of regional interaction in the thirteenth century, as well as a signpost to the active role that small communities and hinterlands played in the larger political economy.

Ecological background to Mutamba

Mutamba is located on the saddle of an east-west running ridge on the northern piedmont of the Soutpansberg mountain range (Figure 2). South of the site, the ridge drops down steeply to the Mutamba River. The ridge is rocky with a few areas containing shallow

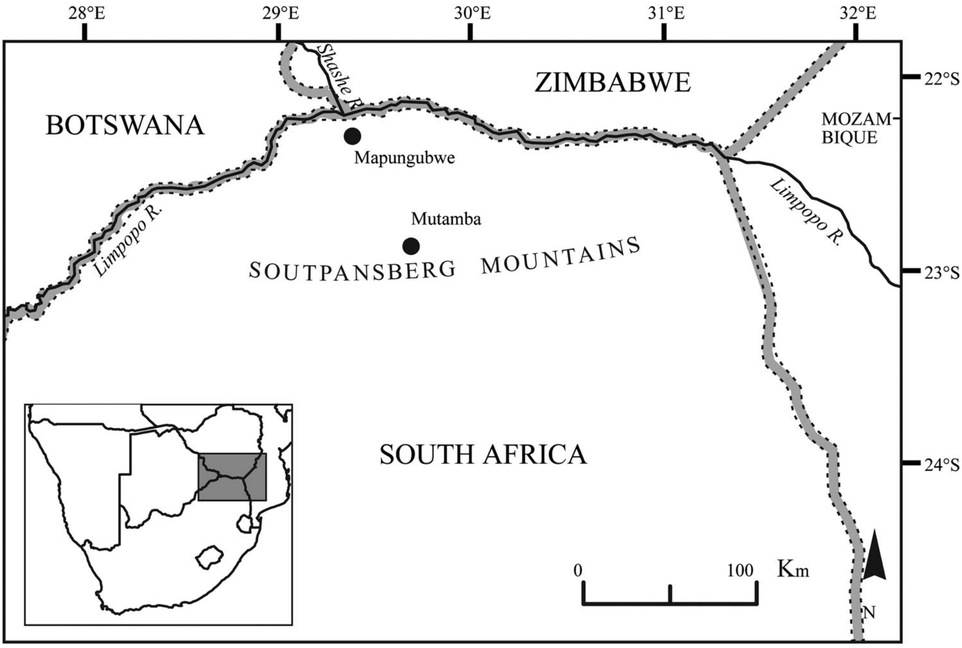

Figure 1. Regional map of southern Africa showing the location of the sites mentioned in the text.

quartzite and sandstone derivative sand (Antonites 2012: 74–76). The site's location falls within South Africa's summer rainfall zone and its climate is moderately arid with periodic droughts (Mostert 2006). The seasons are generally cool and dry winters (May to

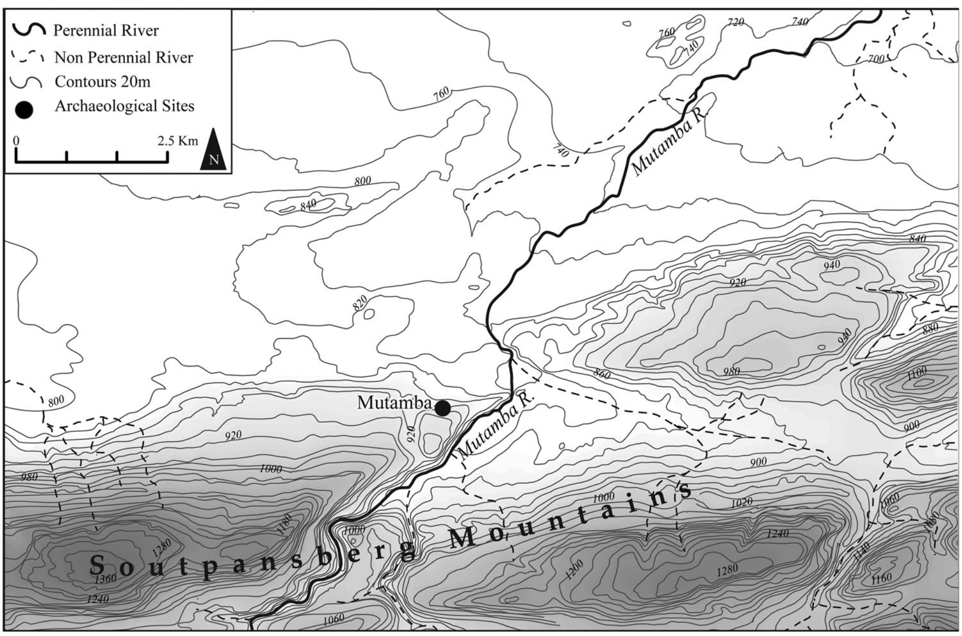

Figure 2. Map showing the detailed location of Mutamba in northern South Africa.

September) and warm and wet summers (October to April). Temperatures during the wet season oscillate between 16 and 40°C, while during the dry season they vary between 12 and 22°C (Kabanda 2003).

Present-day vegetation at Mutamba is characteristic of the northern slopes of the Soutpansberg, commonly referred to as the Arid Northern Bushveld (Mostert *et al.* 2008), comprised of open woodland characterised by *Adansonia digitata*, *Boscia foetida* subsp. *rehmanniana*, *Cordia monoica*, *Commiphora tenuipetiolata*, *Blepharis diversispina*, *Commiphora glandulosa* and various *Grewia* species (Mostert *et al.* 2008). Like other major vegetation types of the Soutpansberg's northern slope, the plant communities around Mutamba are well adapted to unpredictable rainfall (Mostert 2006; Mostert *et al.* 2008).

Sampling and methods

Antonites' excavations at Mutamba were split into two phases. The first phase focused on the excavation of randomly selected 1 × 1 m units over the whole extent of the site. Specific features exposed by these test pits were then expanded through larger aerial excavation during the second phase of research. This second phase focused on three specific areas referred as Features 1, 2 and 3. The first two of these (Features 1 and 2) were domestic areas, while the third (Feature 3) was a centrally located cattle kraal (Figure 3; Antonites 2012). These were excavated as contiguous 1 × 1 m squares following natural stratigraphy, with the locus as the minimum sampling unit in a square. Individual loci were combined into distinguishable depositional events or 'Layers'. All items of material culture were collected and all excavated deposit was screened through 5 mm sieves. All soil from the excavations were collected in 10 litre calibrated buckets in order to calculate excavated soil volume. From every locus in a 1 × 1 m square, a flotation sample of unscreened soil was collected. Most flotation samples were 10 litres, taken as a bulk sample from the centre of a locus. In some instances, such as hut floors and very ashy or carbon rich deposits, the entire locus was collected for flotation in order to maximise recovery of carbonised material. In cases where the locus was less than 10 litres, the entire locus was collected as a single flotation sample and not screened.

