On the botanical findings from excavations at Ahichchhatra: a multicultural site in Upper Ganga Plain, Uttar Pradesh

Anil K. Pokharia[1,*], Chanchala Srivastava[1], Bhuvan Vikram[2], D. N. Dimri[3], Chandra Mohan Nautiyal[1] and Shalini Sharma[1]

[1]Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India
[2]Archaeological Survey of India, Agra Circle, Agra 751 015, India
[3]Archaeological Survey of India, Janpath, New Delhi 110 011, India

This article embodies an impressive array of data on the carbonized remains of crop plants, weeds and wild taxa recovered from archaeological excavations at Ahichchhatra, a multicultural site in Bareilly district, Uttar Pradesh. The crop-remains are represented by the grains and seeds of *Oryza sativa* (rice), *Hordeum vulgare* (barley), *Triticum aestivum* (bread wheat), *Triticum sphaerococcum* (dwarf wheat), *Pisum arvense* (field-pea), *Lens culinaris* (lentil), *Lathyrus sativus* (grass pea), *Vigna* sp. (green/black gram), *Macrotyloma uniflorum* (horse gram), *Sesamum indicum* (sesame), *Linum usitatissimum* (linseed) and *Gossypium arboreum/herbaceum* (cotton) dating back to 1500–100 BC. In addition, a large number of weeds and wild taxa which may be indicative of surrounding ground vegetation and cultivated fields have also been recorded as an admixture in the crop assemblage. The study of the ancient plant remains has been discussed and compared with the information on agriculture remains from other sites in the Ganga Plain.

Keywords: Archaeobotany, carbonized remains, excavations, multicultural site.

THE present article highlights the outcome of archaeobotanical studies on the macroremains recovered during the course of excavations at Ahichchhatra (lat. 28°22′N; long. 79°7′E), a large city, also known in ancient literature as Ahicchatra and Adhicchatra, the capital of Northern Panchala (Figure 1), identified by Cunningham[1]. The sprawling settlement, roughly over 5.60 sq. km. is situated prominently above the surrounding agricultural fields and encompasses a series of rolling mounds, the highest of which, representing the ruined temple, rises to a height of 23 m above the ground level[2]. The Archaeological Survey of India (ASI) under the guidance of Dikshit and co-workers[3] conducted extensive excavations here during 1940–44. However, no seed/fruit remains from this excavation were collected. Only wood charcoal remains from Late phase of painted grey ware (PGW), northern black polished ware (NBPW) up to historical levels (dating 475 BC to AD 1280) were collected, which were used for dating and anatomical investigations by Chanchala[4]. The excavations at the site (Figure 2) were resumed during 2009–10 and 2010–11 by ASI, Agra Circle. The study revealed cultural sequence ranging from PGW to late PGW and Early Mitra Panchal Period. In the present article, the botanical remains (seeds/fruits) retrieved from these periods are discussed in the light of information on agricultural remains from other sites in the Ganga region.

Material and methods

The botanical remains were collected during the course of excavation by standard water floatation technique. Water floatation provides a means of fast and efficient separation of carbonized and silicified plant material from the cultural deposits. Soil samples from varied successive horizons at different depths were floated to retrieve the carbonized and silicified plant remains using 25 mesh geological sieve. However, in some of the layers, the carbonized remains were quite apparent and were picked up using forceps.

Most of the grains, seeds and fruit remains were found in a good state of preservation from the deposits with little or no mud attached to them. The remains were examined under stereobinocular (Leica Z6APO) microscope and sorted into categories of distinctive morphological types (Table 1). However, in some cases severe carbonization prevented revelation of diagnostic features. Cracking of seed coat was also noticed in some seeds.

Results

Chronology

The amount of charcoal in the sample was not enough to facilitate radiocarbon dating. However, the abundance of broken carbonized seeds from only one sample (BX-50 × 75 × 3) representing the upper phase was used for

*For correspondence. (e-mail: pokharia.anil@gmail.com)

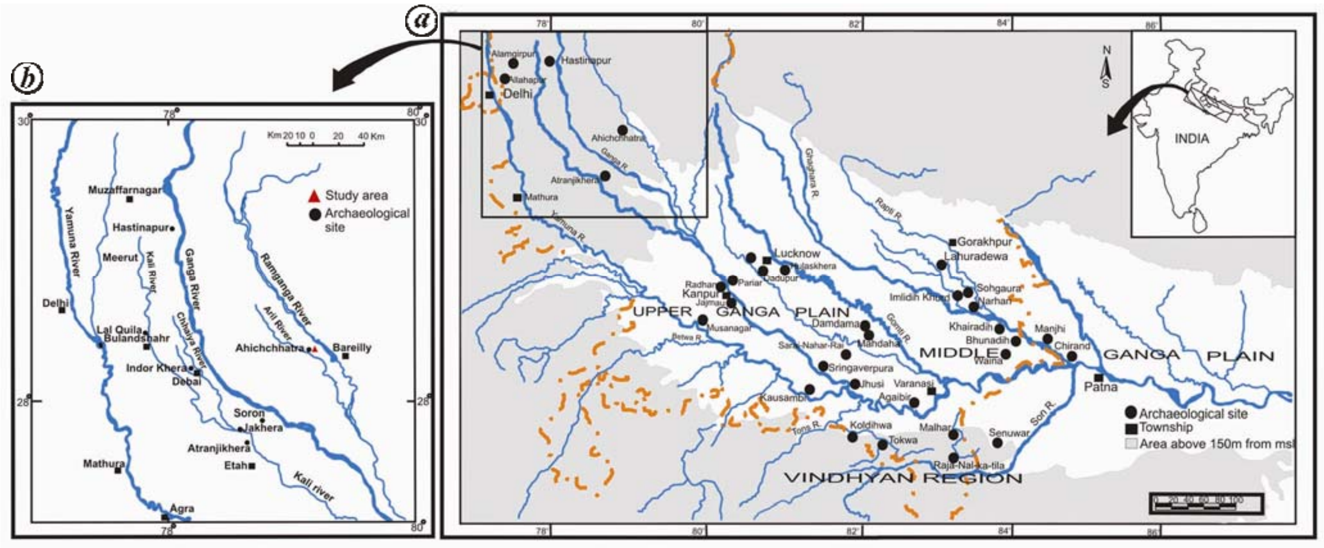

Figure 1. ***a***, Map of Uttar Pradesh showing archaeological sites (modified after Tewari[48]). ***b***, Study area and adjoining archaeological sites in Upper Ganga Plain.

