Palaeoethnobotany at Lahuradewa: a contribution to the 2nd millennium BC agriculture of the Ganga Plain, India

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Carbonized remains from archaeological sites can provide clues that are crucial for understanding and characterizing subsistence strategies during Dark Ages. Analysis of floated samples collected from the archaeological site at Lahuradewa, in the Ganga Plain, has provided data which can be useful in understanding the exploitation of economically important plants by the ancient settlers as dietary preferences during ca. 2000–1500 BC. The crop remains encountered are represented by the grains and seeds of rice, barley, species of wheat, jowar-millet, kodon-millet, chickpea, lentil, fieldpea, grasspea, horsegram, greengram, cowpea, fenugreek, linseed, sesame, Indian mustard and cotton. In addition, there is evidence for fruits of jujube, anwala and phalsa which may have been gathered by the ancient settlers for consumption. This communication also includes an account of some weeds and other wild taxa, which turned up as an admixture with the above economically important remains and are denotative of the surrounding ground vegetation.

Keywords: Agriculture, chalcolithic, palaeoethnobotany, subsistence economy.

THE mound of Lahuradewa (lat. 26°46′N; long. 82°57′E) is located at a distance of about 5 km south of the Bhujaini Railway Crossing, on the Basti–Gorakhpur road (NH 28) in Sant Kabir Nagar District, Uttar Pradesh[1] (Figure 1). The unique mound is surrounded by Holocene Lake from three sides (Figure 2). At present, the surrounding area of the lake as well as archaeological site is influenced by intense agricultural activity and human habitation. In order to unveil the archaeological wealth at this site, excavations were carried out by Uttar Pradesh State Archaeology Department, Lucknow, during 2001–02 (ref. 2), 2002–03, 2003–04 and 2005–06 (ref. 3). The excavations at the site have brought out significant information about the cultural history[2,3]. The recovered artefacts/potsherds have revealed fivefold culture sequence since 6th–5th millennium BC to about early centuries of the Christian era BC/AD as Early Farming Phase (Period I); Developed Farming Phase (Period II); Advanced Farming/Early Iron Age (Period III); NBPW Phase (Period IV) and Early Historic (Period V).

Period I commences sedentary occupation at the site, which was divided into two sub-periods, viz. IA and IB. Sub-period IA was characterized by the presence of a coarse variety of handmade red ware and black-and-red ware industry often displaying cord-impressions on the exterior surface. A few sherds also exhibit decoration by incised patterns and fine red slip. The charcoal pieces retrieved from the lowermost deposit have been dated to 5320 ± 90 yrs BP [4158 BC (BS-1951)] and 6290 ± 140 yrs BP [5298 BC (BS-1967)]. Considerably startling has been the AMS radiocarbon determination of a glume-piece of domesticated rice, irrefutably propelling the age of the fully domesticated *Oryza sativa* to 6409 BC (cal. yrs BP 8360), several centuries earlier to what would have been assumed on the dates of the associated charcoal (Table 1). Sub-period IB encompassing 45-cm thick occupation deposit dated to 4170 ± 180 yrs BP (cal. 2700 BC), is marked by the appearance of some new pottery such as beaker, perforated vessel and dish/or bowl-on-stand. The quality of potteries showed improvement over Sub-period IA.

Period II succession beginning from 3710 ± 90 yrs BP (ca. 2116 BC) was characterized by the presence of copper artefacts. In continuation of ceramic industries of Period I, this period was marked by the appearance of plain and painted black slipped and black-red-wares. The proportion of spouted and lipped-vessel, bowl/dish-on-stand, pedestalled-bowl, disc-based bowl increased many fold. Earthen storage bins, baked terracotta tiles, legs of some terracotta objects, steatite beads, socketed and tanged bone or antler arrowheads with ravishing micro encircled decorations, etc. indicate considerable spurt in material prosperity.

Period III dated to 2940 ± 100 yrs BP (BC 1182) was marked by the appearance of highly rusted iron artefacts. The occupation deposit comprised all types of the ceramic industries of the earlier period. The important iron objects included sickles (?). Earthen floors, hearths, burn clay lumps with reed and straw impressions indicated the continuation of earlier structural tradition. The period IV encompassing 1.20 m thick deposit is characterized by well-known NBPW occupation. Presence of iron slag was noted. Some structures, viz. a brick paved well and remnants of some ground plan of a brick structure comprising a few rooms and typical sherds in red ware known from the deposits of early centuries BC/AD were represented in the deposits of Period V.

The chronology of Lahuradewa archaeological site is based on six radiocarbon dates of wood charcoal and two AMS dates of grain samples, as given in Table 1.

The retrieval of botanical material from the settlement area, to reconstruct the model of agriculture in this region, during the Chalcolithic phase, was carried out by sieving the soil of deposits in water medium (floatation technique), utilizing differences in density of organic and inorganic materials to achieve separation of organic

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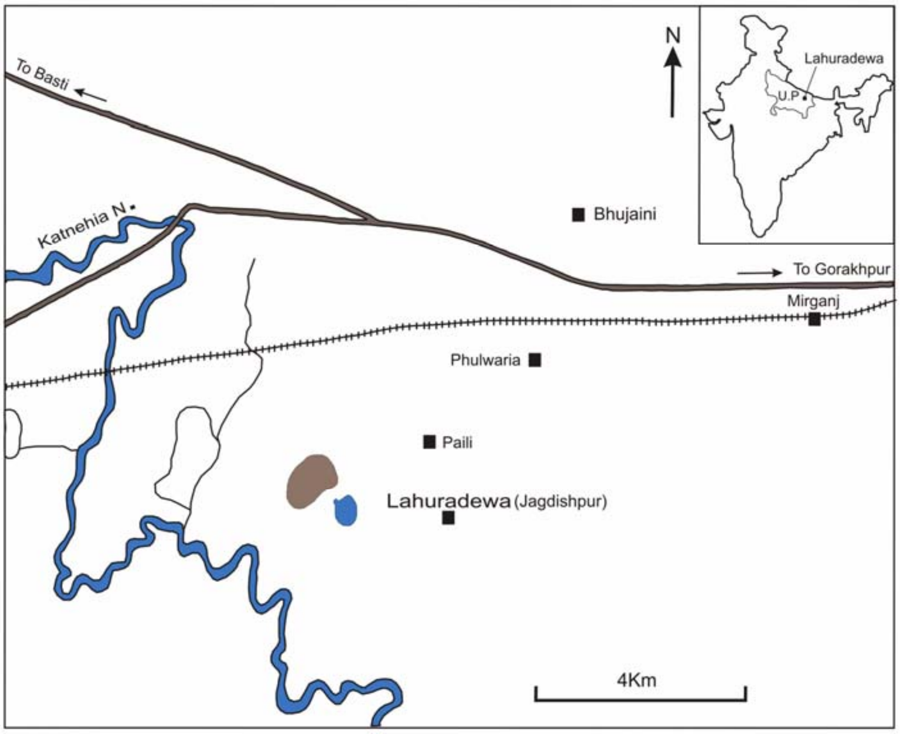

Figure 1. Location map of Lahuradewa area showing Lahuradewa archaeological site and adjoining Lahuradewa Lake (modified after Saxena *et al.*[5]).