Flotation samples were all floated off-site with a SMAP-style machine built by one of us (Antonites) from plans in Pearsall (2015), using a modified 200 litre oil drum fitted with 2 mm mesh and garden hose fittings. Soil was added to the water-filled barrel and agitated. The light fraction, containing archaeobotanical material, passed out of the sluiceway into a suspended chiffon bag. The light fraction bags were then hung to dry before sorting and identification. The heavy fraction was dried in cotton cloth squares, sieved and sorted, mostly without any magnification aid. The botanical material in the heavy fraction was minimal. It did, however, recover several bone flakes, glass beads (Antonites 2014) and metal fragments that included a gold bead, a comparatively rare item for the region.

Ultimately, 285 samples were floated and a sub-sample of 100 samples was chosen for botanical analysis. Selection was purposively focused on deposits associated with domestic features and areas. The sampling was then further broken down and individual loci chosen randomly. Sixty loci were selected from Feature 1 and 22 loci from Feature 2, with the remaining 18 samples taken from Feature 3 and 1 × 1 m pits.

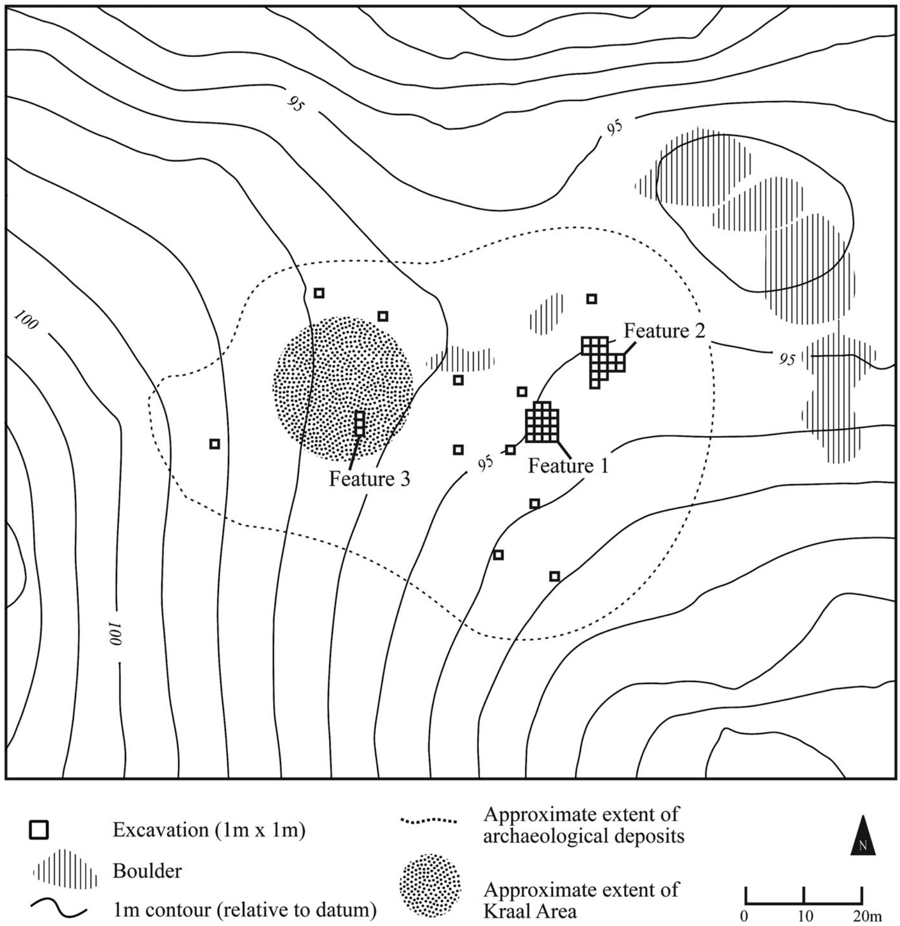

Figure 3. Spatial layout of Mutamba.

To facilitate the identification of archaeobotanical material within the floated material, the samples were sieved with geological sieves with mesh sizes of 9.5, 5.0, 2.0, 1.25, 0.8 and 0.5 mm. The contents of each sieve were placed into a petri dish, with each dish filled only one third of the way through. These dishes were examined under a binocular microscope with a magnification of up to 4.5 x.

Identification was conducted with the aid of reference collections at the University of Pretoria and University College London, as well as published botanical literature, in order to discern key identification characteristics of seeds and fruits (see Reeves 1936; De Wet and Harlan 1971; Brunken *et al.* 1977; Hilu *et al.* 1979; Kay 1979; Von Teichman *et al.* 1980; Ross 1981; Von Teichman and Robbertse 1986; Von Teichman 1988; Neumann *et al.* 1998; Fuller 2006; Venier *et al.* 2012). The morphological identification characteristics, methods and references used for identification are detailed in Table 1.

Minimum Numbers of Individuals (MNI) were calculated due to the highly fragmentary state of some of the archaeobotanical material. An individual, or single seed, was deemed to be such based on whether the seed was completely, or mostly, intact or based on various represented seed parts. For the seed parts represented we used an

Table 1. Seed morphology characteristics used in the identification of archaeobotanical remains at Mutamba.

Taxon	Common name	Seed morphology	Identification method	Reference
Adansonia digitata	Baobab	Reniform or kidney-shaped. Length of up to 15 mm	University of Pretoria Archaeology Laboratory reference collection	Chadare *et al.* 2008; Cappers *et al.* 2009; Chadare *et al.* 2009; Kaboré *et al.* 2011; Moll 2011
Sorghum bicolor	Sorghum	Round to ovate dorso-ventrally compressed caryopsis with projecting concave hilum. Shallow, long wide scutellum (1/2 to 2/3 caryopsis length). Variation is present in size. Width is almost equal to length (i.e. creating an almost round shape)	University of Pretoria Archaeology Laboratory reference collection	Fuller 2006; Xaba 2008; Liu *et al.* 2015
Pennisetum glaucum	Pearl millet	Ovate in plan. Deep scutellum (up to 3/4 of caryopsis length). Hilum and scutellum project. Variation in size is present	University of Pretoria Archaeology Laboratory reference collection	Brunken *et al.* 1977; Fuller 2006
Eleusine coracana	Finger millet	Caryopsis is globose. The scutellum is up to 1/3 of the caryopsis length. The hilum is rounded in shape and the caryopsis surface pusticulate. Size varies between 1 and 2 mm	University of Pretoria Archaeology Laboratory reference collection	Hilu *et al.* 1979; Fuller 2006; Chandrashekar 2010
Vigna radiata	Mung bean	Seeds are small. Shape is globular or oblong with flattened ends. Lengths of approximately 2.5–5 mm x 3–4 mm.	Personal reference collection/ botanical literature	Kay 1979
Vigna unguiculata	Cowpea	Size and shape may vary. Shape is often either reniform or globular. Approximate length variation of 2–12 m.	Laboratory reference collection	Kay 1979
Gossypium herbaceum	Cotton	Shape is ovoid and somewhat pointed. The testa has a longitudinal ridge that ends in a small beak.	Laboratory reference collection/ botanical literature	Bouchaud *et al.* 2011
Sclerocarya birrea	Marula/ Moroela	Large, woody, oval shaped stone or endocarp approximately the size of a walnut. The stone contains 1–4 seed (nut) locules. Each locule possesses its own lid-like structure or operculum/ opercula	University of Pretoria Archaeology Laboratory reference collection	Von Teichman *et al.* 1986; Von Teichman *et al.* 1988; Petjie 2008; Department of Agriculture, Forestry and Fisheries 2010; Midgley *et al.* 2012
Vachellia/ Senegalia sp.	Species-dependent	Large variety present in the seed size and shape. Shape variety includes obovate, globose and obovate-rectangular. Size variants present depending on species. A noted characteristic of seeds of these genera is the horseshoe or obovate areole. Fragments of seed coat can often be identified by its structure of a single layer epidermis with varying number of sclerified parenchyma layers below it	University of Pretoria Archaeology Laboratory reference collection	Al-Gohary & Mohamed 2007; Venier *et al.* 2012; Sivakumar *et al.* 2013
Grewia sp.	Species-dependent	Seed morphology somewhat dependent on specific species due to variations present in size, shape and reticulation.	University of Pretoria Archaeology Laboratory reference collection	Anther *et al.* 2009; Cappers *et al.* 2009
Ziziphus zeyheriana	Dwarf buffalo thorn	Small elliptical stone. Size up to 5 mm	University of Pretoria Botanical Garden reference collection	Cappers *et al.* 2009
Brachiaria deflexa	False signal grass	Broadly elliptic in shape. Lemma's apex is either mucronate or acute. Spikelets range in size from 2.5 to 3.5 mm.	Identified in 2017 at a seed identification course at University College London/ botanical literature	Ibrahim *et al.* 2018
Brachiaria nigropedata	Spotted signal grass	No technical data available concerning caryopsis shape. However, spikelets have a noted cup-shaped callus situated at the base	Identified in 2017 at a seed identification course at University College London/ botanical literature	Thompson 1988

