Plant economy from Early Iron Age site of Malli, Gondia district, Maharashtra, India

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This study presents the plant economy reconstructed based on an analysis of charred plant remains from an Early Iron Age site, Malli, in Gondia district, Maharashtra, India. A radiocarbon date of 3400 ± 100 cal BP was obtained from a wood charcoal sample. Agricultural crops identified included *Oryza sativa* subsp. *indica*, *Oryza* cf. *rufipogon*; millets like *Brachiaria ramosa*, *Echinochloa* cf. *colona*, *Paspalum scrobiculatum*, *Setaria italica* and *Setaria* sp.; pulses such as *Lablab purpureus*, *Lathyrus sativus*, *Macrotyloma uniflorum*, *Vigna mungo*, *Vigna radiata*, grains of *Vigna* sp. and oilseeds of *Brassica* cf. *juncea*. The remains of wild and weedy taxa were also recovered, including seeds of *Commelina* sp., *Cyperus* sp., *Elaeocharis* sp., *Scirpus* sp., *Scleretia* sp., *Fimbristylis* sp., *Solanum* sp., *Ischaemum rugosum* and *Indigofera* cf. *Linifolia*. Fruit stone fragments of *Ziziphus* sp., along with tree species, include *Bombax* sp. and *Ficus* sp. The Malli was part of the agricultural mounded settlement group that existed during the Early Iron Age period in the Upper Wainganga Valley. This archaeobotanical dataset provides evidence of the typical summer crop pattern facilitated by wet environmental conditions.

Keywords: Agriculture, domestication, Early Iron Age, plant economy, radiocarbon dating.

THE plant economy of ancient Malli, Gondia district, Maharashtra, India, is analysed in the present study from the archaeobotanical remains recovered from multiple field season excavations (2010–11 and 2012–13). This study aims to place these archaeobotanical results within the wider archaeological interpretations of past economies, foodways, and to some extent, environmental changes within the region. It provides evidence of ancient domesticated plants and agricultural crop systems at Malli, excavated under the direction of one of the present authors (V.G.S.) from Department of Archaeology, Government of Maharashtra, Nagpur during two field seasons (2010–11 and 2012–13). Excavations of habitational mounds I and II and some megalithic burials unearthed cultural material belonging to the Early Iron Age (megalithic) period[1,2]. The first author (S.S.N.) participated in the excavations, undertaking palaeoenvironmental sampling. The water flotation technique was used systematically in the form of wet sieving and collecting of plant remains at the excavation site, with the aim of recovery of archaeobotanical remains to assist in understanding the ancient settlers at Malli and their economic exploitation of plant resources in their environment. Most cultural levels yielded good evidence of carbonized and semi-carbonized botanical remains, except for the natural deposition at the base of all the trenches. The recovered plant remains were examined and identified based on their morphological and anatomical traits. In addition, a brief phytogeographical survey was undertaken around the site to ascertain ecological formations.

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Study site

Malli (21°19′.221″ N, 79°54′249″ E) is situated nearly 135 km east of Nagpur in the Tiroda block of Gondia district, Maharashtra. This district forms part of the eastern boundary of the state. The site is located on the left bank of the Chorkhambara river, which is a tributary of the Wainganga river. Malli is situated on the Dharwar rock formation with many resources nearby, such as iron ore, manganese, lead, zinc, etc. The site is remarkable for habitations as well as a cemetery dating back to the Iron Age[3–10]. The burial and habitation localities are set apart by a small rain gully or nulla. The megalithic burial ground is located on the outskirts of the village, and the habitation mound is located on its northern side. Nearly 400 megaliths have been documented at the site, indicating the preferred place for burial and a longer period of activity. Megalithic habitation was spread over 500 m and divided into four mounds. Two mounds were chosen for systematic excavation as they were comparatively elevated and, accordingly, trenches were dug (Figure 1). Excavations revealed that Malli was a single culture site of the Early Iron Age with an uninterrupted deposit of over 2 m.

Vegetation

At present, the vegetation at and around Malli is scanty due to modern human activities such as deforestation, animal grazing, etc. An extensive floristic survey of the entire area, covering around 5 km of the site, was conducted during excavations to study floristic diversity and vegetation patterns.

The plants were systematically documented, photographed and identified using flora, identification keys and field guides[11–16]. Table 1 lists the plants documented from Malli.

Modern agriculture

The land in and around the study site (approximately 2 km) has been exploited by modern cultivators for agricultural crops such as rice/paddy, black gram, green gram and pigeon pea in summer (June–September). At present, rice is the major crop of this region as it receives high rainfall, approximately 1300–1500 mm per year[17]. Table 2 lists the crop plants grown in the area by local farmers near the study site.

Materials and methods

The archaeobotanical remains were meticulously collected from habitation deposits and the megalith burials following visual inspection during the excavations. Fourteen soil samples from mound I, trench B (quadrants: B1, B2, B3 and B4); 13 from mound I, trench D; 47 from mound II, trench A (quadrants: A1, A2, A3 and A4), and five from mound II, trench J (20 kg each) were collected from the cultural levels (Table 3 and Figure 2 *a* and *b*). Six soil samples from megalith no. 1, two from megalith no. 3 (68), and one each from megalith nos 2 and 66 (2 kg each) were collected for wet sieving. These samples were floated using bucket flotation to retrieve the carbonized and silicified plant remains using a 0.25 mm mesh geological sieve. The plant remains were segregated and categorized under a low-power stereo microscope (WILD Heerbrugg M 400 and EUROMEX EDU BLUE) at the Palaeobotany Laboratory of the Deccan College, PGRI, Pune and photographs of all recorded taxa were taken. Most of the seeds/grains of crop plants, weedy taxa and fruit remains were found to be in a good state of preservation. However, in a few cases, severe carbonization inhibited the survival of diagnostic features. Grains and seeds were measured using a stage micrometer and an ocular disc. Identifications were made using the reference collection housed at the Deccan College, and relevant published material[18–21].