Figure 2. General view of the Lahuradewa mound in the foreground and lake in the background.

remains from the soil matrix, which greatly enhanced both the quantity and range of botanical materials. Charred grains, seeds and fruits have been found mixed with wood charcoal pieces. Seeds/fruits and wood charcoal were separated, and seeds/fruits were further examined and sorted into categories of distinctive morphological types. These morphotypes were compared with modern reference material. The material presented here is from the Chalcolithic phase (Period II), in continuation with earlier studies from the Neolithic phase[4] and discussed in the context of different archaeological sites studied so far in this region.

The morphological description of the identified grains/seeds recovered from Chalcolithic sequence and their measurements and index values (Table 2) are given below.

Oryza sativa L. (rice, Figure 3 *a* and *d*): Caryopses complete or broken have been recorded. Grains are without husk. However, in some grains rachis with small portion of husk is attached. Grains are elongate to narrowly oblong, laterally flattened and prominently ribbed. Morphologically, they compare with the grains of cultivated form of rice (*O. sativa*). However, bold grains of some perennial and annual species of wild and weedy rice also look more or less similar; the definite identification of *O. sativa* on the basis of grains without husk may be doubtful.

Pottery and burnt pieces of mud-clods with rice-husk impressions were broken up to study characteristic ‘chess-board’ pattern. The granules appeared somewhat cubicular in shape and showed sharp alignment in anastamozing and horizontal wavy rows similar to cultivated forms of extant *O. sativa*. Further, the remains presented here are from the Chalcolithic phase. By this time the agriculture was well established. The phytolith evidence also indicates that the wild rice phytoliths start diminishing, whereas that of cultivated rice phytoliths became more abundant[5]. Therefore, the rice remains have been identified as of *O. sativa* type.

Table 1. Lahuradewa ^{14}C chronology (modified after Tewari *et al.*[3])

Period III. Continuity of earlier cultural assemblage	Trench: ZK1, Qdt.3 Layer: 6 Depth: 1.10–1.20 m	BS-1939. Radiocarbon Age 2940 ± 100 yrs BP Cal. BP 3317 (3133) 2949 yrs Cal BC 1367 (1183) 999
Period II. Advanced farming phase with copper. Painted and plain BSW, BRW, steatite beads, greater presence of dish-on-stand, bowl-on-stand, pedestalled bowl.	Trench: YA2, Qdt.1 Layer: 6 Depth: 2.95–3.15 m	BS-1938. Radiocarbon Age 3180 yrs BP Cal. BP 3469 (3384) 3349 yrs Cal. BC 1519 (1435) 1399
	Trench: YA2, Qdt.4 Layer: 10 Depth: 2.60–2.70 m	BS-2150. Radiocarbon Age 3550 ± 80 yrs BP Cal. BP 3833 yrs Cal. BC 2012 (1884) 1750
	Trench: YA2, Qdt.4 Layer: 11 Depth: 2.90–3.00 m	BS 1950. Radiocarbon Age 3710 ± 90 yrs BP Cal. BP 4221 (4066) 3911 yrs Cal. BC 2271 (2116) 1961
Period IB. Early farming phase without copper. RW and BRW often bearing cord impressed patterns, slipped pottery, pedestalled bowl.	Trench: YA3, Qdt.2 Layer: 14 Depth: 3.00–3.10 m	BS-2274. Radiocarbon Age 4170 ± 180 yrs BP Cal. BP 4869 (4646) 4423 yrs Cal. BC 2919 (2700) 2570 ERL. 6903. AMS Date of Barley: 2345 (2273) 2200 BC
	Trench: YA1, Qdt.1 Layer: 13 Depth: 3.25–3.35 m	BS-2145. Radiocarbon Age 4330 ± 110 yrs BP Cal. 5040 (4865) 4829 BP Cal. BC 3090 (2916) 2879
Period IA. Early farming phase without copper. RW and BRW often bearing corded patterns.	Trench: YA1, Qdt.1 Layer: 14 Depth: 3.30–3.40 m	BS-2148. Radiocarbon Age 4500 ± 100 yrs BP Cal. BP 5313 (5141) 4970 Cal. BC 3363 (3191) 3032
	Trench: ZK1, Qdt.3 Depth: 2.20–2.30 m	BS-2151. Radiocarbon Age 4790 ± 90 yrs BP Cal. BP 5604 (5468) 5332 Cal. BC 3654 (3518) 3382
	Trench: YA2, Qdt.4 Layer: 12 Depth: 3.00–3.15 m	BS-1951. Radiocarbon Age 5320 ± 90 yrs BP Cal. 6270 (6105) 5947 BP Cal. BC 4220 (4158) 3997 ERL. 6904. AMS Date of Rice-husk: 6442 (6409) 6376 BC
	Trench: YA1, Qdt.1 Layer: 11 Depth: 3.00–3.10 m	BS-1967. Radiocarbon Age 6290 ± 140 yrs BP Cal. BP 7414 (7247) 7009 Cal. BC 5464 (5298) 5059

BSW, Black slipped ware; BRW, Black and red ware; RW, Red ware.

Hordeum vulgare L. emend. Bowden (six-rowed hulled barley, Figure 3 *b*): Elongated grains, tapering towards the apex and with a wide ventral furrow have been encountered. Some of the grains are partly asymmetrical or show slight ventro-lateral twist. Hence, barley grains are identified as the six-rowed hulled types.

Triticum L. (wheat, Figure 3 *c*, *e* and *f*): On macroscopic examination, the grains turned out to be of three types, showing differences in shape and size. Grains are short, broad, oval–round, elongate and relatively narrower towards both the ends. Few grains exhibit a hump-like circular area raised on their dorsal side. The grains that are narrower towards both the end and thicker in the middle (Figure 3 *c*) resemble those of bread-wheat (*Triticum aestivum* L. emend. Thell). The short, broad and more or less rounded grains (Figure 3 *f*), compare in all morphological features with caryopses of dwarf-wheat (*Triticum sphaerococcum* Perc.).

In the mixture, three more elongated caryopses (Figure 3 *e*), different from those of barley with dorsal side curved and ventral side broad, deeply furrowed and flat, resemble tetraploid wheat, which may have come as an admixture with the cultivated hexaploid wheats.