Table 2. Identified plant taxa from Mutamba.

Family	Genus	Species	Common name	MNI	State of preservation	Parts identified	**Wild/** Domesticate	**Indigenous/** Exotic
Anarcardiaceae	*Sclerocarya*	*birrea*	Marula	57	Carbonised	Endocarp/operculum	Wild	Indigenous
Anarcardiaceae	*Sclerocarya*	*birrea*	Marula	14	Desiccated	Endocarp	Wild	Indigenous
Fabaceae	*Vachelia/ Senegalia*		Acacia	5	Carbonised	Testa fragments/ Seeds	Wild	Indigenous
Fabaceae	*Vigna*	*radiata*	Mung bean	19	Carbonised	Cotyledons	Domesticate	Exotic
Fabaceae	*Vigna*	*unguiculata*	Cowpea	32	Carbonised	Cotyledons/ Seeds	Domesticate	Indigenous
Malvaceae	*Adansonia*	*digitata*	Baobab	1	Carbonised	Identifiable testa fragments/ Seed	Wild	Indigenous
Malvaceae	*Grewia*		Grewia	19	Carbonised	Endocarp/Identifiable endocarp fragments	Wild	Indigenous
Malvaceae	*Gossypium*	*herbaceum*	Cotton	11	Carbonised	Seeds	Wild	Indigenous
Poaceae	*Brachiaria*	*deflexa*	False signal grass	7	Carbonised	Caryopsis/Represented seed parts	Wild	Indigenous
Poaceae	*Brachiaria*	*nigropedata*	Spotted signal grass	3	Carbonised	Caryopsis	Wild	Indigenous
Poaceae	*Eleusine*	*coracana*	Finger millet	4	Carbonised	Caryopsis	Domesticate	Indigenous
Poaceae	*Pennisetum*	*glaucum*	Pearl millet	150	Carbonised	Caryopsis/Represented seed parts	Domesticate	Indigenous
Poaceae	*Sorghum*	*bicolor*	Sorghum	173	Carbonised	Caryopsis/Represented seed parts	Domesticate	Indigenous
Rhamnaceae	*Ziziphus*	*zeyheriana*	Dwarf buffalo thorn	17	Carbonised	Endocarp/Identifiable endocarp fragments	Wild	Indigenous
Unknown (not identified)	Unknown	Unknown		11	Carbonised/ Desiccated	Seeds/ Endocarp	Unknown	