Figure 2. ***a***, General view of the archaeological mound. ***b***, Trench under excavation showing carbonized remains embedded in the cultural deposit.

dating and yielded a calibrated date of 325–342 BC (BS-3102) for Late PGW. Furthermore, the archaeological artefacts from different cultural layers testify their cultural authenticity.

Macroremains

A morphological description of the identified macroremains from all the cultural periods is given below under separate categories.

Cereals

Oryza sativa L. (rice (i), Figure 3): In general, the grains are found without husk. However, in some grains a small portion of husk could be seen attached. Grains are elongate to narrowly oblong, laterally flattened and prominently ribbed. Ribs vary from 3 to 4 in number. 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 show more or less similar appearance; the definite identification of *O. sativa* on the basis of grains without husk is difficult. The remains recovered here are from PGW and Late PGW cultures. By this time the agriculture was well established. Therefore, the rice remains can safely be identified as of *O. sativa*. Rice is an important crop of the Ganga Valley region and its presence in the Neolithic plant economy has been recorded to 6th millennium BC at Lahuradewa[5].

Measurements: L (5.30–5.50) 5.40 × B (2.35–2.54)2.44 × T (1.30–2.00) 1.65 mm.
Indices: L/B = 2.21, L/T = 3.27, B/T = 1.47.

Table 1. Botanical remains recovered from Ahichchhatra*

Archaeological provenience	Cultural horizon	Botanical remains identified	Mode of preservation
B × 50 × 75 × 3 162–165	PGW	*Oryza sativa* (cultivated rice), *Hordeum vulgare* (barley), *Pisum arvense* (field pea), *Lens culinaris* (lentil), *Vigna* sp. (green/black gram), *Vicia sativa* (common vetch), *Echinochloa crus-galli* (barnyard grass/sawan), *Eleusine indica* (goose grass), *Paspalum* cf. *scrobiculatum* (kodo-millet)	Carbonization
B × 50 × 75 × 3 161–162	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *Vigna* sp., *V. sativa*, *E. crus-galli*, *E. indica*, *Setaria* sp. (foxtail millet), *Chenopodium album* (goosefoot/bathua), *Polygonum plebeium* (knotweed), *Rumex* sp. (dock)	Carbonization
B × 50 × 75 × 3 159–161	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *Vigna* sp., *Ziziphus nummularia* (jujube), *V. sativa*, *E. crus-galli*, *Setaria* sp., *Elaeocharis* sp. (spikerush), *C. album*	Carbonization
B × 50 × 75 × 3 157–159	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *Macrotyloma uniflorum* (horse gram), *Lathyrus sativus* (grass pea/khesari), *Vigna* sp., *V. sativa*, *E. crus-galli*, *E. indica*, *Elaeocharis* sp., *Setaria* sp., *Trianthema triquetra* (red spinach), *Z. nummularia*	Carbonization
B × 50 × 75 × 3 153–157	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *Vigna* sp., *V. sativa*, *E. crus-galli*, *Elaeocharis* sp., *Scirpus* sp. (bulrush), *Rumex* sp., *T. triquetra*, *Z. nummularia*	Carbonization
B × 50 × 75 × 3 151–153	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *Vigna* sp., *Lathyrus sativus*, *Lathyrus aphaca* (yellow vetchling), *Z. nummularia*, *V. sativa*, *E. crus-galli*, *T. triquetra*.	Carbonization
B × 50 × 75 × 3 147–151	PGW	*O. sativa*, *H. vulgare*, *L. culinaris*, *P. arvense*, *Vigna* sp., *L. sativus*, *Sesamum indicum* (sesame), *Chenopodium album*, *E. crus-galli*, *Elaeocharis* sp., *Polygonum plebeium*, *Setaria* sp., *T. triquetra*, *V. sativa*, *Z. nummularia*	Carbonization
B × 50 × 75 × 3 142–147	PGW	*O. sativa*, *H. vulgare*, *L. culinaris*, *P. arvense*, *Lathyrus sativus*, *Vigna* sp., *Chenopodium album*, *Desmodium* sp. (tick clover), *E. crus-galli*, *Elaeocharis* sp., *Fimbristylis* sp. (fimbristylis), *Ischaemum rugosum* (wrinkle duck beak/dhanua), *Lathyrus aphaca*, *Scirpus* sp., *Setaria* sp., *T. triquetra*, *Vicia sativa*, *Z. nummularia*	Carbonization
B × 50 × 75 × 3 141–142	PGW	*O. sativa*, *H. vulgare*, *L. culinaris*, *Pisum arvense*, *Vigna* sp., *Vigna radiata* (green gram), *Lathyrus sativus* (grass pea/khesari), *Coix lachryma-jobi* (job's tear), *Cyperus* sp. (flat sedge), *Chenopodium album*, *E. crus-galli*, *Elaeocharis* sp., *Scirpus* sp., *Scleria* sp. (nutrush), *Vicia sativa*, *T. triquetra*, *Z. nummularia*	Carbonization/ mineralization
B × 50 × 75 × 3 139–141	PGW	*O. sativa*, *H. vulgare*, *Vigna* sp., *P. arvense*, *Lens culinaris*, *Lathyrus sativus*, *E. crus-galli*, *E. indica*, *Setaria* sp., *Elaeocharis* sp., *Vicia sativa*, *Z. nummularia*	Carbonization
B × 50 × 75 × 3 137–139	PGW	*O. sativa*, *H. vulgare*, *Triticum sphaerococcum* (dwarf-wheat), *Vigna* sp. *P. arvense*, *L. culinaris*, *L. sativus*, *S. indicum*, *E. crus-galli*, *Setaria* sp., *Rumex* sp., *T. triquetra*, *Vicia sativa*, *Z. nummularia*	Carbonization
B × 50 × 75 × 3 136–137 cm	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *Vigna* sp., *V. sativa*, *Setaria* sp.	Carbonization
B × 50 × 75 × 3 128–136 cm	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *Vigna* sp., *V. sativa*, *Chenopodium* sp., *Cyperus* sp., *Scirpus* sp., *Z. nummularia*, *Fimbristylis* sp., *D. aegyptium*	Carbonization
B × 50 × 75 × 3 127–128 cm	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *L. sativus*, *Vigna* sp., *Setaria* sp., *Cyperus* sp., *Chenopodium* sp., *Cleome* sp. (spider flower), *T. triquetra*, *Z. nummularia*, *D. aegyptium*, *Ischaemum rugosum*, *Ficus* sp. (gular)	Carbonization
B × 50 × 75 × 3 122–127 cm	PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. culinaris*, *L. sativus*, *Vigna* sp., *V. sativa*, *Setaria* sp., *Cyperus* sp.	Carbonization