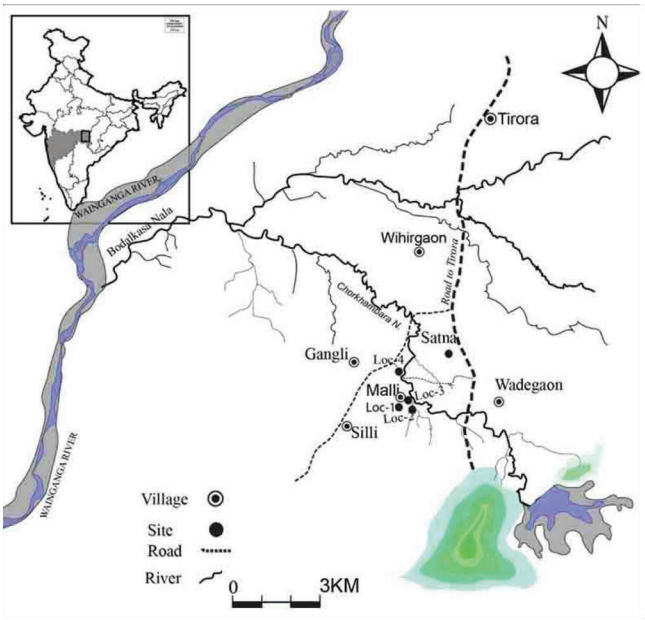

Figure 1. Location map of Malli, Gondia district, Maharashtra, India.

Results

Radiocarbon dating

A wood charcoal sample from the Early Iron Age phase was sent for radiocarbon dating to Birbal Sahni Institute of Paleosciences, Lucknow (BS-4001) and a date of 3400 ± 100 (1947–1494 Cal BC) was returned (Table 4 and Figure 3).

Archaeobotanical results

Several crop plants and wild and weedy taxa were identified within the Early Iron Age samples. However, no macrobotanical remains were found in the samples collected from the four excavated megaliths (nos 1, 2, 3(68) and 66). Rice (*Oryza sativa* cf. subsp. *indica*) was in abundance, making up 48% of the total archaeobotanical assemblage. The length : width ($L : W$) ratio[22] of rice grains from Malli was measured[22]. This was compared with rice data from Early Iron Age sites at Kaundinyapur[23] and Adam[24]. The rice data ($L : W$ ratio) from Early Iron Age rice in Vidarbha, Maharashtra, appears to have been a mixed population of *O. sativa* subsp. *indica* and *Oryza sativa* subsp. *japonica*. The early historic sites of Ter and Balathal, which also showed mixed populations of *indica* and *japonica* rice, were grown at these sites[22]. Table 5 and Figure 4 describe the archaeobotanical remains.

Description of plant remains

Cereals

Oryza sativa L. (rice; Figure 4 *a*, *b*): The rice grains (native to South Asia) were recovered from trenches A, B and D in good amounts, i.e. 48% of the total archaeobotanical assemblage. These were in the form of whole grains, fragmented grains, detached embryos, grain fragments with embryos and spikelet bases. The whole rice grains elongated to narrowly oblong, laterally flattened and prominently ribbed. Husk was noted on a few grains, but not quantified. They measured 3.86–5.37 mm × 1.59–2.64 mm × 1.23–2.15 mm ($L \times B \times T$). Some impressions represented the typical chess-board pattern of rice husks on the potsherds. The grains were comparable to those of *O. sativa* ssp. *indica*

Table 1. Enumeration of the plants documented from Malli, Gondia district, Maharashtra, India

Botanical name	Common name	Habit	Native/non-native
Abrus precatorius L.	Jequirity bean/rosary pea	Perennial climber	Native
Acacia catechu (L.) Willd.	Babul	Tree	Native
Acacia chundra (Roxb. Ex. Rottl.) Willd.	Khair	Tree	Native
Acacia nilotica (L.) Willd.	Jangli babul	Tree	Native
Achyranthes aspera L.	Chaff-flower	Herb	Non-native
Albizia procera (Roxb.) Benth.	White siris	Tree	Native
Alternanthera sessilis (L.) R.Br.	Sessile joyweed	Herb	Non-native
Amaranthus cruentus L.	Red amaranth	Herb	Non-native
Annona reticulata L.	Sugar apple	Tree	Non-native
Annona squamosa L.	Custard apple	Tree	Non-native
Artocarpus heterophyllus Lam.	Jackfruit	Tree	Native
Azadirachta indica A. Juss.	Neem	Tree	Native
Bauhinia racemosa Lam.	Bidi leaf tree	Shrub	Native
Bombax ceiba L.	Cotton tree	Tree	Native
Bridelia retusa Spreng.	Spinous kino tree	Tree	Native
Butea monosperma (Lam.) Taub.	Flame of the forest	Tree	Native
Calotropis procera (Ait.) Dryand	Giant milkweed	Shrub	Native
Carica papaya L.	Papaya	Tree	Non-native
Carissa congesta Wight	Karanda	Shrub	Native
Cassia auriculata L.	Tanner's Cassia	Shrub	Native
Cassia tora L.	Sickle senna	Herb	Non-native
Celosia argentea L.	White cockscomb	Herb	Native
Cocculus hirsutus (L.) Theob.	Broom creeper	Climber	Native
Cynodon dactylon (L.) Pers.	Bermuda grass	Herb	Native
Dalbergia latifolia Roxb.	Rosewood	Tree	Native
Dendrocalamus strictus (Roxb.) Nees.	Bamboo	Tree	Native
Diospyros melanoxylon Roxb.	Tendu	Tree	Native
Ficus hispida L.	Hairy fig	Tree	Native
Ficus racemosa L.	Cluster fig	Tree	Native
Grevillea robusta A. Cunn.	Silver oak	Tree	Non-native
Hardwickia binata Roxb.	Anjan	Tree	Native
Indigofera sp.	Indigo	Shrub	Native
Ipomoea carnea Jacq. Subsp. *fistulosa* (Mart ex Choisy) Austin	Bush morning glory	Herb	Non-native
Lantana camara L.	Lantana	Shrub	Non-native
Madhuca longifolia (Konig) Macbr.	Mohua	Tree	Native
Mangifera indica L.	Mango	Tree	Native
Ocimum basilicum L.	Basil/tulasi	Herb	Native
Parthenium hysterophorus L.	Carrot grass	Herb	Non-native
Polyalthia longifolia (Sonn.) Thwaites	Ashok	Tree	Non-native
Pongamia pinnata (L.) Pierre	Pongame oiltree	Tree	Native
Randia dumetorum Lamk.	Emetic nut tree	Tree	Native
Sesbania sesban (Jacq.) Wight	Common sesban	Tree	Native
Syzygium cumini (L.) Skeels	Black plum	Tree	Native
Tamarindus indica L.	Tamarind	Tree	Native
Terminalia arjuna (Roxb.) Wight & Arn.	Arjun	Tree	Native
Terminalia catappa L.	Indian almond	Tree	Native
Terminalia crenulata Roth.	Ain	Tree	Native
Thespesia populnea (L.) Soland	Indian tulip tree	Tree	Native
Tridax procumbens L.	Coat buttons	Herb	Non-native
Woodfordia fruticosa (L.) Kurtz.	Fire flame bush	Shrub	Native
Ziziphus mauritiana Lam.	Indian jujube	Shrub/tree	Native

stored in the repository of the Palaeobotany Laboratory at Deccan College.