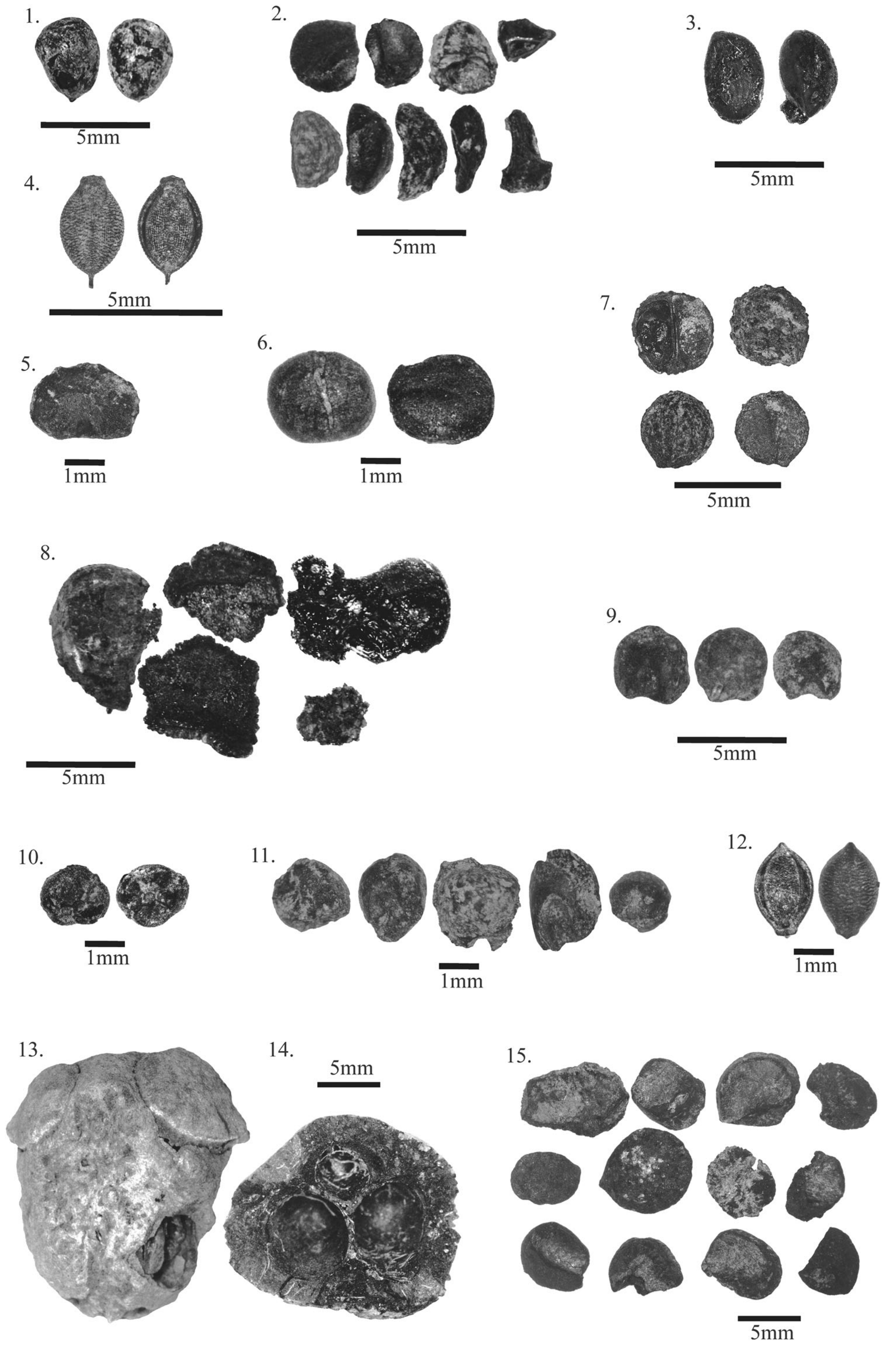

Figure 4. Seeds from Mutamba: (1) *Gossypium herbaceum*; (2) *Ziziphus zeyheriana*; (3) *Acacia* sp.;(4) *Brachiaria deflexa*; (5) *Vigna unguiculata*; (6) *V. radiata*; (7) *Grewia* sp.; (8) *Adansonia digitata*;(9) *Sorghum bicolor*; (10) *Eleusine coracana*; (11) *Pennisetum glaucum*; (12) *B. nigropedata*; (13) desiccated *Sclerocarya birrea*; (14) carbonised *S. birrea*; (15) carbonised *S. birrea* opercula.

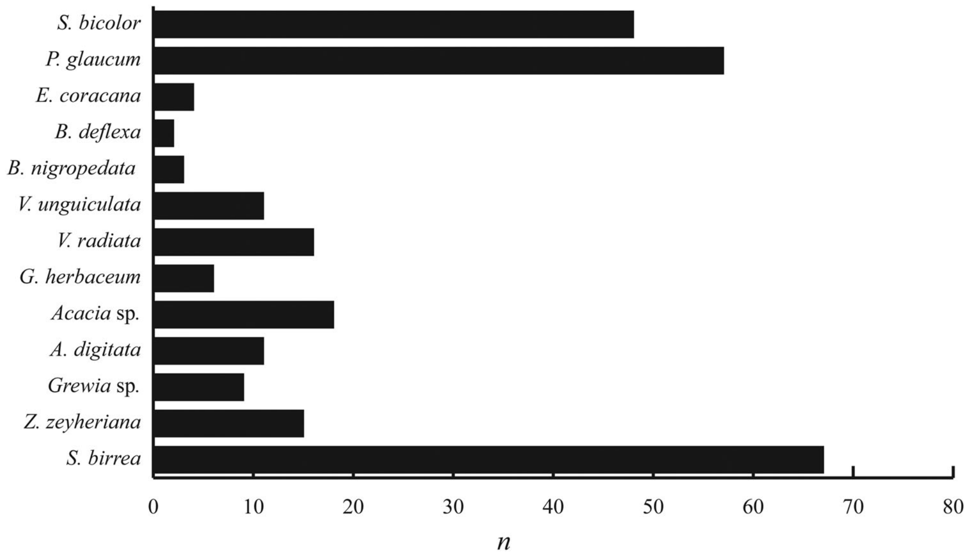

Figure 5. Taxonomic ubiquity of identified plant taxa at Mutamba.

Table 3. Domestic and wild plant taxa at Mutamba: combined MNI.

	Taxa count	MNI
Domestic taxa	5	378
Wild taxa	8	134

adaptation of Antolín and Buxó's (2011) nomenclature (complete caryopsis, transversal apical, transversal medial, transversal embryonal, longitudinal ventral-dorsal, longitudinal ventral and longitudinal dorsal) to define which fragments would yield an MNI. For example, two transversal lateral-dorsal fragments represent one *Pennisetum glaucum* caryopsis or one transversal medial fragment represents a single caryopsis of *Sorghum bicolor*. This allowed for a more precise determination of MNI as opposed to only counting intact caryopses.

Results

Thirteen taxa were identified at Mutamba, 100 of which were identified to species and/or genus level (Table 2). Five of the taxa belong to the Poaceae family, three each to the Fabaceae and the Malvaceae and one each to the Anarcardiaceae and Rhamnaceae (Figure 4). Of the identified taxa five are domestic and eight wild (Table 2). Although ubiquity (Figure 5) appears to suggest higher numbers of wild taxa, calculations of MNI indicate that domestic taxa have a higher percentage (74%) of occurrence than wild species (26%) (Table 3).

Calculations of relative abundance of taxa indicate that the three most frequently occurring taxa were *S. bicolor* (33%), *P. glaucum* (28.6%) and *S. birrea* (13.5%). *V. unguiculata* (6.1%) was the only other taxon with a presence higher than 5%. The remaining taxa were calculated at less than 5% individually, with *Adansonia digitata* being the least abundant. The abundance of *S. birrea* can be attributed to the prodigious fruit-bearing capabilities of the species and its common occurrence in the region. Both carbonised as well as desiccated endocarps were identified (Table 2). Although the latter may potentially suggest modern intrusion, the excavation contexts were secure. In addition, loci with obvious burrowing and contamination were not sampled. The taxa identified and analysed do not necessarily reflect all of the plants used at Mutamba, but may well be a result of recovery and preservation bias (for numbers of plant remains found in specific features, see Steyn 2018).

Indigenous taxa, wild taxa and weed taxa

The vast majority of the identified taxa are indigenous to Africa (Table 2). Only a single species (*V. radiata*) was identified as exotic. This species is a vine and does not originate in southern Africa, but from the forest-savanna regions of India where archaeobotanical evidence places its widespread cultivation to the third millennium BC (Fuller and Harvey 2006; Fuller 2007). Its presence at Mutamba is its first archaeologically recorded occurrence at a MIA settlement and clearly indicates that the involvement of the southern Africa interior in the Indian Ocean trade network extended beyond the more typically considered goods such as gold, ivory and glass beads.

With the exception of the domestic taxa, all the indigenous taxa are representative of species still found in northern South Africa and, more specifically, the Soutpansberg's arid northern slope (Mostert *et al.* 2008). These are made up of trees (*A. digitata*, *Vachellia/Senegalia* spp., *S. birrea*), shrubs/small trees (*Grewia* sp., *Ziziphus zeyheriana* and *G. herbaceum*), a vine (*V. unguiculata*) and grasses (*S. bicolor*, *P. glaucum*, *Brachiaria deflexa*, *B. nigropedata* and *E. coracana*).