(*Contd*)

Table 1. (*Contd*)

Archaeological provenience	Cultural horizon	Botanical remains identified	Mode of preservation
B × 50 × 75 × 3 107–108 cm	Late PGW	*O. sativa*, *H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *L. culinaris*, *Vicia* sp.	Carbonization
B × 50 × 75 × 3 106–107 cm	Late PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. sativus*, *Vigna* sp., *Vicia* sp., *Setaria* sp., *T. triquetra*	Carbonization
B × 50 × 75 × 3 100–109 cm	Late PGW	*O. sativa*, *H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *L. culinaris*, *Vigna* sp., *Gossypium arboreum/herbaceum* (cotton), *Vicia* sp., *Setaria* sp., *Z. nummularia*	Carbonization
B × 50 × 75 × 3 97–107 cm	Late PGW	*O. sativa*, *H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *L. culinaris*, *Vicia* sp., *Setaria* sp.	Carbonization
B × 50 × 75 × 3 96–102 cm	Late PGW	*H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *O. rufipogon*, *Vicia* sp., *T. triquetra*	Carbonization
B × 50 × 75 × 3 95–102 cm	Late PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. sativus*, *O. rufipogon*, *Vicia* sp.	Carbonization
B × 50 × 75 × 3 95–97 cm	Late PGW	*O. sativa*, *H. vulgare*, *P. arvense*, *L. sativus*, *O. rufipogon*, *Vicia* sp., *T. triquetra*	Carbonization
B × 50 × 75 × 3 94–100 cm	Late PGW	*H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *L. culinaris*, *Vigna* sp., *Oryza rufipogon*, *Vicia sativa*	Carbonization
B × 50 × 75 × 3 87–94 cm	Late PGW	*O. sativa*, *H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *L. culinaris*, *Vigna* sp., *Macrotyloma uniflorum*, *Z. nummularia*, *Vicia hirsuta*	Carbonization
B × 50 × 75 × 3 75–87 cm	Late PGW	*O. sativa*, *H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *L. culinaris*, *Vigna* sp., *L. usitatissimum*, *Coccinia* sp. (ivy), *Vicia hirsuta*, *Setaria* sp., *Ziziphus* cf. *nummularia*	Carbonization
B × 50 × 75 × 3 60–75 cm	Late PGW	*O. sativa*, *H. vulgare*, *T. aestivum*, *P. arvense*, *L. sativus*, *L. culinaris*, *Vigna* sp., *Vicia* sp., *Coix lachryma-jobi*, *O. rufipogon*, *Z. nummularia*, *Emblica officinalis* (Indian gooseberry/anwala)	Carbonization
B × 78 × 28 × 4 171 cm	Late PGW	*O. sativa*, *L. culinaris*, *L. sativus*, *V. sativa*, *T. triquetra*, *Chenopodium* sp., *D. aegyptium*, *Cyperus* sp., *Fimbristylis* sp.	Carbonization
B × 78 × 28 × 3 155–166 cm	Early Mitra Panchal	*T. aestivum*, *T. sphaerococcum*, *P. arvense*, *L. culinaris*, *L. sativus*, *V. sativa*, *Coix lachrymal-jobi*	Carbonization/ mineralization
B × 78 × 28 × 4 115–129 cm	Early Mitra Panchal	*Coix lachryma-jobi*	Mineralization

*The botanical remains comprise of cereals, pulses/legumes, oil and fibre-yielding plants along with weeds and wild taxa.

Hordeum vulgare L. emend. Bowden (six-rowed hulled barley (iii), Figure 3): Elongated grains, tapering towards the apex and with a widening ventral furrow have been encountered from PGW and Late PGW cultural periods. Some of the grains show traces of longitudinal ridges caused by lost husk. Since some grains are also partly asymmetrical or show slight ventro-lateral twist, they are identified as the six-rowed hulled barley. A winter-crop of West Asian origin barley, was a staple food during the Harappan civilization[6–12]. It was already in cultivation during 7th millennium BC, as evident in the archaeological deposits of Period IA at Neolithic Mehrgarh in the North Kachi Plain of Pakistan[13].

Measurements: L (5.38–5.80) 5.59 × B (3.04–3.18) × 3.11 × T (2.00–2.50) 2.25 mm.
Indices: L/B = 1.79, L/T = 2.48, B/T = 1.38.

Triticum aestivum L. emend. Thell (bread-wheat (iv), Figure 3): Grains are elongated and relatively narrow towards both the ends. They exhibit a hump-like circular area raised on their dorsal side. The grains resemble those of bread-wheat (*T. aestivum*).