Sorghum bicolor (L.) Moench. (jowar-millet, Figure 3 *h*): Only three carbonized grains, obovate and dorso-ventrally symmetrical have been encountered from Lahuradewa. Oval–round hilum scar attains almost half the length of the grain. Grains are comparable with those of jowar-millet. Linguistic and genetic studies place the origin of *Sorghum* cultivation at Eastern Africa[6,7]. It is planted as a rabi crop at the end of monsoon. It ranks third among cereals in economic importance after wheat and rice. *Sorghum* was grown by early farming communities in the region of the Middle Ganga Plain since Neolithic times (2200–1950 BC)[8].

Paspalum scrobiculatum L. (kodon-millet, Figure 3 *i*): Two spikelets, ovoid, concavo-convex, with rotund ends have been recorded. Surface is finely striate and granular.

Figure 3. ***a***, *Oryza sativa* (rice); ***b***, *Hordeum vulgare* (barley); ***c***, *Triticum aestivum* (bread-wheat); ***d***, *Oryza sativa* with rachis; ***e***, *Triticum* sp. (emmer-wheat); ***f***, *Triticum sphaerococcum* (dwarf-wheat); ***g***, *Lens culinaris* (lentil); ***h***, *Sorghum bicolor* (jowar-millet); ***i***, *Paspalum* sp.; ***j***, *Cicer arietinum* (chick-pea); ***k***, *Vigna unguiculata* (cowpea); ***l***, *Linum usitatissimum* (linseed); ***m***, *Pisum arvense* (fieldpea); ***n***, *Lathyrus sativus* (grass-pea); ***o***, *Vigna radiata* (green gram); ***p***, Cotyledons of green gram; ***q***, *Macrotyloma uniflorum* (horse gram); ***r***, *Trigonella foenum-graecum* (fenugreek); ***s***, *Sesamum indicum* (sesame); ***t***, *Brassica juncea* (Indian mustard); ***u***, *Gossypium arboreum/herbaceum* (cotton).

In appearance spikelets are comparable to those of kodon-millet.

Cicer arietinum L. (chick-pea, Figure 3 *j*): Three complete seeds are squat and somewhat triangular in shape, pointed at one end, and broad and lobed on the other. The seed coat is rough-textured and undulating. The exact position of the hilum could not be seen due to carbonization. The chalazal plate on the ventral side is noticeably broad. Seeds are comparable to those of chickpea (*C. arietinum* L.).

Lens culinaris Medikus (lentil, Figure 3 *g*): Leguminous seeds, almost circular and flattened with keeled margins

Table 2. Measurement and index values of plant remains from Lahuradewa

Taxon	*n*	*nm*	*L* (mm)	*B* (mm)	*T* (mm)	L : B	L : T	B : T
Oryza sativa	1650	50	3.75 (3.40–4.10)	1.91 (1.77–2.05)	1.40 (1.30–1.50)	1.96	2.67	1.36
Hordeum vulgare	280	30	3.95 (3.40–4.50)	2.42 (2.15–2.70)	1.85 (1.70–2.00)	1.63	2.13	1.30
Triticum aestivum	54	20	3.87 (3.60–4.14)	2.50 (2.16–2.84)	2.20 (2.00–2.40)	1.55	1.76	1.14
Triticum sphaerococcum	20	10	2.55 (2.26–2.85)	2.17 (1.90–2.45)	2.10 (2.00–2.20)	1.17	1.21	1.03
Sorghum bicolor	3	2	2.23 (2.22–2.25)	2.18 (2.02–2.35)	1.90 (1.80–2.00)	1.02	1.17	1.15
Paspalum scrobiculatum	2	1	1.99	1.29	1.00	1.54	1.99	1.29
Cicer arietinum	3	2	2.94 (2.76–3.12)	2.87 (2.77–2.97)	2.56 (2.50–2.62)	1.02	1.15	1.21
Lens culinaris	57	20	2.25 (2.10–2.40)	2.07 (1.95–2.20)	1.75 (1.50–2.00)	1.09	1.28	1.18
Pisum arvense	48	10	2.64–2.80 mm in diameter					
Lathyrus sativus	15	5	2.99 (2.73–3.26)	2.92 (2.59–3.26)	2.50 (2.00–3.00)	1.02	1.19	1.17
Macrotyloma uniflorum	30	7	3.64 (3.23–4.05)	2.28 (2.03–2.53)	1.30 (1.20–1.40)	1.59	2.80	1.75
Vigna radiata	38	10	2.73 (2.41–3.06)	1.85 (1.70–2.00)	1.90 (1.80–2.00)	1.47	1.44	0.97
Vigna radiata (cotyledon)	2790	50	2.78 (2.46–3.10)	1.79 (1.64–1.95)	0.95 (0.90–1.00)	1.55	2.93	1.88
Trigonella foenum-graecum	20	10	2.89 (2.46–3.32)	1.93 (1.65–2.22)	1.50 (1.20–1.80)	1.50	1.93	1.29
Linum usitatissimum	1	1	2.83	1.32	1.10	2.14	2.57	1.20
Sesamum indicum	1	1	2.45	1.66	1.00	1.47	2.45	1.66
Brassica cf. *juncea*	4	4	0.90–1.00 mm in diameter					
Gossypium arboreum/herbaceum	1	1	4.13	3.00	3.00	1.38	1.38	1.00
Ziziphus sp.	1	1	11.00	9.00		1.22		
Grewia sp.	1	1	3.67	3.14	3.00	1.17	1.22	1.05
Emblica officinalis	2	2	7.62 (6.86–8.38)	3.91 (3.28–4.55)	1.57 (1.50–1.65)	1.95	4.85	2.50

n, Number of grains/seeds/fruits; *nm*, Number of grains/seeds/fruits measured. L, Length; B, Breadth; T, Thickness.

and appear lenticular in shape. Hilum is very small and lanceolate. In shape and size, the carbonized seeds are comparable to those of *L. culinaris*.

Pisum arvense L., syn. *P. sativum* var. *arvense* (L.) Poir (field-pea, Figure 3 *m*): Seeds are spherical to hemispherical in shape. Chalaza is indicated about 1.50–1.80 mm in breadth, from small hilum flushed with the seed surface. Seeds are comparable to those of *P. arvense*.

Lathyrus sativus L. (grass pea, Figure 3 *n*): Seeds wedge-shaped and end planes somewhat triangular. Small and oval hilum is located in one of the wider angles on one end. Seed coat is rough-textured. These seeds compare with those of grass pea.

Macrotyloma uniflorum (Lam.) Verdc. (horse gram, Figure 3 *q*): The lot is represented by complete and broken, ellipsoidal to more or less kidney-shaped, laterally flattened seeds and cotyledons. Seed surface is smooth. Hilum is small and elliptical, about 1.00 mm long and 0.50 mm broad. The seeds are comparable to those of horse gram.