Discussion

It is widely accepted that communities during the MIA were agropastoralists as seen in the numerous granaries, grinding stones, agricultural hoes and archaeobotanical material recovered from sites of this time period (Fouché 1937; Gardner 1968; Eloff 1979; Huffman 1996, 2007; Reid and Young 2000; Badenhorst 2010; Bradfield and Antonites 2018). Mutamba, like other agropastoralist communities, was tied to the agricultural process in that its inhabitants had to remain in close proximity to the crops in order to tend to them. They also utilised wild taxa such as baobab (*A. digitata*), marula (*S. birrea*) and *Grewia* sp. to supplement their nutritional and other needs (cf. Antonites and Antonites 2014).

Agricultural processes

A preponderant portion of the archaeobotanical material found in the domestic contexts of Mutamba (Feature 1 and Feature 2) originated from agriculture. From this analysis, it is clear that the Mutamba crop package comprised sorghum (*S. bicolor*), pearl millet (*P. glaucum*), finger millet (*E. coracana*), mung beans (*V. radiata*) and cowpeas (*V. unguiculata*). Since the combined growth requirements of these plants would have needed a minimum of 350 mm mean annual rainfall and consistent temperatures of above 15°C cultivation likely took place between spring and summer to early autumn (Doggett 1976; Purseglove 1976; Huffman 2007). The agricultural process of clearing, tilling, planting, manuring, weeding and harvesting would have required intensive labour and time inputs (Quin 1959; Schapera and Goodwin 1962; Stayt 1968; Fuller *et al.* 2010). Additionally, cultivation would have occurred both in the settlement and on the floodplains of the nearby Mutamba River (cf. Greenfield *et al.* 2005). Mutamba's location on a very rocky ridge with poorly developed and shallow soils would have spatially limited the presence of fields directly around the settlement, limiting cultivation to only small garden plots in and around the site itself. The nearby Mutamba River floodplain, on the other hand, would have provided both ample space for cultivation and a source of arable soil while constant water flow in the river channel and seasonal flooding would have ensured a supply of soil moisture and nutrients (cf. Greenfield *et al.* 2005).

The absence of weed taxa or crop by-products within the site's archaeobotanical assemblage suggests that the primary method of harvesting Poaceae grains was likely by cutting them below the ear, whereas legumes were probably hand-picked. Had the grains and legumes been cut lower down the stalk or pulled from the ground, then weed seeds would most certainly have found their way into the archaeobotanical assemblage (cf. Fuller *et al.* 2014).

The lack of crop by-products indicates that the crops were processed away from domestic contexts, possibly in the fields. It is also highly probable that these parts of the plants did not survive conflagration due to their more delicate nature compared to seeds (Boardman and Jones 1990; Gustafsson 2000; Braadbaart *et al.* 2004, 2005; Ferrio *et al.* 2004; Gaurino and Sciarrillo 2004).

Crop processing also has an influence on the structure and content of a charred archaeobotanical assemblage. It can be divided into two groups of activities: those that precede storage and those that occur as crops are taken from storage (Fuller *et al.* 2014). Because crop processing that precedes storage is carried out at harvest time in a location away from the settlement, any processing waste that may have existed does so briefly in a non-carbonised form that does not usually preserve (cf. Fuller *et al.* 2014).

After harvesting and processing (pounding and winnowing) the seeds would have been transferred to various household storage receptacles (cf. Van der Waal 1977). While there is no archaeological evidence for these storage receptacles at Mutamba, their presence can be inferred from finds at other MIA settlements such as Mapungubwe where stone platforms and grain bin stands have been found (Huffman 2007; Meyer and Cloete 2010).

Aside from the archaeobotanical material, the domestic contexts of Features 1 and 2 both contained features associated with the preparation of food. These include middens, hearths and two upper grinding stones. The grinding stones would have been utilised in the preparation of grinding material for cooking and the hearths for cooking, most likely in the form of boiling (Raath 2014), while disposal took place in the middens. The food preparation process from cooking to disposal took place within these domestic contexts, which can thus be interpreted as the primary unit of meal consumption (Twiss 2007).

Plant utilisation

The plants found at Mutamba were most likely utilised in food and beverage preparation, as well as in the production of cotton cloth. Ethnographic accounts indicate that domesticated Poaceae grains were the primary components of meals and beverages, usually in the form of porridge and gruel served alongside various types of accompaniments or as components of alcoholic beverages (Quin 1959; Mabogo 1990).

Based on the presence of both sorghum and pearl millet at K2 and Mapungubwe (Fouché 1937, Eloff 1979), it was expected that the crop package at Mutamba would likely contain these two species as well. However, the additional occurrence of *E. coracana* is potentially significant for understanding the scheduling of crops at the site. *P. glaucum* takes up to two months for grains to reach maturity, while *S. bicolor* requires four months, and *E. coracana* up to six (National Academy of Sciences 1996: 55, 89; Du Plessis 2008; Department of Agriculture, Forestry and Fisheries 2010). Cultivating all three grains may therefore have served to ensure either a variety in the diet or a means of providing a continuous food supply as all three species have similar cultivation requirements (i.e. rain, temperature etc.) and usage (e.g. porridge and beer). Additionally, the *Vigna* species identified at the site further suggests the use of crops with complimentary growing times since *V. unguiculata* and *V. radiata* bear pods at different times and mature at different rates, with *V. unguiculata* being ready for harvest after two months, while *V. radiata* can take up to four (Quin 1959; Kay 1979).

The large numbers of *S. bicolor* (N = 173) and *P. glaucum* (N = 150) specimens can serve as potential indicators of the importance of the crops within the diet. The intact and semi-intact states of the grains suggest that they were either boiled whole or, as is suggested by the upper grinding stone found in Feature 2, were ground for a smoother porridge. Ethnographic texts also show that porridges are served with relishes made from various fruits, vegetables, legumes or nuts, in particular baobab, marula, cowpeas, mung beans, dwarf buffalo thorn (*Z. zeyheriana*) and *Grewia* spp. (Lestrade 1932; Quin 1959; Krige and Krige 1980; Mabogo 1990).

Traditional methods of processing *A. digitata* and *S. birrea* are reflected in Mutamba's archaeobotanical assemblage (cf. Krige 1937; Quinn 1959; Mabogo 1990). The processing of marula requires either the crushing of the endocarps (or stones) for kernel extraction or the use of a thin sharp object such as a *Vachellia* or *Senegalia* sp. thorn (Quin 1959; Cunningham 1988). A large quantity of endocarp fragments was found within the samples, as well a few intact endocarps. In the case of *A. digitata* despite the recovery of a number of minute fragments only a single quantifiable seed was found, but, in similar fashion to *S. birrea*, numerous fragments of testa (seed coat) were also present within the samples. The seed of this taxon is usually either roasted or ground into a powder as a porridge additive (Quin 1959). Both the carbonised state of preservation and the volume of fragments suggest that both methods may have been used in processing its seeds.

