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## Plant macro-remains from Neolithic Jhusi in Ganga Plain: evidence for grain-based agriculture

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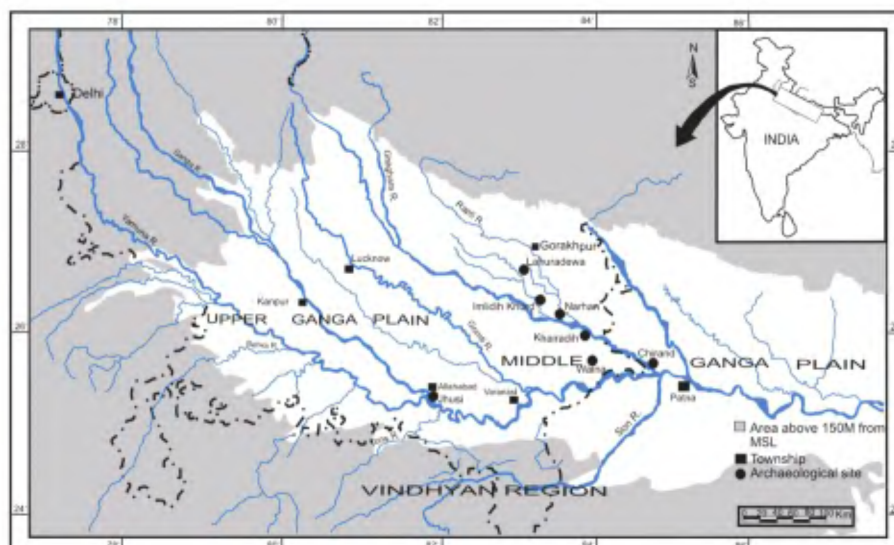
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**The results of the study of archaeobotanical samples from Neolithic site, Jhusi, at the confluence of Yamuna and Ganga rivers in Allahabad, UP, are presented here and discussed in the light of information on prehistoric plants of subsistence in Ganga Plain during 7th millennium BC–2nd century BC. The study indicates that the likely staples were cereals (*Oryza sativa*, *Hordeum vulgare*, *Triticum aestivum* and *Triticum sphaerococcum*), pulses (*Lens culinaris*, *Pisum arvense*, *Vigna radiata*, *Lathyrus sativus* and *Macrotyloma uniflorum*) and two oil-yielding (*Linum usitatissimum* and *Sesamum indicum*) crops. In addition, there is evidence for viticulture or horticulture (*Vitis vinifera*).**

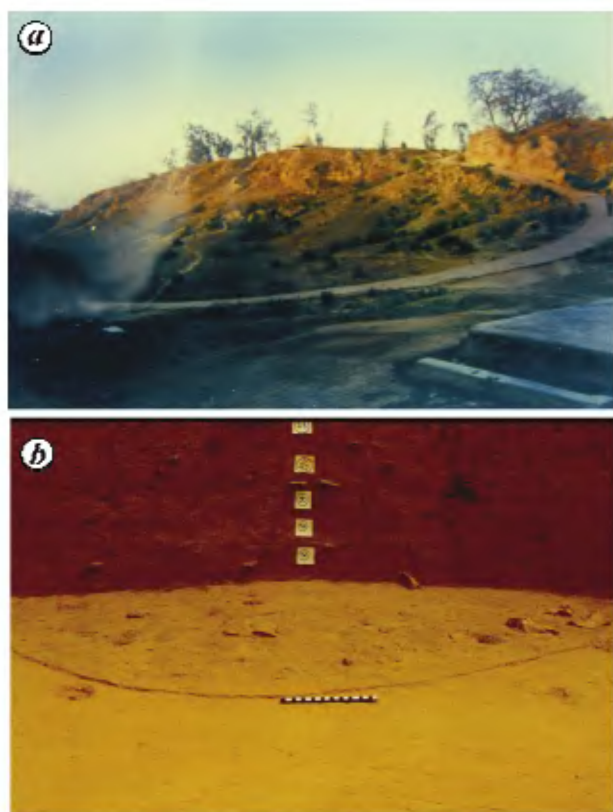
**Keywords:** Archaeobotany, Ganga Plain, Jhusi, macro-remains, neolithic.

THE aim of this communication is to present the results of the charred/carbonized plant remains recovered through archaeological excavations at Jhusi, and compare with the information on agriculture remains from other sites in the Middle Ganga Plain.

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**Figure 1.** Map showing archaeological sites discussed in the text (modified after ref. 49).



**Figure 2.** *a*, Panoramic view of Samudrakup mound. *b*, Excavated trench showing layers of Neolithic deposit.

The archaeological site, Jhusi ( $25^{\circ}26'10''\text{N}$  lat. and  $81^{\circ}54'30''\text{E}$  long.), also known as Pratihthanpur in ancient Indian literature, is situated at the confluence of the Yamuna and Ganga rivers in Allahabad, Uttar Pradesh (Figures 1 and 2). The excavation at Samudrakup mound of this site was started in 1995 by Misra and co-workers<sup>1-5</sup>

and continued for five seasons (1995, 1998, 1999, 2002 and 2003). The ancient habitation deposit at Jhusi<sup>6</sup> is resting on a geological formation having thickness of more than 10 m. The total thickness of cultural deposit at Samudrakup mound of Jhusi is about 16.5 m. It is a multi-culture site having deposits of Neolithic, Chalcolithic, Early Iron Age (Pre-Northern Black Polished Ware Culture (NBPW) with iron), NBPW, Sunga and Kushana period, Gupta period and Early Medieval period. The earliest habitation deposit at the site is Neolithic and has a thickness of 1.5 m. The evidence of Neolithic culture was found during the excavations<sup>5</sup> in 2002 and 2003. The artefacts recovered from Neolithic levels include hand made pottery consisting of cord impressed ware, rusticated ware, burnished red ware, burnished black ware and crude black-and-red ware; microliths, fragments of querns and mullers, bone arrowheads, micro-beads steatite and semi-precious stone beads, and animal bone remains<sup>6</sup>.