Oryza cf. *rufipogon* Griffith (wild rice; Figure 4 *c*, *d*): twelve wild rice grains (native to South Asia) were recovered from trenches A and three D in the form of whole grains, fragmented grains, grain fragments with embryos and spikelet bases. A total of 40 wild rice spikelet bases were documented from trench A. The grains were comparatively more slender than cultivated rice and elongated to narrowly oblong without husk. They measured 4.62–4.96 mm × 1.59–2.64 mm × 1.23–2.15 mm ($L \times B \times T$). A wild weedy species of rice might have been harvested along with the cultivated crop of rice in modern times in the region. The morphological peculiarities were similar to the grains of wild rice (*Oryza* cf. *rufipogon*).

Table 2. Enumeration of modern crop plants documented from Malli

Botanical name	Common name	Native/non-native
Cereals		
Oryza sativa L.	Rice	Native
Zea mays L.	Maize/corn	Non-native
Pulses		
Cajanus cajan (L.) Millsp.	Pigeon pea	Native
Cicer arietinum L.	Chickpea	Non-native
Lablab purpureus (L.) Sweet	Hyacinth bean	Non-native
Pisum arvense L.	Common pea	Non-native
Vigna mungo (L.) Hepper	Black gram	Native
Vigna radiata (L.) Wilczek	Green gram	Native
Vigna unguiculata (L.) Walp	Cow pea	Native
Oil crops		
Brassica juncea (L.) Czern and Coss.	Mustard	Native
Linum usitatissimum L.	Linseed	Non-native
Ricinus communis L.	Castor	Non-native
Vegetables		
Abelmoschus esculentus (L.) Moench	Lady's finger	In dispute
Allium cepa L.	Onion	Non-native
Allium sativum L.	Garlic	Non-native
Amaranthus caudatus L.	Amaranth	Non-native
Brassica oleracea L.	Cabbage	Non-native
Capsicum annuum L.	Chili	Non-native
Coriandrum sativum L.	Coriander	Non-native
Cyamopsis tetragonoloba (L.) Taub	Cluster bean	Unknown
Daucus carota subsp. *sativus* L.	Carrot	Non-native
Ipomoea batatas (L.) Lam.	Sweet potato	Non-native
Luffa acutangula (L.) Roxb.	Ridged luffa	Native
Solanum lycopersicum L.	Tomato	Non-native
Solanum melongena L.	Brinjal	Native
Ziziphus mautitiana Lam.	Indian jujube	Native

Table 3. List of soil samples collected from the activity area and exposed stratigraphic layers in the archaeological trenches for macrobotanical analysis

	Malli 2012–13, mound II, trench A		Malli 2012–13, mound I, trench B		Malli 2010–11, mound I, trench D		Malli 2010–11, mound I, trench J	
Layer no.	No. of samples	Depth (m)	No. of samples	Depth (m)	No. of samples	Depth (m)	No. of samples	Depth (m)
1	1	0.0–0.25	1	0.0–0.16	–	–	–	0.0–0.30
2	4	0.25–0.75	1	0.16–0.50	–	–	–	0.30–0.65
3	5	0.75–1.00	2	0.50–0.60	1	0.55–0.80	1	0.65–1.00
4	3	1.00–1.10	2	0.60–0.65	1	0.80–1.10	1	1.00–1.10
5	7	1.10–1.32	1	0.65–1.25	1	1.10–1.45	1	1.10–1.25
6	5	1.32–1.47	2	1.25–1.30	1	1.45–1.60	1	1.25–1.45
7	3	1.47–1.55	2	1.30–1.45	1	1.60–1.70	1	1.45–1.60
8	3	1.55–1.65	1	1.45–1.75	1	1.70–1.90	–	1.60–2.32
9	1	1.65–1.75	1	1.75–2.25	1	1.90–2.00	–	–
10	1	1.75–1.95	1	2.25–2.75	1	2.00–2.10	–	–
11	1	1.95–2.13	–	–	1	2.10–2.20	–	–
12	1	2.13–2.22	–	–	1	2.20–2.40	–	–
13	2	2.22–2.27	–	–	1	2.40–2.45	–	–
14	2	2.27–2.40	–	–	1	2.45–2.60	–	–
15	1	2.40–2.50	–	–	1	2.60–3.15	–	–
16	2	2.50–2.60	–	–	–	–	–	–
17	1	2.60–2.70	–	–	–	–	–	–
18	1	2.70–2.80	–	–	–	–	–	–
19	1	2.80–2.86	–	–	–	–	–	–
20	1	2.86–2.90	–	–	–	–	–	–
21	1	2.90–3.10	–	–	–	–	–	–
Total number of samples	47		14		13		5	

Table 4. Results of radiocarbon dating

Sr. no	Sample (B S)	Ref. ID	Radiocarbon age (years BP) ± 1σ	Calibrated age range in (BC/AD) (1σ and 2σ range)	Sample CO_2
S-4909	BS-4001	ID-3, Malli-3, SD: 100 cm, ED: 116 cm, layer: 013; charcoal	3400 ± 100	Cal BC 1783: cal BC 1608 cal BC 1947: cal BC 1494	98.74%

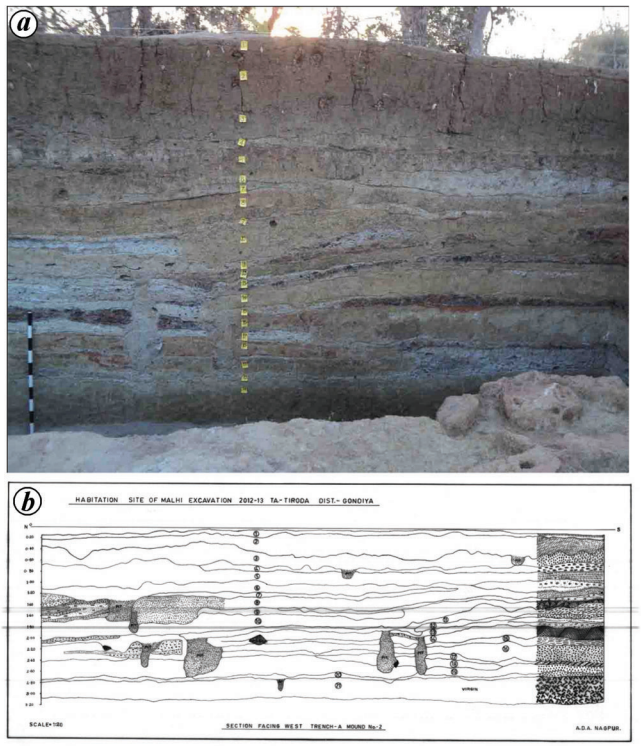

Figure 2. ***a***, Early Iron Age deposit of mound II, trench A (section facing west). ***b***, Stratigraphical sequence of trench A (section facing west).