There is also potential evidence for grain- and fruit-based brewing at Mutamba. Inferences for potential brewing activities can be drawn from the presence of sprouted *S. bicolor* grains (N = 6) and ethnographic examples of drinks made from fermented marula. Historical and ethnographic descriptions of traditional grain-based beer indicate that this beverage was a gruel-like opaque liquid that required a complex process of steeping, malting, mashing and straining. While the sprouted sorghum grains are by no means conclusive evidence for brewing, the ubiquitous and important social, economic and dietary roles of sorghum and millet beer in communities across southern Africa does hint at beer having also been brewed in earlier times. According to ethnographic records, making a fermented beverage from marula was a much simpler task, requiring that the flesh of the fruit was cut and pressed, after which the liquid was diluted, agitated and sealed in a vessel to ferment (Van Warmelo 1932; Owuama 1999; Dlamini and Dube 2008; Rampedi 2010; Lyumugabe *et al.* 2012).

The earliest evidence for cloth production in northern South Africa takes the form of spindle whorls and dates to the thirteenth century AD (Antonites 2019b). The poor preservation of cloth in the archaeological record means that such artefacts are typically the only indicators of cloth production in the Iron Age (Huffman 1971; Davies and Harries 1980). At Mutamba both spindle whorls (N = 187) and 11 *Gossypium herbaceum* seeds were found together in domestic contexts that suggest production at the household level, possibly involving multiple members of a family (Antonites 2012). Such involvement would signify participation in an economy exceeding that of an individual community as the cloth produced was likely far greater than the requirements of that community alone (Antonites 2012).

Conclusion

The archaeobotanical assemblage from Mutamba comprises hundreds of macrobotanical remains drawn from at least eleven species and two genera. The taxa present were utilised in food, beverage and cloth production. Both domestic and wild taxa were used, yet based on MNI per taxon domestic taxa are more present on site than wild species. This larger representation of domestic taxa over wild ones suggests that they were utilised more, with wild taxa harvested as supplementary resources to a diet principally founded on domestic plants. Cultivation at Mutamba seems to have taken place in and around the settlement itself, reiterating the hypothesis put forward by Greenfield *et al.* (2005) concerning the location of cultivation in the Iron Age. The archaeobotanical assemblage also points to cultivation of a potential crop package made up of *E. coracana*, *S. bicolor*, *P. glaucum*, *V. unguiculata* and *V. radiata*. Mutamba contains the first documented example of this last species in South Africa.

The Mutamba archaeobotanical assemblage provides the first archaeologically documented case of *V. radiata* in southern Africa. It also offers the first tangible evidence for the occurrence of malted grains used in beer brewing. A further significant contribution of this study is that it provides the first archaeological links between *G. herbaceum* and cotton spinning. To date, the use of *G. herbaceum* to produce cotton cloth in the southern African Iron Age has been based solely on ethnographic inference.

Analysis of the archaeobotanical assemblage from Mutamba also provides a better understanding of how crops were harvested in the southern African Iron Age. Based on the absence of weed taxa in the assemblage, handpicking of legumes and cutting below the ear in the case of grains appear to have been the methods used in harvesting. Additionally, crop processing can be inferred to have occurred away from domestic households, unless the relevant parts did not survive incineration. The archaeobotanical assemblage from Mutamba therefore provides an important contribution to the likely uses of plants among agropastoralist communities in southern Africa's Iron Age, shedding much-needed light on the poorly understood but very important role of plants in Middle Iron Age society.

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References

Al-Gohari, I. and Mohamed, A.M. 2007. "Seed morphology of *Acacia* in Egypt and its taxonomic significance." *International Journal of Agriculture and Biology* 9: 435–438.

Antolín, F. and Buxó, R. 2011. "Proposal for the systematic description and taphonomic study of carbonized cereal grain assemblages: a case study of an early Neolithic funerary context in the cave of Can Sadurní (Begues, Barcelona province, Spain)." *Vegetation History and Archaeobotany* 20: 53–66.

Antonites, A. 2012. "Political and economic interactions in the hinterland of the Mapungubwe polity, *c.* AD 1200–1300, South Africa." PhD diss., Yale University.

Antonites, A. 2019a. "Mapungubwe's hinterland: excavations, ceramics and other material culture from Mutamba in the Soutpansberg." *Southern African Humanities* 32: 1–22.

Antonites, A. 2019b. "Fibre spinning during the Mapungubwe period of southern Africa: regional specialisms in the hinterland." *African Archaeological Review* 36: 105–117.

Antonites, A. and Antonites, A.R. 2014. "The archaeobotany of Farming Communities in South Africa." In *The Archaeology of African Plant Use*, edited by C.J. Stevens, S. Nixon, M.A. Murray and D.Q. Fuller, 225–232. Walnut Creek: Left Coast Press.

Badenhorst, S. 2010. "Descent of Iron Age farmers in southern Africa during the last 2000 years." *African Archaeological Review* 27: 87–106.

Baouchaud, C., Tengberg, M. and Dal Prâ, P. 2011. "Cotton cultivation and textile production in the Arabian Peninsula during antiquity: the evidence from Madâ'in Sâlih (Saudi Arabia) and Qal'at al Bahrain (Bahrain)." *Vegetation History and Archaeobotany* 20: 405–417.

Boardman, S. and Jones, G. 1990. "Experiments on the effects of changes in cereal plant components." *Journal of Archaeological Science* 17: 1–11.

Braadbaart, F. 2004. "Carbonization of peas and wheat — a window into the past: a laboratory study." PhD diss., Leiden University.

Braadbaart, F., Bakels, C.C., Boon, J.J. and van Bergen, P.F. 2005. "Heating experiments under anoxic conditions on varieties of wheat." *Archaeometry* 47: 103–114.

Bradfield, J. and Antonites, A.R. 2018. "Bone hoes from the Middle Iron Age, Limpopo, South Africa." *Quaternary International* 472: 126–134.