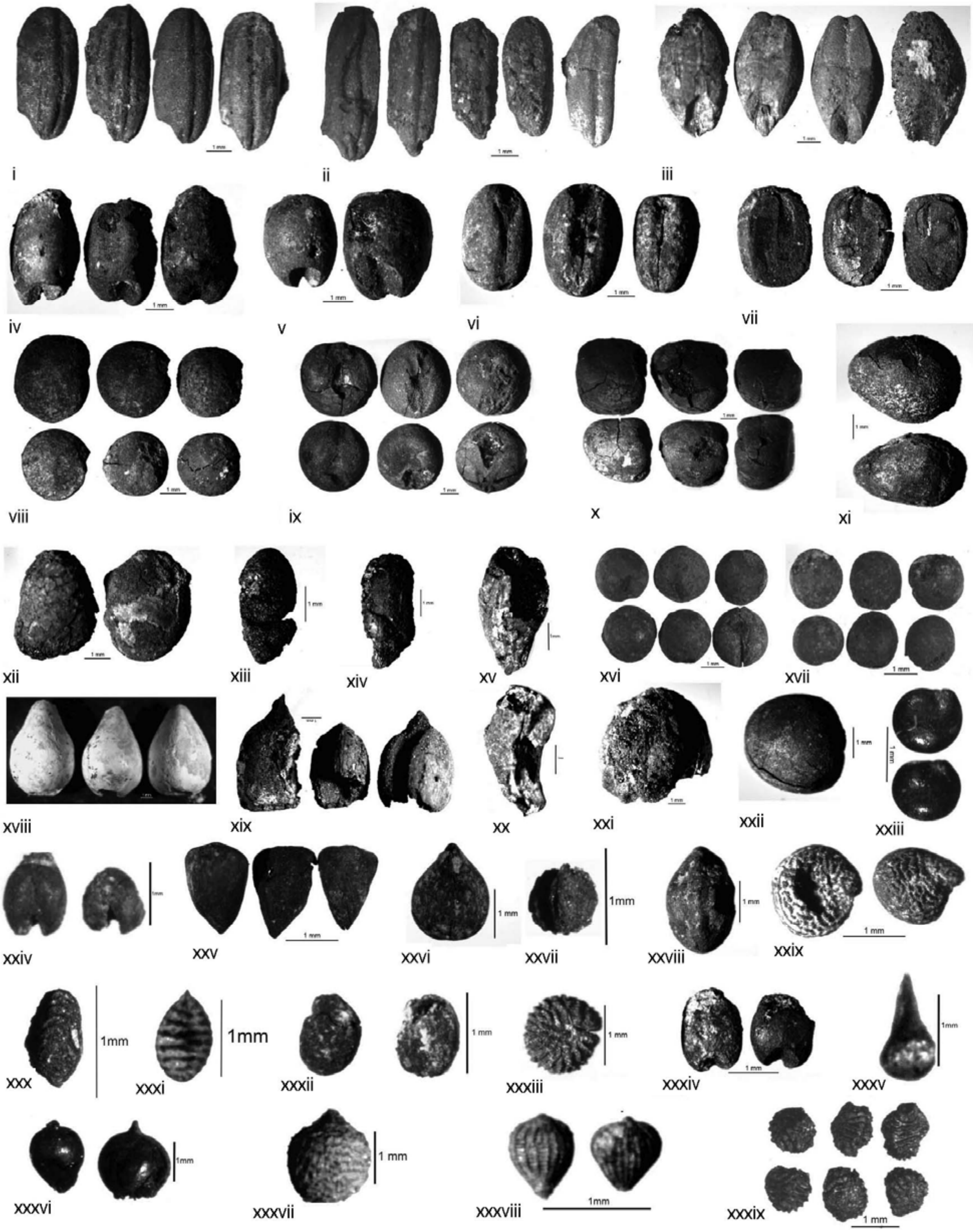

Figure 3. Cultivated crops, weeds and wild taxa. i, *Oryza sativa*; ii, *Oryza* cf. *rufipogon*; iii, *Hordeum vulgare*; iv, *Triticum aestivum*; v, *Triticum sphaerococcum*; vi, *Vigna* sp.; vii, *Vigna* sp. cotyledons; viii, *Lens culinaris*; ix, *Pisum arvense*; x, *Lathyrus sativus*; xi, *Gossypium arboreum/ herbaceum*; xii, *Macrotyloma uniflorum*; xiii, *Sesamum indicum*; xiv, *Linum usitatissimum*; xv, *Coccinia* sp., xvi, *Vicia sativa*, xvii, *Vicia hirsuta*, xviii, *Coix lachryma-jobi*; xix, *Coix* grains; xx, *Emblica officinalis*; xxi, *Ziziphus nummularia*; xxii, *Lathyrus aphaca*; xxiii, *Chenopodium album*; xxiv, *Setaria* sp.; xxv, *Scirpus* sp.; xxvi, *Rumex* sp.; xxvii, *Polygonum plebeium*; xxviii, *Cyperus* sp.; xxix, *Trianthema triquetra*; xxx, *Eleusine indica*; xxxi, *Ischaemum rugosum*; xxxii, *Desmodium* sp.; xxxiii, *Cleome* sp.; xxxiv, *Paspalum* cf. *scrobiculatum*; xxxv, *Ficus glomerata*; xxxvi, *Eleocharis* sp.; xxxvii, *Scleria* sp.; xxxviii, *Fimbristylis* sp. and xxxix, *Dactyloctenium aegyptium.*

Measurements: *L* (3.94–4.36) 4.15 × *B* (2.55–2.70) × 2.62 × *T* (2.00–2.50) 2.25 mm.
Indices: *L*/*B* = 1.58, *L*/*T* = 1.84, *B*/*T* = 1.16.

Triticum sphaerococcum Perc. (dwarf-wheat (v), Figure 3): The short, broad and more or less rounded grains compare in all morphological respects with caryopses of dwarf-wheat. *T. sphaerococcum* has long been considered as a staple crop of the Harappan civilization[13,14].

Measurements: *L* (3.22–3.78) 3.50 × *B* (2.54–3.12) × 2.83 × *T* (2.20–2.60) 2.40 mm.
Indices: *L*/*B* = 1.23, *L*/*T* = 1.45, *B*/*T* = 1.18.