Vigna radiata (L.) R. Wilczek (green gram, Figure 3 *o* and *p*): Seeds are almost cylindrical, with rounded to angular ends. Elliptical hilum is about 1.00 mm long and evenly flat on the surface of the seed coat. Large number of cotyledons have also been recorded in the collection.

Vigna cf. *unguiculata* (L.) Walp. (cowpea, Figure 3 *k*): Leguminous seed partly broken at the midway resembles in morphological features with the seed of *V. unguiculata* L.

Trigonella foenum-graecum L. (fenugreek, Figure 3 *r*): Twenty seeds, somewhat oblong with a deep groove between the radicle and the cotyledon in the collection, have been identified as *Trigonella* cf. *foenum-graecum*. It is an annual herb indigenous to the countries bordering on the eastern shores of the Mediterranean[9] and also occurs in wild state in the areas of Kashmir and Punjab of the Indo-Pakistan region, and also in the upper Gangetic Plain[10]. Earlier evidence of fenugreek in Early and Mature Harappan phases has come out at Kunal and Banawali in Haryana, and Rohira in Punjab[11–13].

Linum usitatissimum L. (linseed/alsi, Figure 3 *l*): Single, flattish, elliptic to elliptic–ovate seed with one end much narrower. The seed is comparable to linseed and, therefore, identified as such. Linseed belongs to Near-Eastern group of crops, where evidences of its cultivation go back as far as to those of barley and wheat[14].

Sesamum indicum L. (sesame/til, Figure 3 *s*): Single, somewhat flattish–ovate seed, having one end rounded and the other broken, resembles *S. indicum*. The seed coat surface appears to be smooth. Recent evidences from Miri Qalat, Baluchistan, Pakistan, and north-western India (Harappan region and Rajasthan) suggest cultivation of sesame was more widespread in the subcontinent by the second half of the 3rd millennium BC[12,15–17]. The carbonized sesame seeds with smooth surface have, therefore, been regarded to be of the cultivated sesame.

Brassica cf. *juncea* (L.) Czern and Coss. (Indian mustard, Figure 3 *t*): Four seeds, exhibiting six-sided polygonal

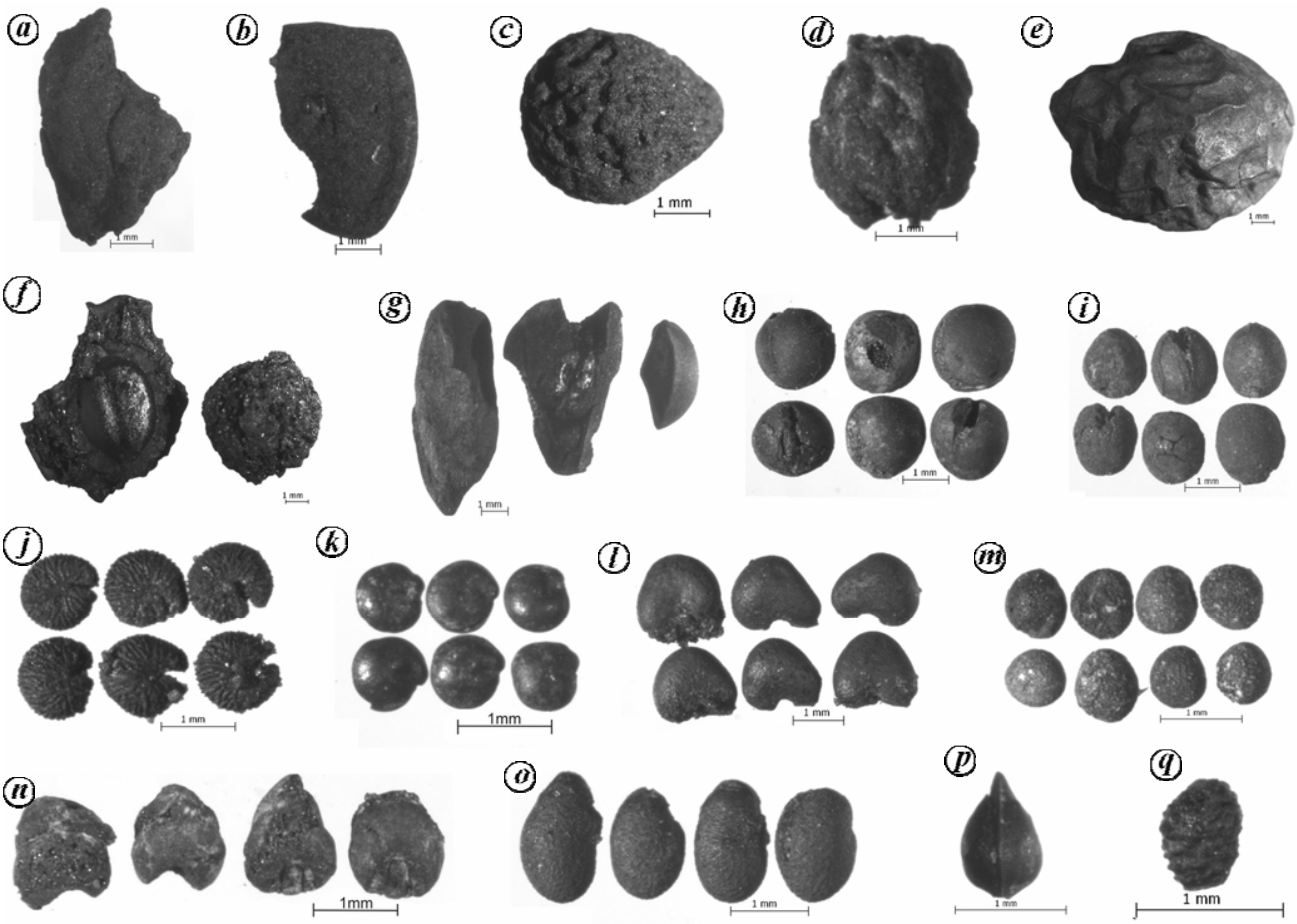

Figure 4. ***a***, *Luffa* sp.; ***b***, *Carissa* sp.; ***c***, *Grewia* sp.; ***d***, *Ziziphus* cf. *oenoplia*; ***e***, *Ziziphus nummularia*; ***f***, *Ziziphus* stones and seeds; ***g***, *Emblica officinalis* endocarp and seed; ***h***, *Vicia sativa*; ***i***, *Vicia* cf. *hirsuta*; ***j***, *Cleome* sp.; ***k***, *Chenopodium album*; ***l***, *Abutilon* sp.; ***m***, *Oldenlandia* sp.; ***n***, *Setaria* cf. *glauca*; ***o***, *Medicago* sp.; ***p***, *Rumex dentatus* and ***q***, *Dactyloctenium aegyptium*.

areas forming a characteristic reticulum on the surface were identified. Seeds were compared with similarly looking seeds of *Brassica oleracea* L., *B. rapa* L., *B. napus* L., *B. juncea* (L.) Czern and Coss, *B. nigra* Koch and cultigens of *Brassica campestris*. *B. oleracea* and *B. napus* have no polygonal reticulations. Seed samples from this site having strictly six-sided reticulations may belong to either of these two forms. The cultivation of *B. juncea* goes back to Harappan times[18]. Therefore, the ancient *Brassica* seeds from Lahuradewa have tentatively been referred to *Brassica* cf. *juncea*.