Brunken, J., De Wet, J.M.J. and Harlan, J.R. 1977. “The morphology and domestication of pearl millet.” *Economic Botany* 31: 163–174.
Calabrese, J.A. 2000. “Interregional interaction in southern Africa: Zhizo and Leopard’s Kopje relations in northern South Africa, southwestern Zimbabwe and eastern Botswana, AD 1000 to 1200.” *African Archaeological Review* 17: 183–210.
Calabrese, J.A. 2007. *The Emergence of Social and Political Complexity in the Shashi-Limpopo Valley of Southern Africa, AD 900 to 1300: Ethnicity, Class and Polity*. Oxford: Archaeopress.
Cappers, R.T.J., Neef, R. and Bekker, R.M. 2009. *Digital Atlas of Economic Plants, Volume 2b: Icacinaceae — Zygophyllaceae*. Barkhuis: Barkhuis and Groningen University Library.
Chandare, F.J., Hounhouigan, F.J., Linneman, J.D., Nout, A.R. and Van Boekel, M.A.J.S. 2008. “Indigenous knowledge and processing of *Adansonia digitata* L. food products in Benin.” *Ecology of Food and Nutrition* 47: 338–362.
Chandare, F.J., Hounhouigan, F.J., Linneman, J.D., Nout, A.R. and Van Boekel, M.A.J.S. 2009. “Baobab food products: a review on their composition and nutritional value.” *Critical Reviews in Food Science and Nutrition* 49: 254–274.
Chandrashekar, A. 2010. “Finger millet: *Eleusine coracana*.” *Advances in Food and Nutrition Research* 59: 215–262.
Cunningham, A.B. 1988. “Collection of wild plant foods in Tembe Thonga society: a guide to Iron Age gathering activities?” *Annals of the Natal Museum* 29(2): 433–446.
Davison, P. and Harries, P. 1980. “Cotton weaving in South-East Africa: its history and technology.” *Textile History* 10: 175–192.
De Wet, J.M.J and Harlan, J.R. 1971. “The origin and domestication of *Sorghum bicolor*.” *Economic Botany* 25: 128–135.
Department of Agriculture, Forestry and Fisheries. 2010a. *Sorghum: Production Guidelines*. Pretoria: Department of Agriculture, Forestry and Fisheries of South Africa.
Department of Agriculture, Forestry and Fisheries. 2010b. *Marula: Production Guidelines*. Pretoria: Department of Agriculture, Forestry and Fisheries of South Africa.
Dlamini, N.R. and Dube, S. 2008. “Studies on the physico-chemical, nutritional and microbiological changes during the traditional preparation of Marula wine in Gwanda, Zimbabwe.” *Nutrition and Food Science* 38: 61–69.
Doggett, H. 1976. “Sorghum.” In *Evolution of Crop Plants*, edited by N. Simmonds, 112–116. London: Longman.
Du Piesanie, J. 2008. “Understanding the socio-political status of Leokwe society during the Middle Iron Age in the Shashe-Limpopo Basin through a landscape approach.” MSc diss., University of the Witwatersrand.
Du Plessis, J. 2008. *Sorghum Production*. Pretoria: Department of Agriculture of South Africa.
Eloff, J.F. 1979. *Die Kulture van Greefswald: ‘n Argeologiese Studie van die Ystertydperkkulture op die Plaas Greefswald, Deel III*. Pretoria: University of Pretoria.
Ferrio, J.P., Alonso, N., Voltas, J. and Araus, J.L. 2004. “Estimating grain weight in archaeological cereal crops: a quantitative approach for comparison with current conditions.” *Journal of Archaeological Science* 31: 1635–1642.
Fouché, L. 1937. *Mapungubwe Ancient Bantu Civilization on the Limpopo: Report on Excavations at Mapungubwe (Northern Transvaal) from February 1933 to June 1935*. Cambridge: Cambridge University Press.
Fuller, D.Q. 2006. *A Millet Atlas: Some Identification Guidance*. http://www.homepages.ucl.ac.uk/~tcrndfu/Abot/Millet%20Handout06.pdf Site accessed 15 May 2019.
Fuller, D.Q. 2007. “Contrasting patterns in crop domestication and domestication rates: recent archaeobotanical insights from the Old World.” *Annals of Botany* 100: 903–924.
Fuller, D.Q., Allaby, R.G. and Stevens, C. 2010. “Domestication as innovation: the entanglement of techniques, technology and chance in the domestication of cereal grains.” *World Archaeology* 42: 13–28.
Fuller, D.Q. and Harvey, M.L. 2006. “The archaeobotany of Indian pulses: identification, processing and evidence for cultivation.” *Environmental Archaeology* 11(2): 219–246.

Fuller, D.Q., Stevens, C. and McClatchie, M. 2014. "Routine activities, tertiary refuse, and labour organization: social inferences from everyday archaeobotany." In *Ancient Plants and People: Contemporary Trends in Archaeobotany*, edited by M. Madella, C. Lancelotti and M. Savard, 176–217. Tucson: University of Arizona Press.

Gardner, G.A. 1968. *Mapungubwe Volume 2: Report on Excavations at Mapungubwe and Bambandyanalo in Northern Transvaal from 1935 to* 1940. Pretoria: Van Schaik.

Greenfield, H.J., Fowler, K.D. and van Schalkwyk, L.O. 2005. "Where are the gardens? Early Iron Age horticulture in the Thukela River Basin of South Africa." *World Archaeology* 37: 307–328.

Guarino, C. and Sciarrillo, R. 2004 "Carbonized seeds in a protohistoric house: results of hearth and house experiments." *Vegetation History and Archaeobotany* 13: 65–70.

Gustaffson, S. 2000. "Carbonized cereal grains and weed seeds in prehistoric houses — an experimental perspective." *Journal of Archaeological Science* 27: 65–70.

Hilu, K.W., De Wet, J.M.J. and Harlan, J.R. 1979. "Archaeobotanical studies of *Eleusine coracana* ssp. *coracana* (Finger millet)." *American Journal of Botany* 66: 330–333.

Huffman, T.N. 1971. "Cloth from the Iron Age in Rhodesia." *Arnoldia* 5: 1-19.

Huffman, T.N. 1996. "Archaeological evidence for climate change during the last 2000 years in southern Africa." *Quaternary International* 33: 55-60.

Huffman T.N. 2000. "Mapungubwe and the origins of the Zimbabwe culture." *South African Archaeological Society Goodwin Series* 8: 14–29.

Huffman, T.N. 2007. *Handbook to the Iron Age: The Archaeology of Pre-colonial Farming Societies in Southern Africa*. Scottsville: University of Kwazulu-Natal Press.

Ibrahim, K.A., Dube, S., Peterson, P.M. and Hosni, H.A. 2018. *Grasses of Mali*. Washington DC: Smithsonian Institution Scholarly Press.

Iles, L. 2009. "Impressions of banana pseudostem in iron slag from eastern Africa." *Ethnobotany Research and Applications* 7: 283–291.

Kabanda, T.A. 2003. "Climate." In *A First Synthesis of the Environmental, Biological and Cultural Assets of the Soutpansberg*, edited by K. Berger, J.E. Crafford, I. Gaigher, M.J. Gaigher, N. Hahn and H.I. Macdonald, 10–11. Louis Trichardt: Leach Printers and Signs.

Kaboré, D., Sawadogo-Lingani, H., Diawara, B., Compaoré, C.S. Dicko, M.H. and Jakobsen, M. 2011. "A review of baobab (*Adansonia digitata*) products: effect of processing techniques, medicinal properties and uses." *African Journal of Food Science* 5: 833–844.

Kahlheber, S., Bostoen, K. and Nueman, K. 2009. "Early plant cultivation in the Central African rainforest: first millennium BC pearl millet from south Cameroon." *Journal of African Archaeology* 7: 253–272.

Kay, D.E. 1979. *Crop and Product Digest No. 3 — Food Legumes*. London: Tropical Products Institute.

Klapwijk, M. and Huffman, T.N. 1996. "Excavations at Silver Leaves: a final report." *South African Archaeological Bulletin* 51: 84–93.

Krige, E.J. 1937. "Note on the Phalaborwa and their Morula complex." *Bantu Studies* 11: 357–366.

Lestrade, G. P. 1932. "Some notes on the ethnic history of the Vhavenda and their Rhodesian affinities". In *Contributions to Venda History, Religion and Tribal Rituals*, edited by N.J. Van Warmelo, 20–28. Pretoria: Government Printer.