Pulses

Vigna sp. (green/black gram (vi) and (vii), Figure 3): A few seeds and cotyledons have been encountered in the collection. The complete seeds are elongated and somewhat cylindrical in shape. Both the seeds and the cotyledons have angular to rounded ends. *Vigna radiata* (L.) Wilczek and *V. mungo* (L.) Hepper seeds have a number of common characters, size and shape of the seeds overlap. Therefore, the carbonized seeds and cotyledons have been kept under *Vigna* sp. However, on the basis of hilum, if preserved, the distinction between the two can be made unambiguously. The *V. mungo* seed has a raised hilum with an encircling lip, while in *V. radiata* hilum is more or less flush with the seed coat surface[15,16]. The green gram/black gram, like rice and horse-gram, is also an indigenous crop.

Measurements (seeds): *L* (3.65–4.17) 3.91 × *B* (2.44–2.97) 2.70 × *T* (2.80–3.50) 3.15 mm.
Indices: *L*/*B* = 1.44, *L*/*T* = 1.24, *B*/*T* = 0.85.
Measurements (cotyledons): *L* (3.52–3.71) 3.61 × *B* (2.34–2.72) 2.53 × *T* (1.20–1.80) 1.50 mm.
Indices: *L*/*B* = 1.42, *L*/*T* = 2.40, *B*/*T* = 1.68.

Lens culinaris Maedik. (lentil (viii), Figure 3): Leguminous seeds, circular and flattened with keeled margins appear lenticular in shape. Hilum is very small and lanceolate. In shape and size, the carbonized seeds are comparable to those of lentil.
Measurements: 2.40–3.40 mm (approx.) in diameter.

Pisum arvense L., syn. *P. sativum* var. *arvense* (L.) Poir (field-pea (ix), Figure 3): A large number of complete and broken seeds have been recovered from all the cultural periods. The recovered seeds are spherical to hemispherical in shape. The seed coat is blurred and rubbed-off at places. Small ovate hilum measuring about 1.00 mm in length is flushed evenly with the seed surface. The carbonized seeds are comparable to those of field-pea.

Measurements: 3.89–4.33 mm (approx.) in diameter.

Lathyrus sativus L. (grass-pea (x), Figure 3): Seeds are wedge-shaped and the end planes are somewhat triangular. Small and oval hilum is noticed in some seeds. Seed coat is rough textured. These seeds compare with those of grass-pea.

Measurements: *L* (3.70–4.65) 4.17 × *B* (3.60–4.59) × 4.09 × *T* (2.80–3.50) 3.15 mm.
Indices: *L*/*B* = 1.01, *L*/*T* = 1.32, *B*/*T* = 1.29.

Macrotyloma uniflorum (Lam.) Verdcourt (horse gram (xii), Figure 3): The seeds are flat, ellipsoidal to somewhat kidney-shaped or reniform. The hilum can be seen on the lateral margin of the seed. It is widely cultivated as summer crop in India. Not much is known about its wild progenitors, although they were probably native to the sub-savanna or thorny vegetation of the Indian peninsula[16].

Measurements: *L* (4.20–4.35) 4.27 × *B* (2.98–3.29) × 3.13 × *T* (1.20–1.40) 1.30 mm.
Indices: *L*/*B* = 1.36, *L*/*T* = 3.28, *B*/*T* = 2.40.

Oilseeds

Sesamum indicum L. (sesame, (xiii), Figure 3): The single seed in highly carbonized state of preservation, is flattish–ovate in shape, having one end narrow and the other end rounded. The seed with smooth surface can be identified as that of cultivated sesame. Evidences from Miri Qalat, Baluchistan, Pakistan, and northwestern India suggest[10,11,17,18] cultivation of sesame was more widespread in the subcontinent by the second half of 3rd millennium BC.

Measurements: *L* (3.36) × *B* (1.63) mm.
Indices: *L*/*B* = 2.06.

Linum cf. usitatissimum L. (linseed, (xiv), Figure 3): The single carbonized seed, partly broken, is elliptic to elliptic–ovate with one end narrower, has apex with a characteristic hooked tip similar to *Linum* sp. It is a winter crop requiring moderately high rainfall or irrigation. It can be sown immediately after monsoon, in an area having high rainfall or water-retaining clayey soils, or in the remaining standing water of harvested rice field[19]. Linseeds belong to West Asian group of crops, where antiquity of their cultivation goes back to those of barley and wheat[20].

Measurements: *L* (4.23) × *B* (1.88) mm.
Indices: *L*/*B* = 2.25.

Fibre-crop

Gossypium arboreum/herbaceum L. (cotton, (xi), Figure 3): Seeds having one end rounded and the other end narrow and slightly angular in cross view have been encountered. Seed surface is ragged as a result of the distortion of seed coat. Ventral side of the seeds is somewhat flattened and dorsal side shows bulging. In all morphological features, the seeds compare with that of cotton. The archaeobotanical records from Neolithic Mehrgarh (6000–4500 BC), and Harappan sites such as Mohenjodaro (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 subcontinent[11–13,21–27]. Cotton was also grown by early farming communities in the region of Middle Ganga Plain[28,29].

Measurements: *L* (4.61–4.62) 4.61 × *B* (3.02–3.60) 3.31 mm.
Indices: *L*/*B* = 1.39.

Weeds and wild taxa

Oryza cf. *rufipogon* Griffith (wild rice, (ii), Figure 3): Grains are relatively much longer than broad and appear slender in shape, measuring 4.49–5.73 mm in length and 1.77–2.00 mm in breadth. They show conformity with the long grains of a form of wild rice belonging to *O. rufipogon*. It grows as a weed in the crop-fields of *O. sativa* and in the natural shallow depressions filled with water.

Coccinia sp. Wight & Arn. (ivy-gourd (xv), Figure 3): Single oblong to somewhat elongated seed, having one end narrow, measures 4.70 mm in length and 2.58 mm in breadth. Margins are characteristically compressed. The seed is comparable to *Coccinia*, a climbing herb common in hedges.