Gossypium arboreum/herbaceum (cotton, Figure 3 *u*): Single complete seed having one end rounded and the other end narrow and slightly angular in cross-view has been recorded in the collection. Seed surface is ragged as a result of the distortion of the seed coat. Ventral side of the seeds is somewhat flattened and the dorsal side shows bulging. In all morphological features, the seed compares with that of cotton. The archaeobotanical records from Mehrgarh (6000–4500 BC), Mohenjodara (2600–2000 BC), Balakot (2500–2000 BC), Harappa (2600–1900 BC), Kunal (2500–2000 BC), Banawali (2200–1900 BC), Kanmer (2500–1700 BC), Sanghol (1900–1400 BC) and Hulas (1800–1300 BC) attest its importance in the early development of textile production in the sub-continent[7,12,19–27]. Cotton was also grown by early farming communities in the region of the Middle Ganga Plain[11,28]. The genus comprises about 30 tropical and subtropical species in the Old World. *G. herbaceum*-race *africanum*, distributed in the savanna vegetation of South Africa, was probably first cultivated in Arabia and Syria before finding its way to the Indian subcontinent, where *G. arboreum* had differentiated under cultivation in northwestern India and Pakistan[29,30].

Luffa sp. (tori, Figure 4 *a*): Fragment of a cucurbit seed with irregular surface and two oblique tubercles is comparable to *Luffa* sp.

Carissa sp. (karaunda, Figure 4 *b*): Single, ovate, compressed seed, measuring 7.00 mm × 5.00 mm (*L* × *B*) is comparable to *Carissa*, which is a spinous and evergreen shrub found throughout India in the dry regions.

Grewia sp. (phalsa, Figure 4 *c*): Single, circular to somewhat oval round and plano-convex stone has been encountered with the crop remains. Outer convex side is roughened with coarse tuberculations. There are several species of *Grewia* growing wild and also cultivated for their fruits. The specific identification of the seed is not possible in carbonized state; so it has been identified as *Grewia* sp.

Ziziphus sp. (jharberi/jujube, Figure 4 *d–f*): Globose or somewhat oval stones and the spherical fruits in carbonized state, with characteristic tubercled surface have been recorded in the collection. These stones and fruits have been found comparable to those of *Ziziphus nummularia* (Burm. f.) W.&A. However, single stone somewhat obovoid measuring 3.00 mm × 2.60 mm ($L \times B$), compares closely with *Ziziphus oenoplia* (L.) Mill.

Emblica officinalis Gaertn. (emblic, anwala, Figure 4 *g*): Woody endocarp pieces with trigonous seed have been recorded in the collection. Endocarp pieces show locules in the form of depressions on their inner faces.

Vicia sativa L. (common vetch, Figure 4 *h*): Seeds varying in diameter from 1.50 to 2.50 mm are globular to somewhat cubicular in shape. A few seeds have also developed cracks. Ovate to wedge-shaped hilum is raised along the median groove. These seeds compare with *V. sativa*, a common leguminous weed in the winter crop fields.

Vicia hirsuta (L.) S.F. Gray (tiny vetch, Figure 4 *i*): Mixed in the collection of *Vicia sativa* seeds, some seeds are smaller in size. They measure 1.20–1.40 mm in diameter. Hilum is linear, against ovate hilum of *V. sativa*. These smaller seeds may be referred to as *V. hirsuta*.

Cleome cf. *gynandra* L. (spiderflower, Figure 4 *j*): Reniform seeds, compressed and tubercled, measuring 1.30–1.50 mm in diameter show close resemblance with those of *C. gynandra*, a weed of waste lands and cultivated field. Seeds are smooth in *C. viscosa* and *C. brachycarpa*. Therefore, the ancient tubercled seeds from Lahuradewa have been identified as *C. gynandra*.

Chenopodium album L. (goosefoot, Figure 4 *k*): Seeds circular and compressed–lenticular having rounded margins and a distinctive marginal notch, measuring about 1.80 mm in diameter, are comparable to those of *C. album*.

Abutilon sp. (kanghii, Figure 4 *l*): Reniform seeds with one end ascending and the other end descending have been encountered. Seeds measure 2.00–2.50 mm × 1.50–2.00 mm ($L \times B$). Surface is faintly tubercled. Seeds resemble to that of *Abutilon* sp.

Oldenlandia sp. (Figure 4 *m*): Seeds angled to almost round with pitted surface, measure 0.50–0.80 mm × 0.50–0.85 mm ($L \times B$). For morphological features, the seeds may be referred to some species of *Oldenlandia*.

Setaria cf. *glauca* (L.) P. Beauv. (foxtail-grass, Figure 4 *n*): Grains, ovoid to slightly oblong with narrow upper end, dorsal side are curved. Hilum conspicuously broad and occasionally covers up to half the length of the grains. The grains are comparable to those of *Setaria* cf. *glauca*.

Medicago sp. *indica* All. (clover, Figure 4 *o*): Compressed, oval seeds with hilum in a shallow indentation on one side above the middle part, measure 1.30–1.80 mm × 1.00–1.20 mm ($L \times B$). *M. alba* and *M. parviflora* have smooth surface. The carbonized seeds have roughened surface by minute tubercles, which is the characteristic feature of *M. indica*.

Rumex dentatus L. (dock-weed, Figure 4 *p*): Single, triangular nut with pointed upper end and smooth surface measures 1.50 × 1.20 mm ($L \times B$) and closely resembles the nut of *R. dentatus* of polygonaceae.

Dactyloctenium aegyptium (L.) P. Beauv. (crowfoot grass, Figure 4 *q*): Single, ovoid caryopsis with rugose surface, measuring about 1.00 mm in size, has been encountered. The carbonized grain on morphological grounds, compares closely with that of *D. aegyptium*.