Pulses

Lablab purpureus L. (hyacinth bean; Figure 4 *e*): A single intact, oval to elliptical, kidney-shaped, carbonized grain (non-native to South Asia)) was recovered from trench A. The characteristic curved hilum scar covering almost half the periphery of the grain was noticeable. The grain showed unequal thickness in its different parts with bulging cotyledons. It measured 6.29 mm × 4.44 mm × 4.00 mm ($L \times B \times T$).

Lathyrus sativus L. (grass pea; Figure 4 *f*): A single complete grain (non-native to South Asia) was recovered from trench A. The grain was squat with end planes, somewhat triangular and measured 3.23 mm × 3.36 mm × 3.30 mm ($L \times B \times T$). The oval hilum scar occurred on one side of the wider or thicker end. The grain was comparable to that of grass pea.

Macrotyloma uniflorum (Lam.) Verdc. (horse gram; Figure 4 *g*): Two intact, ellipsoidal, somewhat kidney-shaped and laterally flattened grains (native to South Asia) of horse gram with a smooth seed coat were recovered, one each from trenches A and J. Twelve fragments from trench A and three from trench D were recorded. The complete horse gram grain present in the assemblage measured 4.29–5.23 mm × 3.11–3.43 mm × 1.85–1.96 mm ($L \times B \times T$).

Vigna mungo (L.) Hepper (black gram; Figure 4 *h*): A single intact grain (native to South Asia), rectangular to sub-cylindrical in shape with a smooth surface, was recovered from trench D. The complete seed was slightly larger than that of a green gram and measured 3.72 mm × 2.71 mm × 2.62 mm ($L \times B \times T$). The hilum was raised above the level of the seed surface. The embryo extended up to a two-thirds portion of the cotyledon.

Vigna radiata (L.) Wilczek (green gram; Figure 4 *i*): Nine intact grains (native to South Asia) and six cotyledons from trench A, four intact grains and six cotyledons from trench D, and two cotyledons from trench J were found in a carbonized state. Both complete grains and cotyledons were characterized by somewhat rounded ends. An elliptical and flat hilum was situated at the level of the seed-coat surface. The embryo was noticeable and extended up to four-fifths portion of the cotyledon. Grains were smaller than black gram, elongated and somewhat cylindrical in appearance. They measured 3.11–3.68 mm × 2.42–2.51 mm × 2.35–2.45 mm ($L \times B \times T$).

Vigna sp. (Figure 4 *j*): Nine intact, carbonized grains (native to South Asia) were recorded from trench A. The grains were globose-shaped and measured 2.57–2.75 mm × 2.13–2.23 mm × 1.75–1.80 mm ($L \times B \times T$).

Oil crops

Brassica cf. *juncea* (L.) Czern and Coss. (Indian mustard; Figure 4 *k*): Two intact grains (native to South Asia) from trench A and one from trench B of oleiferous seeds forming a characteristic reticulum on the surface were identified. The seeds were comparable to those of *Brassica juncea* and measured 1.45 mm in diameter. Therefore, the ancient *Brassica* seeds from Malli have tentatively been referred to as *Brassica* cf. *juncea*.

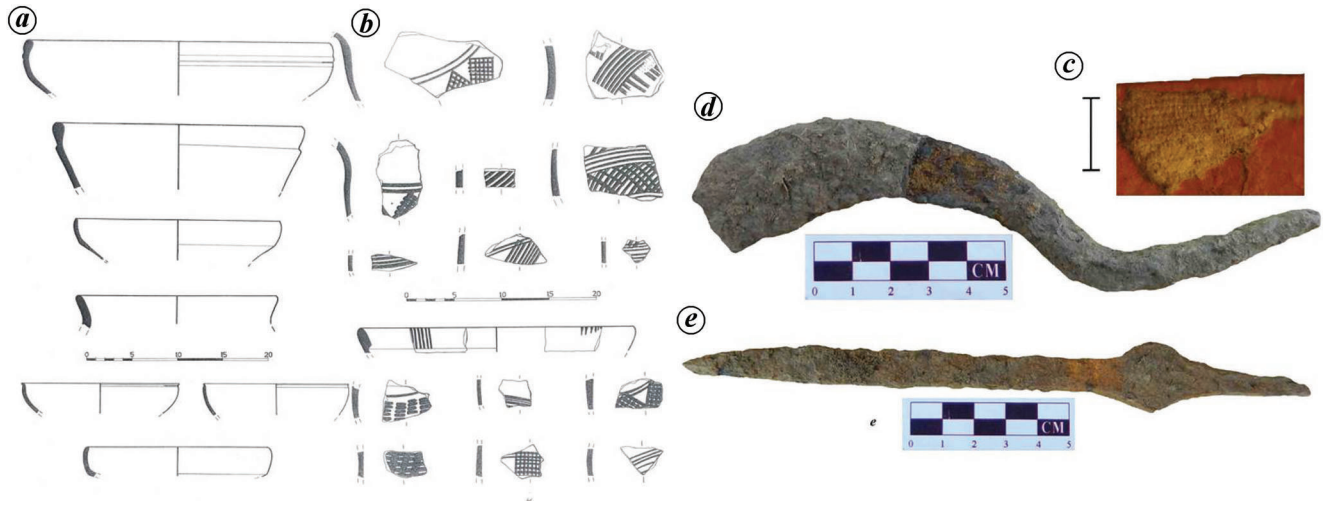

Figure 3. (***a***) Ceramics, (***b***) paintings, (***c***) typical chess-board pattern of rice husk impressions on potsherd, (***d***) iron sickle and (***e***) iron adze of Early Iron Age period.

Millets

Brachiaria ramosa (L.) Stapf. (Browntop millet; Figure 4 *l*): Twenty-four grains of browntop millet (native to South Asia) were recovered from trench A. The grains were broadly elliptic with a smooth pericarp; the scutellum was wide with a rounded apex. Hilum was conspicuously broad and about one-third to half the length of the caryopses. They measured 1.15–1.40 mm × 0.87–1.09 mm ($L \times B$).

Echinochloa cf. *colona* (L.) Link. (Sawa millet; Figure 4 *m*): Sixty-six ovoid–orbicular carbonized grains of Sawa millets (native to South Asia) having a smooth surface and a well-marked hilum scar were recovered from trench A. They measured 0.70–1.48 mm × 0.70–1.27 mm × 0.48–1.10 mm ($L \times B \times T$). *Echinochloa* cf. *colona* commonly grows in water-logged areas such as paddy fields.