Liu, H., Hy, X.Y. and Liu, Q. 2015. "Caryopsis micromorphological survey of *Sorghum* (Poaceae): taxonomic implications." *South African Journal of Botany* 99: 1–11.

Loubser, J.N.H. 1988. "Archaeological contributions to Venda ethnohistory." PhD diss., University of the Witwatersrand.

Loubser, J.N.H. 1991. "The ethnoarchaeology of Venda-speakers in southern Africa." *Navorsinge van die Nasionale Museum, Bloemfontein* 7(8): 148–463.

Lyumugabe, F., Gros, J., Nzungize, J., Baljyana, E. and Thonart, P. 2012. "Characteristics of African traditional beers brewed with sorghum malt: a review." *Biotechnology, Agronomy, Society and Environment Journal* 16: 509–530.

Mabogo, D.E.N. 1990. "The ethobotany of the Vhavenda." MA diss., University of Pretoria.

Mercuri, A.M. 2008. “Human influence, plant landscape evolution and climate inferences from the archaeobotanical records of the Wadi Teshuinat area (Libyan Sahara).” *Journal of Arid Environments* 72: 1950–1967.
Meyer, A. and Cloete, C.E. 2010. “Architectural traditions of Mapungubwe and Bambandyanalo (K2).” *Journal of Transdisciplinary Research in Southern Africa* 6: 241–270.
Midgley, J.J., Gallaher, K. and Kruger, L.M. 2012. “The role of the elephant (*Loxodonta africana*) and the tree squirrel (*Paraxerus cepapi*) in marula (*Sclerocarya birrea*) seed predation, dispersal and germination.” *Journal of Tropical Ecology* 28: 227–231.
Moll, E. 2011. *What’s that Tree?: A Starter’s Guide to Trees of Southern Africa*. Cape Town: Struik Nature.
Mostert, T.H.C. 2006. “Vegetation ecology of the Soutpansberg and Blouberg in the Limpopo Province.” PhD diss., University of Pretoria.
Mostert, T.H.C., Bredenkamp, G.J., Klopper, H.L., Verway, G., Mostert, R.E. and Hahn, N. 2008. “Major vegetation types of the Soutpansberg Conservancy and the Blouberg Nature Reserve, South Africa.” *Koedoe* 50: 32-48.
National Academy of Sciences. 1996. *Lost Crops of Africa: Volume 1 Grains*. Washington: National Academy Press.
Neumann, K., Kahlheber, S. and Uebel, D. 1998. “Remains of woody plants from Saouga, a medieval West African village.” *Vegetation History and Archaeobotany* 7: 57–77.
Owuama, C. 1999. “Brewing beer with sorghum.” *Journal of the Institute of Brewing* 105: 23–34.
Pearsall, D.M. 2015. *Paleoethnobotany: A Handbook of Procedures*. Walnut Creek: Left Coast Press.
Petje, K.F. 2008. “Determination of fruit yield and fruit quality in marula (*Sclerocarya birrea* subsp. *caffra*) selections.” MInst Agrar (Horticultural Science) diss., University of Pretoria.
Purseglove, J.W. 1976. “Millets”. In *Evolution of Crop Plants*, edited by N. Simmonds, 91–-92. London: Longman.
Quin, P.J. 1959. *Foods and Feeding Habits of the Pedi*. Johannesburg: University of the Witwatersrand Press.
Raath, A. 2014. “An archaeological investigation of Zhizo/Leokwe foodways at Schroda and Pont Drift, Limpopo Valley, South Africa.” PhD diss., Yale University.
Rampedi, I.T. 2010. “Indigenous plants in the Limpopo Province: potential for their commercial beverage production.” PhD diss., University of Pretoria.
Reeves, R.G. 1936. “Comparative anatomy of the seeds of cottons and other malvaceous plants. II. Hibisceae.” *American Journal of Botany* 23: 394–405.
Reid, D.A.M. and Young, R. 2000. “Pottery abrasion and the preparation of African grains.” *Antiquity* 74: 101–111.
Ross, J.H. 1981. “An analysis of the African *Acacia* species: their distribution, possible origins and relationships.” *Bothalia* 13: 389–413.
Schapera, I. and Goodwin, A.J.H. 1962. “Work and wealth”. In *The Bantu Speaking Tribes of South Africa*, edited by I. Schapera, 131–171. London: George Routledge and Sons.
Schoeman, M.H. 2006. “Clouding power? Rain-control, space, landscapes and ideology in Shashe-Limpopo state formation.” PhD diss., University of the Witwatersrand.
Scott, C. 2005. “Analysis and interpretation of botanical remains from Sibudu Cave, KwaZulu-Natal.” PhD diss., University of the Witwatersrand.
Sivakumar, V., Anandalakshmi, R., Warrier, R.R., Singh, B.G., Tigabu, M. and Nagarajan, B. 2013. “Discrimination of *Acacia* seeds at species and subspecies levels using an image analyser.” *Forest Science and Practice* 15: 253–260.
Stayt, A. 1968. *The Bavenda*. London: Frank Cass.
Steyn, B. 2018. “The archaeobotany of Mutamba, a thirteenth century Mapungubwe settlement in northern South Africa.” MA diss., University of Pretoria.
Thompson, R.A.J. 1988. “Studies in the Paniceae: generic boundaries in the *Brachiaria* complex (Poaceae).” PhD diss., Oklahoma State University.
Twiss, K.C. 2007. “Home is where the hearth is: food and identity in the Neolithic Levant.” In *The Archaeology of Food and Identity*, edited by K. Twiss, 50–68. Carbondale: Southern Illinois University.

Van der Waal, C.S. 1977. "Die woning en woonwyse onder die Venda." MA diss., University of Pretoria.
Van Warmelo, N.J. (ed.). 1932. *Contributions Towards Venda History, Religion and Tribal Rituals*. Pretoria: Government Press.
Venier, P., Carrizo García, C., Cabido, M. and Funes, G. 2012. "Survival and germination of three hard-seeded *Acacia* species after simulated cattle ingestion: the importance of the seed coat structure." *South African Journal of Botany* 79: 19–24.
Von Teichman. I. 1988. "Notes on the ontogeny and structure of the seed-coat of *Sclerocarya birrea* (Richard) Hochst. subsp. *caffra* (Sonder) Kokwaro (Anacardiaceae)." *Botanical Journal of the Linnaean Society* 98: 153–158.
Von Teichman, I. and Robbertse, P.J. 1980. "Development and structure of the drupe in *Sclerocarya birrea* (Richard) Hochst. subsp. *caffra* Kokwaro (Anarcardiaceae), with special reference to the pericarp and the operculum." *Botanical Journal of the Linnaean Society* 92: 303–323.
Von Teichman, I., Small, J.G.C. and Robbertse, P. 1986. "A preliminary study on the germination of *Sclerocarya birrea* subsp. *caffra*." *South African Journal of Botany* 52: 145–148.
Xaba, P. 2008. "Sorghum: gardening with traditionally useful plants." *Veld and Flora* 94: 224–225.