The gradually growing database on crop remains from excavations in the Ganga Plain during past decades has securely established that in addition to the indigenous crops such as rice and millets, a continuous and substantial expansion of subsistence resources of the Mediterranean, Central Asian, African and Eurasian has made generous dynamism in the economy of the early farming communities[31]. The archaeobotanical remains presented and discussed here are from the Chalcolithic phase (Period-II) in continuation to an earlier study of Neolithic occupation[4]. The Chalcolithic cultures, distinguished by the use of copper, were spread in a broad time range from about 2200 to 800 BC. They are either partly contemporaneous or later than the Indus Civilization. Their basic economy was based on farming and animal husbandry, stock-raising, hunting and fishing[32].

Excavations at Lahuradewa have brought to light ceramics of coarse variety of handmade red ware and black-and-red ware often displaying cord-impressions on the exterior surface, black and grey ware, and rice–millet domestication/cultivation to an early post-glacial time (early Holocene), during 6th–5th millennium BC[2–4,31,33]. The Neolithic or non-metallic phase of occupation on a lake edge marked as far back in Early Holocene and spanned for several thousand of years up to around 2000 BC, and was further succeeded by a Chalcolithic and phases of early historical cultures. The preliminary studies of Neolithic occupation in the bottom layers of two trenches revealed scant remains of domesticated rice (*O. sativa*), wild rice (*O. rufipogon*) and grains of foxtail-millet (*Setaria* sp.) during the first season of excavations[4]. The associated charcoal in these layers dated to 6th–5th millennia BC. Dating of glume-piece of domesticated rice by AMS method (University of Erlangen-Nuremberg, Germany) has affirmed the antiquity of domesticated rice to cal. BC 6409 (Table 1). This directly dated rice-glume from Lahuradewa settlement has provided ample ground to surmise that the idea of domestication and cultivation was perceived prior to the initiation of sedentary occupation, during the Early Holocene. Significant evidence of wild rice phytoliths from a depth of 2.70 m of the adjacent lake profile dated to about 10,300 ca. yrs BP has been recorded. The cultivated rice phytoliths make their appearance at about 2.40 m depth, dated to about 8300 cal. yrs BP[5]. Further, evidence of anthropogenic activity in the area is also available in the form of Cheno/Ams pollen grains since 7822 cal. yrs BP and cerealia pollens since 7500 cal. yrs BP[34].

The sign of economic change in the agriculture and dietary habits of Neolithic settlers becomes noticeable in the upper level dated to 4170 ± 180 yrs BP (cal. 2700 BC), by the appearance of barley, a crop of Harappan zone. From this level onward, subsequent additional inclusion of two types of wheat, lentil, etc. has been encountered. Rice remained of regular occurrence. Gradual improvement in agricultural economy during the succeeding Chalcolithic period appears similar to the collective evidence from Senuwar[8], Imlidih-Khurd[31], Narhan[35] and Waina and Khairadih[36].

The majority of the remains preserved at Lahuradewa due to incidental carbonization reflect differential preservation, and turned to be a mixture of grains and seeds of domesticated and wild plants in a bulk of wood charcoal pieces. Domesticated species reflect on the food economy, and weeds and wild forms on the surrounding ecology.

The remains of crop plants analysed from 38 samples of diverse origins in the Chalcolithic occupational phase are demonstrative of the practice of rotation of crops. Rice, kodon-millet, jowar millet, green gram, horse gram, cowpea, til and cotton of indigenous and African origins were grown in warm, rainy season. Barley, bread-wheat, dwarf-wheat, field pea, lentil, chickpea, grass pea, fenugreek, linseed of Near-Eastern complex and Indian mustard were grown in the winter season. Rice is most important in the development of agriculture in the Ganga Plain, which is a part of natural habitats of wild rice. The crops of African and Near East origin may have spread from the northwestern region due to direct or indirect contacts.

The archaeobotanical studies at Lahuradewa[2,3,4,31] and Senuwar[8] in the Ganga Plain and Mahagara[37] in the Vindhyan region suggest that the cultivation of indigenous crops (*O. sativa* and millet) was well established before the adoption of West Asian crops. Direct AMS dating of barley grains (*H. vulgare*) at Damdama by 2500–2400 BC and Lahuradewa during 2300–2000 BC[31] suggests winter crops reached the Ganga Valley in the later 3rd millennium BC. The findings of West Asian or Harappan nutritional traits in the Ganga Plain suggest that these species were supplemented to existing agricultural systems and did not get agriculture started[38].

The settlement became more regular. Species from external sources were adopted, in particular Harappan nutritional traits. Some domesticated sheep/goats adopted from the West were also present (Joglekar, pers. commun.). The wider crop repertoire as evidenced from botanical and faunal assemblage is predominantly domesticated, including cattle, sheep and goats. Subsistence was not based on rice–millet alone.

In the Gangetic region the indigenous Chalcolithic culture developed with the diffusion and adoption of elements of Harappan technology and agricultural traits. Economy of this rural culture was mainly based on farming and animal husbandry[32]. The climatic conditions and intimate trade connections with the contemporary cultural communities in NW India have favoured the development of agricultural crops and original forest cover of greater density. However, the preceding Neolithic culture has laid the foundation for agricultural crops. A large number of archaeological sites such as Chirand[39–41] and Senuwar[8,42] in Bihar and Narhan[35,43], Imlidih-Khurd[31,44], Khairadih[31,45], Waina[31,46], Malhar[47,48], Jhusi[49,50], Dadupur[51] and Lahuradewa[1–3] in Uttar Pradesh have revealed cultural deposits related to the early farming communities based on radiocarbon dates, archaeobotanical remains and other archaeological artefacts.

The findings of weeds and other wild taxa identified in the collection are of particular significance to derive information on the soil conditions and the general picture of the vegetation cover in the region of settlement. Plants might have arrived through direct or indirect human activities along with the cultural produce. Some species, occurring noticeably in the cultivated fields, may be taken as dependable evidence of crop and weed association. *V. sativa/hirsuta*, *Medicago* sp. and *Chenopodium album* are the weeds in the winter crops. *Vicia* sp. is a forage legume of rich protein value, eaten by cattle and also used as hay. *Medicago* is cultivated for fodder and used as green manure. *Chenopodium* is also eaten as vegetable[52,53]. Grains of wild grass, viz. *Setaria* sp. and *D. aegyptium* are also eaten in times of scarcity[54,55]. *Cleome* sp., *R. dentatus* and *Oldenlandia* sp. are also common weeds in damp and moist localities in fields, marshy areas and along the ditches, ponds and streams[55,56]. The thorny shrubs of *Carissa*, *Ziziphus* and *Abutilon* are xeric elements. Fruits of *Ziziphus* sp. are eaten and the bark containing tannin is powdered and used for dressing the wounds[57]. *Carissa* sp. occurs throughout the drier sandy or rocky soils of India; from the Punjab to the forests of Ganga Plains, Bengal, Madhya Pradesh and southern India. The fruits are used for pickles. *Emblica* and *Grewia* fruits, fresh or dried are edible and largely used in indigenous medicine. Emblic-myrobolan fruits are the richest source of vitamin C and it is the drug of choice in a number of ailments[54].