Vicia sativa L. (common vetch (xvi), Figure 3): The seeds, varying in diameter from 2.30 to 2.54 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 (xvii), Figure 3): Small seeds measuring 1.53–1.84 mm in diameter are globular in shape. Hilum is linear. These smaller seeds may be referred to as *V. hirsuta*.

Coix lachryma-jobi L. (job's tear (xviii) and (xix), Figure 3): Evidence is furnished by carbonized grains and pear-shaped false fruit (pseudocarp) formed from the hard shell-like bracts or metamorphosed leaf sheaths[30,31]. Pseudocarp measures 7.40–7.97 mm in length and 4.99–5.30 mm in breadth. Grains measuring 4.36–5.96 mm in length and 3.01–3.77 mm in breadth are more or less oval to orbicular in shape and ventrally furrowed. On morphological grounds, the pseudocarp and grains are referred to *C. lachryma-jobi* occurring commonly in wild state along the water-courses, ditches, etc.

Emblica officinalis Gaertn. (Indian gooseberry/anwala (xx), Figure 3): A trigonous seed measuring 4.50 mm in length and 2.30 mm in breadth has been recorded in the collection.

Ziziphus nummularia (Burm. f.) W. & A. (jujube/jharberi (xxi), Figure 3): Globose or somewhat oval stone measuring 6.60–6.85 mm has been encountered from PGW and Late PGW cultural periods. The stone pieces exhibit tubercled surface. The stone has been found comparable to jujube/jharberi.

Lathyrus aphaca L. (yellow-vetchling (xxii), Figure 3): Leguminous weed, broadly oval and laterally compressed, measures 3.40 mm in length and 3.34 mm in breadth. In morphological features, carbonized seed compares with *L. aphaca*.

Chenopodium album L. (goosefoot (xxiii), Figure 3): Seeds circular and compressed–lenticular having rounded margins and a distinctive marginal notch, measuring about 1.20–1.30 mm in diameter, are comparable to those of *C. album*.

Setaria sp. (L) P. Beauv. (foxtail-grass (xxiv), Figure 3): Grains, ovoid to somewhat oblong measuring 1.50–1.66 mm in length and 1.24–1.28 mm in breadth, are similar to *Setaria* sp.

Scirpus sp. L. (bulrush (xxv), Figure 3): Nuts ovate in outline and somewhat trigonous with smooth surface measure 1.63–1.80 mm in length and 1.13–1.18 mm in breadth. The style base present at the top is similar to bulrush and distinguishes it from other members of Cyperaceae[32].

Rumex sp. L. (dock (xxvi), Figure 3): Single, nut with smooth surface and angled, measuring 2.05 × 1.64 mm (*l* × *b*), closely resembles *Rumex* sp. It occurs mostly as weed in moist places such as ditches, channels and bunds of paddy fields.

Polygonum plebeium R.Br. (knotweed (xxvii), Figure 3): Nut triangular in cross view, measures 0.68 mm in length and 0.70 mm in breadth compares closely with *P. plebeium*, a tiny plant found abundantly growing on dried-up ponds and in the crop fields.

Cyperus sp. L. (flatsedge (xxviii), Figure 3): Trigonus nut measures 2.59 mm in length and 1.65 mm in

Table 2. Summary of stratigraphic grain findings from Ahichchhatra, Uttar Pradesh

Plant taxa		Cultural phases			
Botanical name	Common name	PGW (1500–800 BC)	Late PGW (800–400 BC)	Early Mitra Panchal (300–100 BC)	Cropping season
Oryza sativa L.	Rice	+	+		Summer
Hordeum vulgare L. emend. Bowden	Barley	+	+		Winter
Triticum aestivum L. emend. Thell	Bread-wheat		+	+	Winter
Triticum sphaerococcum Perc.	Dwarf-wheat			+	Winter
Pisum arvense L.	Field-pea	+	+	+	Winter
Lens culinaris Maedik.	Lentil	+	+	+	Winter
Lathyrus sativus L.	Grass-pea	+	+	+	Winter
Vigna sp. L.	Green-gram/black-gram	+	+		Summer
Macrotyloma uniflorum (Lam.) Verdc.	Horse-gram		+		Summer
Sesamum indicum	Sesame	+			Summer
Linum usitatissimum L.	Linseed		+		Winter
Gossypium arboreum/herbaceum L.	Cotton		+		Winter
Ziziphus nummularia (Burm.f.) W.&A.	Jujube		+	+	Winter

+, Indicates presence.

breadth. On morphological ground, the ancient nut is comparable to *Cyperus* sp. It grows in paddy fields and swampy areas.

Trianthema triquetra Rottle. ex Willd. (red spinach (xxix), Figure 3): The seeds are discoid with concentric broken undulating raised lines and characteristically beaked near the hilum. These seeds on morphological grounds closely compare with *T. triquetra*.

Eleusine indica L. Gaertn. (Indian goose grass (xxx), Figure 3): Grain oblong, transversely rugose and obtusely trigonous measures 0.88 mm in length and 0.49 mm in breadth, is comparable to *E. indica*.

Ischaemum rugosum Salisb. (kander grass/wrinkle duck beak (xxxi), Figure 3): Grain oblong and transversely–rugosely ridged. It is a common grass in the region; therefore, the grain with glume-I of the sessile spikelet showing transversely ridged structure has been identified as *I. rugosum*.

Desmodium sp. Desv. (tick clover (xxxii), Figure 3): Seeds are oval to elliptic and flattened. They measure 0.94–0.95 mm in length and 0.69–0.70 mm in breadth. The carbonized seeds have been referred to *Desmodium*, without specific diagnosis.

Cleome sp. L. (spiderflower (xxxiii), Figure 3): Reniform seed, compressed and tubercled, measuring 1.30 mm in diameter shows close resemblance to *Cleome* sp., a weed of wasteland and cultivated fields.

Paspalum sp. L. (kodo-millet (xxxiv), Figure 3): Ovate to elliptical grain with scutellum length closer to one-third of caryopsis length, measures 1.48–1.68 mm in length and 1.23–1.26 mm in breadth and compares closely with *Paspalum* sp.