Paspalum scrobiculatum L. (kodo millet; Figure 4 *n*): Twenty-three grains (native to South Asia) were recovered from trench A. The husk was entirely covered on the dorsal surface and a part of the ventral surface on four grains recovered from habitational deposits, while 18 grains were found separated or dehusked due to carbonization. The grains were somewhat ovoid and exhibited a typical plano-convex nature. They measured 1.46–1.66 mm × 1.41–1.50 mm × 1.18–1.28 mm ($L \times B \times T$).

Setaria italica (L.) P. Beauv. (Italian millet; Figure 4 *o*): Twenty-four carbonized grains of Italian millet (non-native to South Asia) from trench A and two from trench J were recovered. They were elliptical, plano-convex in nature with a slight dorsal dome and tightly fitting lemma and palea on the ventro-lateral sides, measuring 2.20–2.38 mm × 1.42–1.58 mm ($L \times B$) with a fine ridge on the dorsal surface.

Setaria cf. *verticillata* (foxtail millet, Figure 4 *p*): Two grains of foxtail millet (a non-native to South Asia) were recovered from trench A. The grains were ovoid to somewhat oblong with a narrow upper end and measured 1.22–1.26 mm × 1.00–1.12 mm × 0.76–0.78 mm ($L \times B \times T$). The dorsal side was curved. The hilum was conspicuously broad and occasionally covered up to half the length of the grains.

Setaria sp. (Figure 4 *q*): Fifty-seven dehusked grains of *Setaria* sp. (native to South Asia) were recovered from trench A. They were ovoid to somewhat oblong, with a narrow upper end and a curved dorsal side. They measured 1.27–1.45 mm × 0.85–1.11 mm × 0.48–0.60 mm ($L \times B \times T$). The scutellum was rounded, deep, thick and straight to concave in the length-wise section; the sides were parallel and nearly semi-circular in cross-section. The hilum was conspicuous, broad and about one-third of the length of the caryopses.

Wild and weedy taxa

Commelina sp. (dayflower; Figure 4 *r*): Four flat seeds of dayflower (native to South Asia) were recovered from trench A. They varied from elliptic – truncate to ovoid or nearly globular in shape and measured 2.80–2.88 mm × 2.48–2.56 mm ($L \times B$). An elongated and narrow hilum was seen on the flat side. *Commelina* sp. grows abundantly during the rainy season on high ground and in damp places.

Curculigo orchioides Gaertn.(black musli; Figure 4 *s*): A single carbonized, beaked seed (native to South Asia) was recovered from trench D. The seed was sub-globose with a short knob, in which the funicle had an expanded end and the seed surface exhibited a striate pattern. It measured 2.82 mm × 1.39 mm ($L \times B$).

Table 5. Absolute count and ubiquity (%) of plant remains from Malli

	Trench	A		B		D		J	
Malli 2010–11 and 2012–13 Early Iron Age	Plant remains	Absolute count	Ubiquity (%)	Absolute count	Ubiquity (%)	Absolute count	Ubiquity (%)	Absolute count	Ubiquity (%)
	No. of samples	47		14		13		5	
Species	Notes								
Cereals									
Oryza sativa	Intact grains	102	72.22	3	20	118	66.67		
O. sativa	Embryo ends	415	72.22	4	30				
O. sativa	Fragments	1003	94.44	14	40	204	83.33		
O. sativa (cultivated)	Spikelet bases	86	27.78						
Oryza cf. rufipogon (wild)	Intact grains	12	11.11			3	8.33		
Oryza cf. rufipogon (wild)	Embryo ends	3	5.56						
Oryza cf. rufipogon (wild)	Fragments	13	5.56						
Oryza cf. rufipogon (wild)	Spikelet bases	40	16.67						
Millets									
Brachiaria ramosa	Intact grains	24	38.89						
Echinochloa cf. *colona*	Intact grains	66	50.00						
Paspalum scrobiculatum	Intact grains	23	27.78						
Setaria italica	Intact grains	24	33.33					2	25
Setaria cf. *verticillata*	Intact grains	2	11.11						
Setaria sp.	Intact grains	57	38.89						
Pulses									
Lablab purpureus	Intact grains	1	5.56						
Lathyrus sativus	Intact grains	1	5.56						
Macrotyloma uniflorium	Intact grains	1	5.56					1	25
Macrotyloma uniflorium	Fragments	12	44.44			3	16.67		
Vigna mungo	Intact grains					1	8.33		
Vigna radiata	Intact grains	9	33.33			4	25.00		
Vigna radiata	Cotyledons	6	11.11			6	16.67	2	50
Vigna sp.	Intact grains	9	33.33						
Pulse	Fragments	61	44.44	3	20				
Oil crops									
Brassica cf. *juncea*	Intact seeds	2	11.11	1	10				
Friuts and nuts									
Nutshell	Fragments	94	83.33	3	30				
Ziziphus sp.	Intact seeds					1	8.33		
Ziziphus sp.	Fragments	5	11.11	1	10	2	16.67		
Wild and weedy taxa									
Bombax sp.	Fragments	8	16.67	1	10				
Commelina sp.	Intact seeds	4	22.22						
Curculigo orchioides	Intact seeds					1	8.33		
Cyperus sp.	Intact seeds	9	38.89	1	10			2	25
Elaeocharis sp.	Intact seeds	11	22.22	1	10	46	50.00		
Elaeocharis sp.	Fragments	7	27.78						
Ficus sp.	Intact seeds	1	5.56	1	10				
Fimbristylis sp.	Intact seeds	155	83.33	2	20				
Indigofera cf. *linifolia*	Intact seeds	1	5.56						
Ischaemum rugosum	Intact seeds	1234	72.22	15	40	116	66.67	5	50
Ischaemum rugosum	Fragments	4	16.67			5	25.00		
Scirpus sp.	Intact seeds	7	22.22						
Scleria sp.	Intact seeds	17	27.78	2	20				
Solanum sp.	Intact seeds	4	5.56						
Unidentifiable seeds	Fragments	40	61.11	6	10	10	50.00	11	100
Fungal sclerotia	Intact	24	22.22						

Cyperus sp. L. (sedge; Figure 4 *t*): Nine nuts (native to South Asia) from trench A, one from trench B and two from trench J were recovered. They were obovate and trigonous in shape, measured 1.17–1.60 mm × 0.57–1.08 mm ($L \times B$), and showed minute and somewhat papillae-like cellular patterns on the outer surface. These plants commonly grow in shallow, fresh or brackish water, marshy places, along drains and in lowland–irrigated and tidal rice fields.