The plant remains discussed in the present communication are a fraction of the actual botanical wealth utilized by the settlers, but provide an insight into the considerable economic exploitation of plant resources at Lahuradewa during 2nd millennium BC. The region is vast and the scope of future studies is immense. Hence studies on the lakes and archaeological sites of other sectors of the Ganga Plain are urgently needed in order to reconstruct a precise and comprehensive picture of the past landscape, climate and the course of crop evolution in a definite time-frame.

1. Tewari, R., Srivastava, R. K. and Singh, K. K., Excavation at Lahuradeva, District Sant Kabir Nagar, Uttar Pradesh. *Puratattva*, 2002, **32**, 54–59.
2. Tewari, R., Srivastava, R. K., Singh, K. K., Saraswat, K. S. and Singh, I. B., Preliminary report of the excavations at Lahuradewa, district Sant Kabirnagar, UP – 2001–2002. *Pragdhara*, 2003, **13**, 37–68.
3. Tewari, R. *et al.*, Second preliminary report of the excavations at Lahuradewa, district Sant Kabirnagar, UP – 2002–2003–2004 and 2005–2006. *Pragdhara*, 2006, **16**, 35–68.
4. Saraswat, K. S. and Pokharia, A. K., Plant economy at Lahuradewa – a preliminary contemplation. Joint Annual Conference (IAS, ISPQS, IHCS) and National Seminar on the Archaeology of the Ganga Plain, Abstr., December 2004, Lucknow, pp. 46–47.
5. Saxena, A., Prasad, V., Singh, I. B., Chauhan, M. S. and Hasan, R., On the Holocene record of phytoliths of wild and cultivated rice from Ganga Plain: evidence for rice-based agriculture. *Curr. Sci.*, 2006, **90**(11), 1547–1551.
6. Harlan, J. R., The origins of cereal agriculture in the Old World. In *Origins of Agriculture* (ed. Reed, C. A.), Mouton Publishers, The Hague, 1977, pp. 357–383.
7. Weber, S. A., Seeds of urbanism: paleoethnobotany and the Indus civilization. *Antiquity*, 1999, **73**, 813–826.
8. Saraswat, K. S., Plant economy of early farming communities. In *Early Farming Communities of the Kaimur* (ed. Singh, B. P.), Publication Scheme, Jaipur, 2004, vol. II, pp. 416–535.
9. Wallis, T. E., *Text Book of Pharmacognosy*, L&A Churchill Ltd, London, 1967.
10. Hooker, J. D., *The Flora of British India*, *Vol. II: Sabiaceae to Cornaceae*. Royal Gardens, Kew, 1874 (Reprinted 1973: M/s Bishen Singh Mahendra Pal Singh, Dehra Dun and M/s Periodical Experts, Delhi).
11. Saraswat, K. S., Ancient crop remains from Sringeverapura, Allahabad, UP (ca. 1050–700 BC). *Geophytology*, 1986, **16**(1), 97–106.
12. Saraswat, K. S. and Pokharia, A. K., Palaeoethnobotanical investigations at ancient Kunal, Haryana. *Pragdhara*, 2003, **13**, 105–139.
13. Saraswat, K. S., Srivastava, C. and Pokharia, A. K., Palaeobotanical and pollen analytical investigations. *Indian Archaeology (1994–95) – A Review*, ASI, New Delhi, 2000, pp. 96–97.
14. Van Zeist, W. and Bakker-Heeres, J. H. S., Evidence of linseed cultivation before 6000 BC. *J. Archaeol. Sci.*, 1975, **2**, 215–219.
15. Tengberg, M., Crop husbandry at Miri Qalat, Makaran, SW Pakistan (4000–2000 BC). *Veg. Hist. Archaeobot.*, 1999, **8**, 3–12.
16. Saraswat, K. S. and Pokharia, A. K., Harappan plant economy at ancient Balu, Haryana. *Pragdhara*, 2002, **12**, 153–171.
17. Pokharia, A. K., Record of macrobotanical remains from the Aravalli Hill, Ojiyana, Rajasthan: evidence for agriculture-based subsistence economy. *Curr. Sci.*, 2008, **94**(5), 612–622.
18. Mackay, E. J. H., *Chanhudaro Excavations – 1935–1936*, American Oriental Series 20, American Oriental Society, New Haven, USA, 1943.
19. Costantini, L., The beginning of agriculture in the Kachi Plain: the evidence of Mehrgarh. In *South Asian Archaeology 1981* (ed. Allchin, B.), Cambridge University Press, Cambridge, 1984, pp. 29–33.
20. Costantini, L. and Biasini, L. C., Agriculture in Baluchistan between the 7th and the 3rd millennium BC. *Newsl. Baluchistan Stud.*, 1985, **2**, 16–30.
21. Turner, A. J. and Gulati, A. N., The early history of cotton. *Indian Central Cotton Committee Bull*, 1928, **17**, 14–20.
22. Mckean, M. B., The palynolgy of Balakot, a pre-Harappan and Harappan age site in Las Bela, Pakistan. Ph D dissertation, Southern Methodist University, 1983.
23. Saraswat, K. S., Plant economy of Late Harappans at Hulas. *Puratattva*, 1993, **23**, 1–12.
24. Saraswat, K. S., Plant economy of Barans at ancient Sanghol (ca. 1900–1400 BC), Punjab. *Pragdhara*, 1997, **7**, 97–114.
25. Saraswat, K. S., Banawali (29°37′55″N; 75°23′6″E), District Hissar. *Indian Archaeology 1996–97: a review*, ASI, New Delhi, 2002, p. 203.
26. Moulherat, C., Tengberg, M., Haquet, J.-F. and Mille, B., First evidence of cotton at Neolithic Mehrgarh, Pakistan: analysis of mineralized fibres from a copper bead. *J. Archaeol. Sci.*, 2002, **29**, 1393–1401.
27. Kharakwal, J. S., Rawat, Y. S. and Osada, T., Kanmer: a Harappan site in Kachchh, Gujarat, India. In *Linguistics, Archaeology and the Human Past*, *Occasional Paper 2* (ed. Osada, T.), Indus Project, Research Institute for Humanity and Nature, Kyoto, 2007, pp. 21–46.
28. Pokharia, A. K., Annual Report 2009–10, Birbal Sahni Institute of Palaeobotany, Lucknow.
29. Sanathanam, V. and Hutchinson, J. B., Cotton. In *Evolutionary Studies in World Crops – Diversity and Change in the Indian Subcontinent* (ed. Hutchinson, J.), Cambridge Univ. Press, Cambridge, 1974, pp. 89–100.
30. Phillips, L. L., Cotton. In *Evolution of Crop Plants* (ed. Simmonds, N. W.), Longman, London, 1976, pp. 196–200.
31. Saraswat, K. S., Agricultural background of the early farming communities in the Middle Ganga Plain. *Pragdhara*, 2005, **15**, 145–177.
32. Saraswat, K. S., Archaeobotanical remains in ancient cultural and socio-economic dynamics of the Indian subcontinent. *Palaeobotanist*, 1992, **40**, 514–545.
33. Tewari, R., Srivastava, R. K., Singh, K. K., Vinay, R., Trivedi, R. K. and Singh, G. C., Recently excavated sites in the Ganga Plain and north Vindhyas: some observations regarding the pre-urban context. *Pragdhara*, 2005, **15**, 39–49.
34. Chauhan, M. S., Pokharia, A. K. and Singh, I. B., Pollen record of Holocene vegetation, climate change and human habitation from