Ficus glomerata Roxb. (Indian fig tree/gular (xxxv), Figure 3): Seed oblong–elliptic in outline and measuring 1.45 × 0.79 mm ($l \times b$) has been identified as that of *F. glomerata* (tuberculate achene).

Elaeocharis sp. Brongn. (spikerush (xxxvi), Figure 3): Ovoid nut, measures 1.99 mm in length and 1.87 mm in breadth. Presence of cap (tubercle) at the top indicates that it belongs to genus *Elaeocharis*.

Scleria sp. P.J. Bergius (nutrushes (xxxvii), Figure 3): Ovoid to globose nut with pitted-reticulate surface, measures 1.81 mm in length and 1.63 mm in breadth. Several species are known to occur in the moist–warm regions of the country.

Fimbristylis sp. Vahl (fimbristylis (xxxviii), Figure 3): Nuts orbicular to ovate, stalked and measuring about 0.68–0.75 mm in length and 0.46–0.57 mm in breadth. Surface cells quadrate, hexagonal and aligned in 8–9 longitudinal rows on each face of the nut.

Dactyloctenium aegyptium L. Willd. (crowfoot grass (xxxix), Figure 3): Ovoid caryopses with rugose surface, measuring 0.62–0.73 mm in size. The carbonized grains on morphological grounds closely resemble *D. aegyptium*.

Discussion and conclusion

The archaeobotanical samples recovered systematically from a wide range of deposits at different depths, during the course of excavations, have provided empirical evidence for a rich and varied plant economy of settlers in the Upper Gangetic Plain. The biases introduced by differential preservation of botanical remains in different

Table 3. Record of field-crops from archaeological sites in Upper and Middle Ganga Plain

	Upper Ganga Plain							Middle Ganga Plain														
	Atranjikhera, Etah, Uttar Pradesh (UP)				Lal Quila, Bulandshahr, UP	Indor-Khera,Bulandshahr, UP	Hastinapur, Meerut, UP	Hulashkhera, Lucknow, UP	Radhan, Kanpur, UP	Kausambi, Allahabad, UP	Srigaverapura, Allahabad, UP		Khairadih, Ballia, UP		Waina, Ballia, UP		Imlidih-khurd, Ballia, UP			Narhan, Gorakhpur, UP		
Taxa	2000–1500 BC	1500–1000 BC	1050–600 BC	600–200 BC	2000–1500 BC	1300–600 BC	900–500 BC	800–200 BC	1st millennium BC (500 AD)	600–200 BC	1050–1000 BC	950–700 BC	2000–800 BC	800–200 BC	1600–800 BC	800–600 BC	2000-1400 BC	1400–1300 BC	1300–800 BC	1300–800 BC	800–600 BC	600–200 BC
Oryza sativa L.	+	+	+	+	+	+		+	+		+	+	+	+	+	+	+	+	+	+	+	+
Oryza sp. L.							+															
Hordeum vulgare L. emend. Bowden	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Triticum aestivum L. emend. Thell.				+	+									+	+	+	+	+	+	+		+
Triticum compactum Host.			+									+							+			
Triticum sphaerococcum Perc.						+						+	+	+	+	+	+	+	+	+		+
Eleusine coracana (L.) Gaertn.								+								+			+			
Sorghum bicolor (L.) Moench														+		+	+		+			
Pennisetum glaucum (L.) R.Br																		+		+		
Setaria italica (L.) P. Beauv															+	+						
Paspalum scrobiculatum L.						+									+				+	+		+
Lens culinaris Medik.						+							+	+	+	+	+	+	+	+		
Pisum arvense (L.) Poir					+				+				+	+	+	+	+	+	+	+	+	+
Lathyrus sativus L.	+					+								+	+	+	+		+	+		+
Cicer arietinum L.	+				+							+		+	+				+	+		
Macrotyloma uniflorum (lam) Verdcourt						+								+	+	+	+	+	+	+		
Vigna radiata (L.) Wilczek						+	+					+		+	+	+	+	+	+	+	+	+
Vigna mungo (L.) Hepper				+		+																+
Vigna aconitifolia (Jacq.) Marechal														+					+	+		
Vigna unguiculata (L.) Walp														+								
Lablab purpureus L.																	+		+			
Sesamum indicum L.											+			+			+		+	+		+
Brassica juncea (L.) Czern and Coss.														+	+	+	+		+	+		
Linum usitatissimum L.														+		+	+		+	+		
Carthamus tinctorius L.																+			+		+	
Gossypium arboreum/herbaceum L						+				+	+				+				+			
Allium cepa L.															+							

+, Indicates presence; Atranjikhera[41,49]; Lal Quila[50]; Indor-Khera[51]; Hastinapura[52]; Hulaskhera[53]; Radhan[54]; Kausambi[55,56]; Srigaverapura[57]; Khairadih, Waina and Imlidih-khurd[28]; Narhan[58].

cultural periods continue to be of prime concern. The greater variety of crop plants was found in the late phase of PGW period (800–400 BC, Table 2). In the preceding phase of PGW culture (1500–800 BC) and subsequent phase of Early Mitra Panchal Period (300–100 BC), no abundance of the food grains could be noticed. It would, of course, have been accidental which plants or plant parts got carbonized.

Among the food grains encountered at Ahichchhatra, cereals included rice (*O. sativa*), hulled-barley (*H. vulgare*), bread-wheat (*T. aestivum*) and dwarf-wheat (*T. sphaerococcum*). Pulses, especially field-pea

(*P. arvense*), figured more prominently in the mixture of food grains. They are represented by field-pea, lentil (*L. culinaris*), grass-pea (*L. sativus*), green-gram/black-gram (*V. radiata/mungo*), and horse gram (*M. uniflorum*). From the point of view of agricultural economy, there is enough justification to surmise that rotation of crops was practised. Rice, green gram, black gram and horse gram are grown in warm–rainy season, while wheat, barley, field-pea, lentil, pigeon-pea and grass-pea are winter crops. Pulses have been the mainstay of Indian agriculture, enabling the land to turn out reasonable quantities of food grains when, over a long period, the area under cultivation has hardly received any manure or fertilizers. They constitute a group of crops of the legume family which, with the help of bacteria in their root nodules, fix atmospheric nitrogen and improve the soil fertility. The oleiferous crops are represented by sesame (*Sesamum indicum*) and linseed (*Linum usitatissimum*), whereas the fibre-crop is represented by cotton (*Gossypium arboreum/herbaceum*). These crop plants have also been recorded from other sites in the Upper and Middle Ganga Plain (Table 3). Their presence at Ahichchhatra is, therefore, clearly understood.