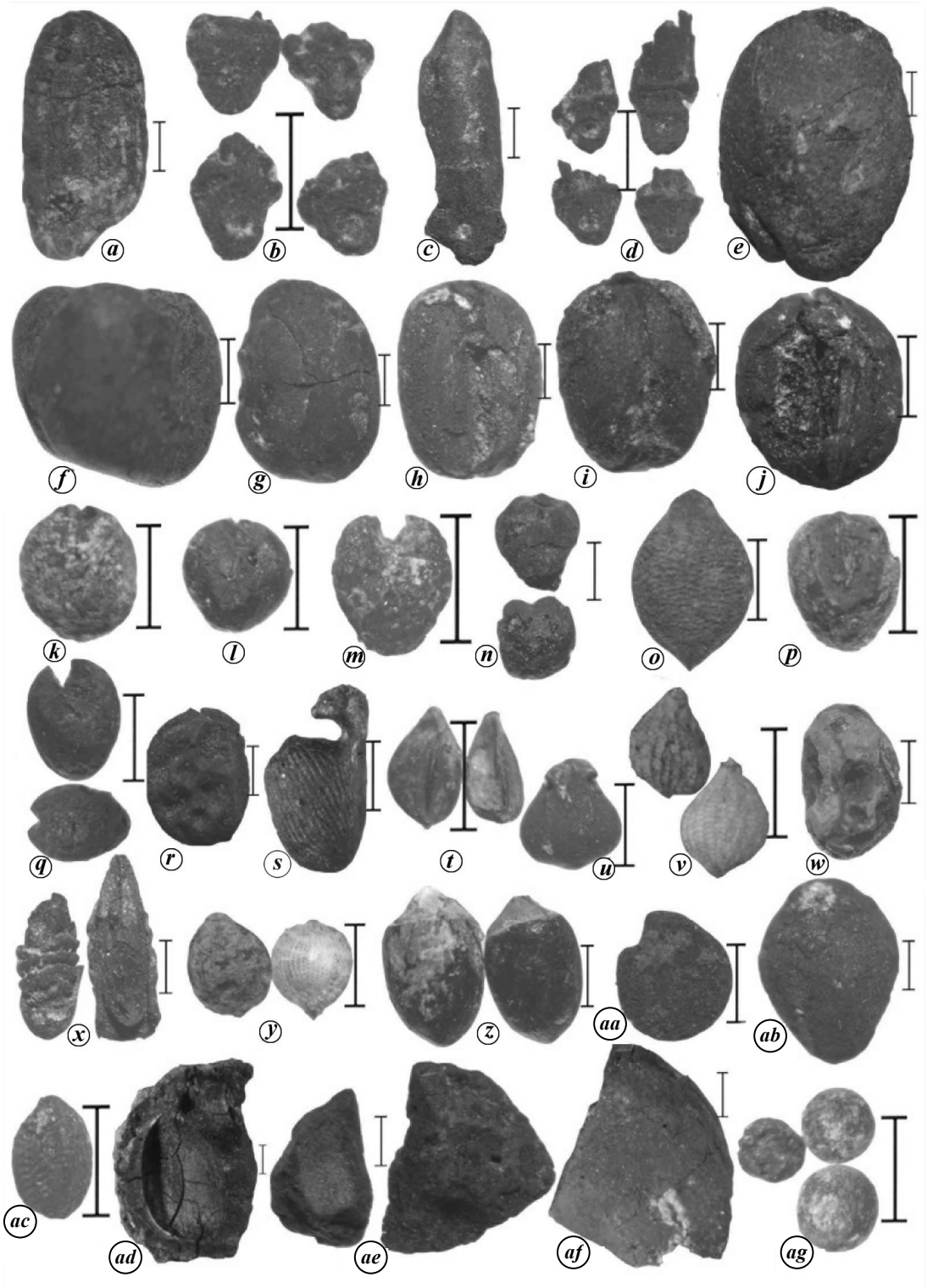

Figure 4. Archaeobotanical remains from Malli. ***a***, Rice (*Oryza sativa*); ***b***, Spiklet bases of cultivated rice (*O. sativa*); ***c***, Wild rice (*Oryza* cf. *rufipogon*); ***d***, Spiklet bases of wild rice; ***e***, Hyacinth bean (*Lablab purpureus*); ***f***, Grass pea (*Lathyrus sativus*); ***g***, Horse gram (*Macrotyloma uniflorum*); ***h***, Black gram (*Vigna mungo*); ***i***, Green gram (*Vigna radiata*); ***j***, *Vigna* sp.; ***k***, Mustard (*Brassica* sp.; ***l***, Browntop millet (*Brachiaria ramosa*); ***m***, Sawa millet (*Echinochloa* cf. *colona*); ***n***, Kodo millet (*Paspalum scrobiculatum*); ***o***, Italian millet (*Setaria italica*); ***p***, Foxtail millet (*Setaria* cf. *verticillata*); ***q***, *Setaria* sp.; ***r***, Dayflower (*Commelina* sp.); ***s***, Black musli (*Curculigo orchioides*); ***t***, *Cyperus* sp.; ***u***, *Ficus* sp.; ***v***, *Fimbristylis* sp.; ***w***, Narrow-leafed Indigo (*Indigofera* cf. *linifolia*); ***x***, Wrinkle grass (*Ischaemum rugosum*); ***y***, Spike sedge (*Elaeocharis* sp.); ***z***, *Scleria* sp.; ***aa***, *Solanum* sp.; ***ab***, *Bombax* sp.; ***ac***, Club-rush (*Scirpus* sp.); ***ad***, Indian jujube (*Ziziphus* sp.); ***ae***, ***af***, Unidentifiable nutshells; ***ag***, Fungal sclerotia (scale bar = 1 mm).

On the basis of morphological features, the nuts have been identified as *Cyperus* sp. L. (sedge).

Ficus sp. L. (fig seeds; Figure 4 *u*): One seed each (native to South Asia) from trenches A and B respectively, was recorded. Seeds had one end rounded and the other end narrow and slightly angular in cross-view. The surface of the seed was smooth. The seeds were somewhat flattened on the ventral side and bulged on the dorsal side. The morphological features were close to those of fig seeds (*Ficus* cf. *benghalensis* or *Ficus* cf. *religiosa*). They measured 1.42–1.46 mm × 1.27–1.34 mm ($L \times B$).

Fimbristylis sp. Vahl. (sedge; Figure 4 *v*): One hundred and fifty-five nutlets (native to South Asia) from trench A, one from trench B, and two from trench J were recovered. They were biconvex, orbicular to ovate in shape, stalked, and measured about 0.78–1.08 × 0.58–0.80 mm ($L \times B$). The characteristic feature of these nutlets was the presence of 7–8 longitudinal grooves and transversal lines with a round to truncate apex. This plant typically grows in wet environments and is mostly considered as a weed in paddy fields.