Lahuradewa Lake, Sant Kabir Nagar District, Uttar Pradesh, India. *Man Environment*, 2009, **XXXIV**(1), 88–100.
35. Saraswat, K. S., Sharma, N. and Saini, D. C., Plant economy at ancient Narhan (ca. 1300 BC–300/400 AD). In *Excavations at Narhan – 1984–1989* (ed. Singh, P.), Banaras Hindu University, Varanasi, 1994, pp. 255–346.
36. Saraswat, K. S. and Pokharia, A. K., Annual Report 2003–2004, Birbal Sahni Institute of Palaeobotany, Lucknow.
37. Harvey, L. E. and Fuller, D. Q., Investigating crop processing using phytolith analysis: the example of rice and millets. *J. Archaeol. Sci.*, 2005, **32**, 739–752.
38. Fuller, D. Q., Agricultural origins and frontiers in South Asia: A working synthesis. *J. World Prehist.*, 2006, **20**, 1–86.
39. *Indian Archaeology: A Review*. 1962–1963, pp. 6–8; 1968–1969, pp. 5–6; 1969–1970, pp. 3–4; 1970–1971, pp. 6–7; 1971–1972, pp. 6–7.
40. Varma, B. S., Black-and-red ware in Bihar. In *Potteries in Ancient India* (ed. Sinha, B. P.). The Department of Ancient Indian History, Culture and Archaeology, Patna University, Patna, 1969, pp. 102–111.
41. Vishnu-Mittre, Neolithic plant economy at Chirand. *Palaeobotanist*, 1972, **21**, 18–22.
42. Singh, B. P., Early farming communities of Kaimur foothills. *Puratattva*, 1990, **19**, 6–18.
43. Singh, P., *Excavations at Narhan (1984–1989)*, Banaras Hindu University, Varanasi, 1994.
44. Singh, P., Archaeological excavations at Imlidih Khurd – 1992. *Pragdhara*, 1993, **3**, 21–35.
45. Singh, B. P., Khairadih – a Chalcolithic settlement. *Puratattva*, 1989, **18**, 28–34.
46. Singh, P. and Singh, A. K., Trial excavations at Waina. *Pragdhara*, 1996, **6**, 41–61.
47. Tewari, R., Srivastava, R. K., Saraswat, K. S. and Singh, K. K., Excavations at Malhar 1999: a preliminary report, District Chandauli (UP). *Pragdhara*, 2000, **10**, 69–98.
48. Saraswat, K. S., Plant economy in ancient Malhar. *Pragdhara*, 2004, **4**, 137–171.
49. Misra, V. D., Pal, J. N. and Gupta, M. C., Further excavations at Jhusi. *Pragdhara*, 2000, **10**, 23–30.
50. Pokharia, A. K., Pal, J. N. and Srivastava, A., Plant macro-remains from Neolithic Jhusi in Ganga Plain: evidence for grain-based agriculture. *Curr. Sci.*, 2009, **97**(4), 564–571.
51. Tewari, R., Srivastava, R. K. and Singh, K. K., Dadupur excavations 1999–2000–2001, District Lucknow, Uttar Pradesh: Preliminary report. *Pragdhara*, 2002, **12**, 99–116.
52. Anon., *The Wealth of India: Raw Materials* and *Industrial Products*, *Vol. III* (Revised): Ca–Ci, CSIR, New Delhi, 1992.
53. Anon., *The Wealth of India: Raw Materials, Vol. VI: L-M*, CSIR, New Delhi, 1962.
54. Anon., *The Wealth of India: Raw Materials, Vol. III.: D-E*, CSIR, New Delhi, 1952.
55. Anon., *The Wealth of India: Raw Materials, Vol. IX: Rh-So*, CSIR, New Delhi, 1972.
56. Anon., *The Wealth of India: Raw Materials, Vol. II: C*, CSIR, New Delhi, 1950.
57. Anon., *The Wealth of India: First Supplement Series* (*Raw Materials*), *Vol. 5: R-Z*, CSIR, New Delhi, 2004.

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Clonal propagation in *Eucalyptus camaldulensis* using minicutting technique

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Efficient nursery management with rapid and cost-effective clonal propagation is a prerequisite for successful plantation. Mass propagation has become an important tool for increasing the competitiveness of the forest-based industry. However, in several hardwood species, most notably in eucalypts, the popular stem-cutting method poses limitations in rooting behaviour, such as rapid loss of rooting competence, intra-clonal variation and poor rooting quality which collectively negates genetic expression of some useful clones thereby hindering field deployment.

To overcome production barrier, a study was initiated using novel minicutting-based propagation with a primary objective of reducing the nursery duration from six to four months and in the process improving its productivity. To cater to this need, the hydroponic-aided minicuttings production technique for *Eucalyptus camaldulensis* has been standardized in India. The success lies in the plant nutrition management to get maximum harvestable sprouts. Further, as an imperative step to get vigorous saplings from minicutting sets, an efficient, ecosand-based growing medium was employed to boost survival rate, rapid rooting and early establishment.

Keywords: Clonal propagation, coppice, ecosand, hydroponics, minicuttings.

RED GUM (*Eucalyptus camaldulensis* L.) is renowned globally for its fast growth, high levels of drought tolerance and adaptability to diverse climatic conditions and soils, which makes it popular among eucalypt tree growers. Clonal propagation is an extensively used strategy to gain economic potential of eucalypt species/hybrids by multiplying desirable types. With moderate degree of sophistication in most forest nurseries, it is performed to strategically improve the productivity. Since yields from eucalypt forestry will continue to increase with improved clones and silvicultural methods, the availability of a highly reliable and cost-effective propagation technique is required[1]. The conventional (stem-cutting) technique, though the most common and widely used propagation method, suffers due to intrinsic genetic and physiological limitations. For instance, poor rooting and rapid loss of

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