Rice is the most important cereal crop being grown with a production of over 468,275 million tonnes in the world[33]. It is also probably the world's most versatile crop[34]. Today rice grows at more than 3000 m elevation in the Himalayas and at sea level in the deltas of the great rivers of Asia. The archaeological records suggest that *O. sativa* has been the most popular cereal in South Asia and played an important role in the development of agriculture in the Ganga Plain, which is a part of the natural habitat of wild rice. In India, the archaeobotanical studies at Lahuradewa[28,35], Senuwar[36] and Mahagara[37] denote that the cultivation of *O. sativa* was well established in northern India. The earliest evidence for paddy cultivation in Sri Lanka dated around 900 BC was found at ancient Anuradhapura[38]. Available data from Thailand show that rice was the ubiquitous cereal in prehistory (2000–1500 BC)[39] and particularly during the Metal/Iron Age (400–200 BC)[40]. A large number of rice remains and associated weeds, as well as Indian pulses *V. radiata* and *M. uniflorum* recorded at Khao Sam Kaeo (KSK) and Phukhao Thong (PKT) in Thialand during Metal/Iron Age (400–200 BC) attest the South Asian influence[40].

The other constituents of indigenous crop plants at Ahichchhatra include green/black gram, horse gram, sesame and cotton. The crops of West Asian origin such as barley, wheat, field pea, lentil, grass pea and linseed, which the Harappan's already had in their economy[6–8,10–12,24], became firmly established in the crop economy of Ahichchhatra settlers. These crops of diverse groups became well represented in the early and contemporaneous settlements throughout the northern plains and peninsular India, as a result of direct or indirect contacts of cultural groups during 3rd–2nd millennium BC[16,28,29,36,41–45]. Direct AMS dating of barley grains (*H. vulgare*) at Damdama (2500–2400 BC) and Lahuradewa (2300–2000 BC)[28] demonstrates the introduction of winter crop in the Ganga Plain in the late third millennium BC. The findings of Harappan nutritional traits in the Ganga Plain suggest that these species supplemented the existing agricultural system and were not instrumental for its beginning[46].

A large number of weeds and other wild taxa are of particular significance to derive information regarding the soil condition and the general picture of vegetation cover in and around the settlement area. Many plants might have arrived through human activity, albeit not necessarily intentionally. Some species occurring in the cultivated fields may be taken as dependable evidence of crop and weed association. *Rumex* sp., *P. plebeium*, *Cyperus* sp., *Coix* sp., *Elaeocharis*, *Desmodium* sp., *Fimbristylis* sp., and *Cleome* sp. occur in marshy and flooded localities. Ephemeral growth of these grasses, sedges and herbs follows the rains and may be regarded to subsist in the wellwatered and marshy areas around the ancient settlement and along the river courses. *Vicia* sp., *L. aphaca*, *Chenopodium* sp., *P. plebeium*, *Rumex* sp., *O. rufipogon*, *E. indica*, *I. rugosum*, *D. aegyptium*, *Trianthema* sp., *Setaria* sp. and *Scirpus* sp., represent the weedy flora of the field-crops. *Coix* sp., occur commonly in wild state along the water-courses, ditches, etc. and were also cultivated on well-drained highlands during monsoon. *Coccinia* sp., a climbing herb is common in hedges. *Scleria* sp. grows as wasteland plant. *Ziziphus* cf. *nummularia*, a wild shrub commonly grows in the region. Its fruits are regarded to have been collected by the settlers for consumption. *Emblica* fruits, fresh or dried, are edible and largely used in indigenous medicine. Its fruits are the richest source of vitamin C and are the drug of choice in a number of ailments[47]. *F. glomerata* fruits are used as vegetable and pickle.

The assemblage presented here represents only a small fraction of the botanical wealth at Ahichchhatra. However, it provides additional data for understanding the ancient plant economy of the Upper Ganga Plain during 1500–100 BC.

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	10	1,12,000	1,87,000	1,65,000	2,62,000	2,22,000	2,97,000
	12	1,25,000	2,06,000	1,83,000	2,90,000	2,52,000	3,31,000
Half page (H = 11 cm; W = 17.5 cm)	1	8,500	15,000				
	2	15,500	27,500				
	4	29,000	52,000				
	6	40,000	75,000				
	8	51,000	93,000				
	10	60,000	1,12,000				
	12	66,000	1,25,000				

We also have provision for **quarter page** display advertisement: **Quarter page (H = 11 cm; W = 8 cm)**: Rs 5,000 per insertion

Note: For payments towards the advertisement charges, Cheque (at par/multicity) or Demand Drafts may be drawn in favour of '**Current Science Association, Bengaluru**'.

Other Countries	Tariff (US $)*						
Size	No. of insertions	Inside pages		Inside cover pages		Back cover pages	
		B&W	Colour	B&W	Colour	B&W	Colour
Full page (H = 23 cm; W = 17.5 cm)	1	300	650	450	750	600	1000
	6	1500	3000	2250	3500	3000	5000
Half page (H = 11 cm; W = 17.5 cm)	1	200	325				
	6	1000	2000				

25% rebate for Institutional members

Contact us: Current Science Association, C.V. Raman Avenue, P.B. No. 8001, Bengaluru 560 080 or e-mail: csc@ias.ernet.in

Last date for receiving advertising material: Ten days before the scheduled date of publication.

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