Indigofera cf. *linifolia* (narrow-leafed indigo; Figure 4 *w*): A single, ovoid to spheroid shaped seed (native to South Asia) from trench A, one from trench B, and two from trench J were recovered in carbonized state was recovered from trench A. It showed a more or less circular hilum, centrally located on one margin. The seed measured 2.23 mm × 1.37 mm (L × B).

Ischaemum rugosum Salisb. (wrinkle grass; Figure 4 *x*): One thousand two hundred and thirty-four grains (native to South Asia) from trench A, 15 from trench B, 116 from trench D, and five from trench J, in the form of intact grains and fragments, were recorded. The grains were oblong and transversely–rugosely ridged. The grains with glume-I of the sessile spikelets showed a transversely ridged structure. They measured 1.70–2.28 mm × 0.77–1.31 mm ($L \times B$).

Elaeocharis sp. Brongn. (spikerush; Figure 4 *y*): Eleven intact nuts and seven fragments (native to South Asia) from trench A, one from trench B, and 46 intact nuts from trench J were recorded. The nuts were ovoid and measured 1.12–1.48 × 0.94–1.10 ($L \times B$). A cap (tubercle) on the top indicates that it belongs to *Elaeocharis* sp.

Scleria sp. P.J. Bergius (nutrush; Figure 4 *z*): Seventeen seeds (native to South Asia) from trench A and two from trench B were recovered. The nuts were ovoid to globose with a pitted–reticulate surface and measured 2.52–2.68 mm × 1.62–1.88 mm ($L \times B$).

Solanum sp. L. (Figure 4 *aa*): Four complete carbonized seeds (native to South Asia), obovate or reniform in shape, were recorded from trench A. They measured 1.57–1.71 mm × 1.14–1.47 mm ($L \times B$).

Bombax sp. L. (Semal; Figure 4*ab*): Eight carbonized seeds (native to South Asia) from trench A and a single seed from trench B were recovered. The seeds were ovoid to almost globose in shape and smooth surfaced, measuring 3.90 mm × 3.20 mm ($L \times B$).

Scirpus sp. L. (bulrush; Figure 4 *ac*): Seven intact nuts (native to South Asia) from trench A were recorded. The nuts were ovate in outline and somewhat trigonous with a rugose surface, measuring 1.15 mm × 0.72 mm ($L \times B$). The style base on the top of the nut is similar to that of bulrush and distinguishes it from other members of the Cyperaceae.

Zizyphus sp. L. (Indian jujube; Figure 4 *ad*): Five fragments of fruit stones (native to South Asia) from trench A, a single fragment from trench B, and two from trench D were recovered. These were globose to somewhat oval and spherical fruit stones with a rough convulose surface of the endocarp. The broken stones exhibited a bicarpellate ovary. The fruit stones measured 7.11–7.24 mm in diameter.

Nutshell fragments (Figure 4 *ae*, *af*): Ninety-four fragments from trench A and three from trench B of unidentifiable carbonized nuts were recovered.

Fungal sclerotia (Figure 4 *ae–af*): Twenty-four globose fungal sclerotia were recovered from trench A. It was a compact mass of hardened *fungal* mycelium containing food reserves.

Statistical analysis

A total of 79 samples were collected and processed from trenches A, B, D and J, and mounds I and II. From the Early Iron Age habitational deposits examined in this study, 4174 charred plant macroremains representing 29 taxa were recovered and identified. These were in the form of carbonized grains/seeds of cultivated and uncultivated taxa, including 77 fragments of unidentifiable seeds and 64 fragments of indeterminate pulses. Thus, the plant economy during the Early Iron Age includes cereals (48%), millets (5%), pulses (3%), oil crops (<1%), fruits and nuts (3%), and wild and weedy taxa (41%; Figure 5 *a*). The only abundant cereal was rice (*Oryza sativa*) (96%), followed by wild rice (4%; Figure 5 *b*). Millets comprised sawa millet (*Echinochloa* cf. *colona*; 33%), foxtail millet (29%), Italian millet (13%), browntop millet and kodo millet (12% each) and foxtail millet (1%; Figure 5 *c*). Among the pulses, green gram was found in a significant proportion (48%) in comparison to horse gram (22%), *Vigna* sp. (23%), black gram (3%) and hyacinth bean and grass pea (2% each; Figure 5 *d*). The only oil crop identified was mustard (<1%) in the

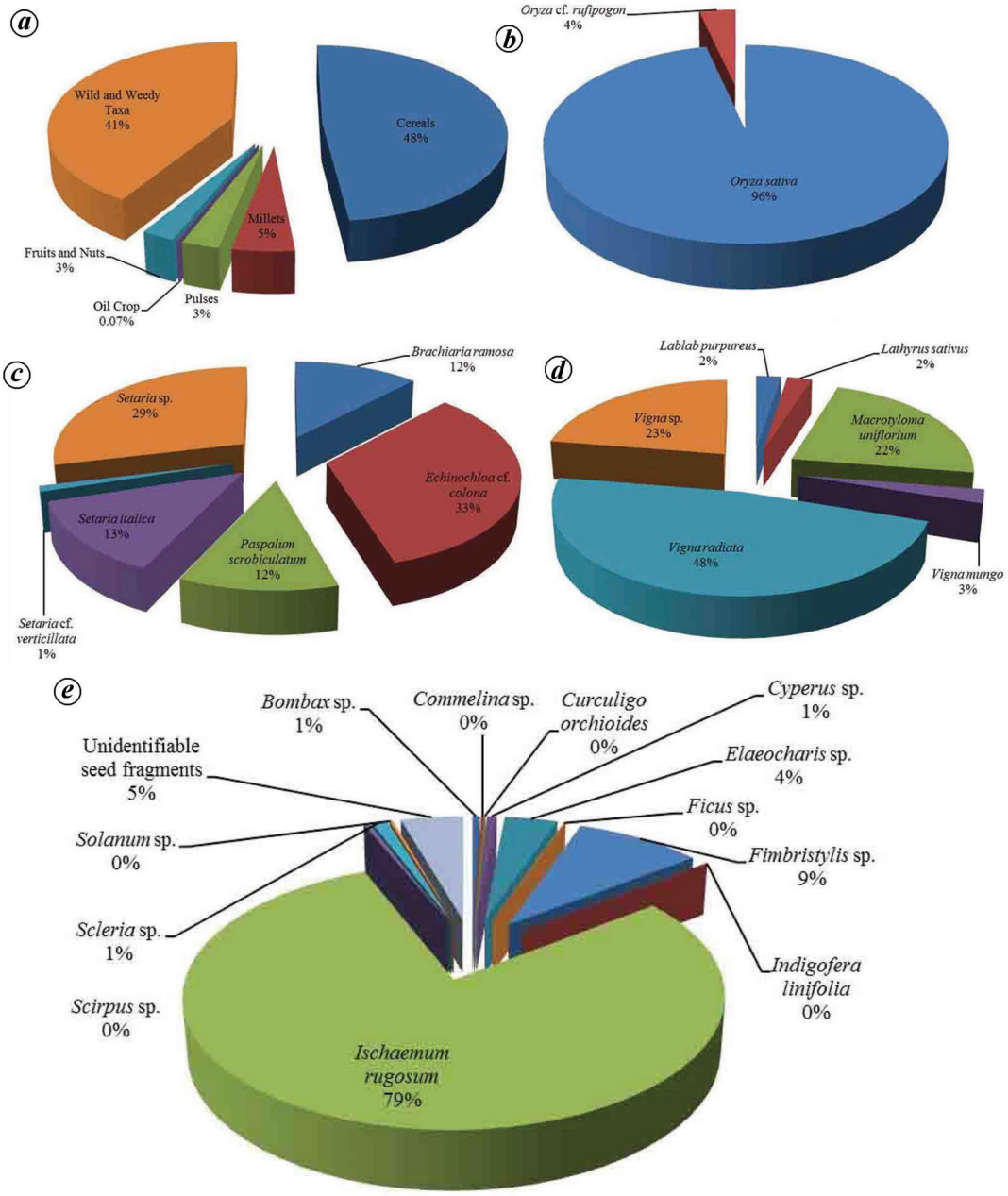

Figure 5. Average relative % of abundance of (***a***) plant remains, (***b***) cereals, (***c***) millets, (***d***) pulses and (***e***) wild and weedy taxa from Malli.

archaeobotanical assemblage. Furthermore, the fragments of fruit stones included nutshells (indeterminate) and Indian jujube (3%), which may be regarded as a collected food resource consumed by the ancient settlers. Remains of wild and weedy taxa comprised dayflower, black musli, *Cyperus* sp., *Ficus* sp., *Fimbristylis* sp., narrow-leafed Indigo, wrinkle grass (79% of the total assemblage of wild and weedy taxa), spike sedge, *Scleria* sp., *Solanum* sp., *Bombax* sp. and club-rush (Figure 5 *e*). Most of these taxa grow during the summer season in modern rice paddy fields. The higher percentage of wrinkle grass in the assemblage of wild and weedy taxa indicates its occurrence in moist tropical habitats, as it is found in swamps, paddy or flooded fields. It is a C_4 grass, can produce 400 seeds per plant, and is thus a serious weed in paddy fields[25–27]. Therefore, its occurrence at Malli sheds light on the prevalence of wet environmental conditions during the Early Iron Age.

Discussion

The archaeobotanical results presented here are from two different localities (mounds I and II) in the vicinity of Malli, which offer valuable insights into the well-developed agricultural system adopted by the site's inhabitants during the Early Iron Age. This fact is well-supported by the availability of a number of agricultural tools excavated at the site, e.g.

sickles, knives (Figure 3 *d–e*) and axes. The favourable climatic conditions may have facilitated the development of a rice agricultural system and laid the foundations for the subsequent long-term habitation at this site. The recovered archaeobotanical remains from Malli reveal that its inhabitants practised self-sufficient arable agriculture consisting dominantly of rice. Agriculture was the major activity since Chalcolithic times, as evident from the recovery of food grains from the neighbouring archaeological sites of Adam[23] and Tuljapur Garhi[24], likely characterized by crop rotation in the Vidarbha region[25–35].

The evidence for rice at Malli demonstrates that it was the only cereal cultivation practised during the Early Iron Age. This attests to the fact that rice was a major food resource cultivated in the summer season before crops from other regions were adopted in Vidarbha. Rice needs ample water to grow, and it is important to note that it became predominant during the Early Iron Age period. This archaeobotanical evidence for rice helps contextualize the spread of cultivated rice across other parts of India[36–40].

The small-grained millets are represented by indigenous browntop millet, sawa millet, kodo millet, Italian millet and foxtail millet encountered in the Early Iron Age deposits. These millets were grown with paddy in a wet environment[41–44].

The pulse crops were represented by hyacinth bean, grass pea, horse gram, black gram, green gram, grains of *Vigna* sp. and 64 unidentifiable pulse fragments, thus indicating their occurrence in the summer season. These pulses were also found at other contemporary sites in parts of Vidarbha such as Adam, Kaundinyapur, Mahurjhari and Naikund. The oilseeds of mustard were recorded in the cultural phase at Malli. It has also been reported from other sites in Vidarbha. The cultivation of mustard goes back to the Harappan times[44–46].

The fruit-stone fragments of Indian jujube indicate that the inhabitants might have eaten wild Indian jujube, consuming flesh pulp while the stones were spitted out randomly, growing as jujube shrubs at and around the site. The other unidentifiable nuts attest to their availability locally in the wild state. The remains of wild and weedy taxa encountered at the site comprised 41% of the total archaeobotanical assemblage. It comprised seeds of dayflower, *Cyperus* sp., *Elaeocharis*, *Scirpus* sp., *Scleretia* sp., *Fimbristylis* sp., *Solanum* sp., wrinkle grass and narrow-leafed indigo, while the tree species included cotton tree/semal (*Bombax* sp.) and banyan/pipal tree (*Ficus* sp.). Among these, wrinkle grass was the most dominant (79%) compared to other wild elements. These plants occur frequently around settlements and in crop fields, grasslands, moist and wet places along ditches, ponds and streams. They are important for acquiring information about the ground vegetation, the state of agricultural fields, and the fallow and grassland in the vicinity of the site. Since black musli was found at Malli, it is possible that it was used as a medicine during the Early Iron Age.

Conclusion

The archaeobotanical dataset from the habitational deposits at Malli dates back to the Early Iron Age and shows that the inhabitants were cultivating and consuming more rice than millets, pulses, oilseeds and other crop plants. The summer crops such as rice, millets, black gram, green gram and horse gram were predominantly cultivated by the inhabitants at Malli. Rice cultivation has been further confirmed and well-supported by the occurrence of typical wild and weedy taxa that grow in paddy fields, indicating that possibly wet environmental conditions prevailed during that time in the region. Thus, the present archaeobotanical dataset provides information on the seasonal agricultural system and crop selection facilitated by favourable environmental conditions that prevailed during the Early Iron Age at the archaeological site of Malli.

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