The plant remains from the Neolithic cultural sequence were collected from bulk sediment samples by means of water floatation technique during excavation in 2002. This helped in recovery of charred macro-remains, including wood charcoal, fruits and seeds. Floats were collected on a 25 mesh geological sieve. In general, the carbonized fruits and seeds have been found in a better state of preservation. However, severe carbonization in some cases turned the seeds and fruits devoid of diagnostic features. Fruits and seeds were examined and sorted into categories of distinctive morphological types under a stereobinocular. These morphotypes were then identified taxonomically on the basis of comparison with modern reference material as well as published seed illustrations and descriptions<sup>7-9</sup>. The bulk of fruit and seed material was found to consist of cereals (*Oryza sativa*, *Hordeum vul-*

**Table 1.**  $^{14}\text{C}$  radiocarbon dates of charcoal samples from Jhusi

Trench	Depth (m)	Layer	Lab no. BSIP	$^{14}\text{C}$ date (yrs BP)	Calibrated date (BP)	Calibrated date (BC)
SF-7	12.99–13.14	47	BS-2526	8140 $\pm$ 220	9055–9029	7106–7080
SF-7	13.37–13.47	50	BS-2524	6760 $\pm$ 190	7609–7591	5660–5642
SF-7	13.70–13.80	53	BS-2525	7110 $\pm$ 170	7939–7881	5990–5932

**Table 2.** Measurement and index values of plant remains recorded from Jhusi

Taxa	<i>n</i>	<i>nm</i>	<i>L</i> (mm)	<i>B</i> (mm)	<i>T</i> (mm)
<i>Oryza sativa</i>	250	100	4.60 (4.00–5.20)	2.35 (2.20–2.50)	1.85 (1.40–2.00)
<i>Hordeum vulgare</i>	148	100	4.70 (4.50–5.00)	3.25 (3.00–3.50)	2.25 (2.00–2.50)
<i>Triticum aestivum</i>	14	14	5.00 (4.70–5.30)	3.15 (3.00–3.30)	2.20 (2.00–2.40)
<i>Triticum sphaerococcum</i>	12	12	3.75 (3.50–4.00)	3.50 (3.00–4.00)	2.25 (2.00–2.50)
<i>Lathyrus sativus</i>	6	6	3.50 (3.00–4.00)	3.40 (3.00–3.80)	1.65 (1.50–1.80)
<i>Macrotyloma uniflorum</i>	9	5	4.13 (4.00–4.25)	2.65 (2.50–2.80)	1.40 (1.30–1.50)
<i>Vigna radiata</i>	76	20	3.65 (3.30–4.00)	2.75 (2.50–3.00)	2.75 (2.50–3.00)
<i>Lens culinaris</i>	310	100	3.10 (2.80–3.40)	2.75 (2.50–3.00)	1.25 (1.00–1.50)
<i>Sesamum indicum</i>	1	1	3.50	1.80	0.80
<i>Linum usitatissimum</i>	2	2	3.80–4.00	2.00–2.25	1.20
<i>Vitis vinifera</i>	1	1	6.50	4.50	2.50

nm, number of species measured.

*gare*, *Triticum aestivum* and *Triticum sphaerococcum*) and leguminous seeds (*Lens culinaris*, *Pisum arvense*, *Vigna radiata*, *Lathyrus sativus* and *Macrotyloma uniflorum* pulses). In addition, two oiliferous crops (*Linum usitatissimum* and *Sesamum indicum*), *Vitis vinifera*, *Emblica officinalis*, *Vicia sativa* and *Coix lachryma-jobi* could be identified.

Three radiocarbon dates of charcoal samples from different layers are available. Their calibrated values in BP and BC are detailed in Table 1.

Table 1 shows that dates correspond to early dates from Lahuradewa in Ganga Plain<sup>10–12</sup>, and Koldihwa<sup>13–15</sup> and Tokwa<sup>16,17</sup> in the Vindhyan region. On the basis of these radiocarbon dates, the Neolithic culture at Jhusi is dated to the 7th–6th millennium BC, though the beginning of the culture may be pushed back to the later half of 8th millennium BC<sup>6,16</sup>. However, our main objective here is to present the botanical findings.

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

*Oryza sativa* L. (rice, Figure 3a): Two hundred and fifty more or less complete and some broken grains could be segregated from the mixture. Practically all the grains are without husk. Grains are elongate to narrowly oblong, flattened and ribbed. Ribs vary from 3 to 4 in number.

*Hordeum vulgare* L. emend. Bowden (six-rowed hulled barley, Figure 3b): One hundred and forty eight somewhat more elongated grains, tapering towards the apex and with a widening ventral furrow have been encountered. Some of the grains show traces of longitudinal ridges along the flanks and the shallow ventral-furrow,

caused by lost husk. As some of the grains are partly asymmetrical or showing slight ventro-lateral twist (thus coming from lateral spikelets), the barley is identified as the six-rowed hulled type.

*Triticum* cf. *aestivum* L. (bread-wheat, Figure 3c): Grains elongate and relatively narrower towards both the ends. The thickest portion is in the middle and near the embryo. Dorsal side is flattish to somewhat rounded. Therefore, on the basis of shape and other morphological features, grains closely compare to those of *T. aestivum*.

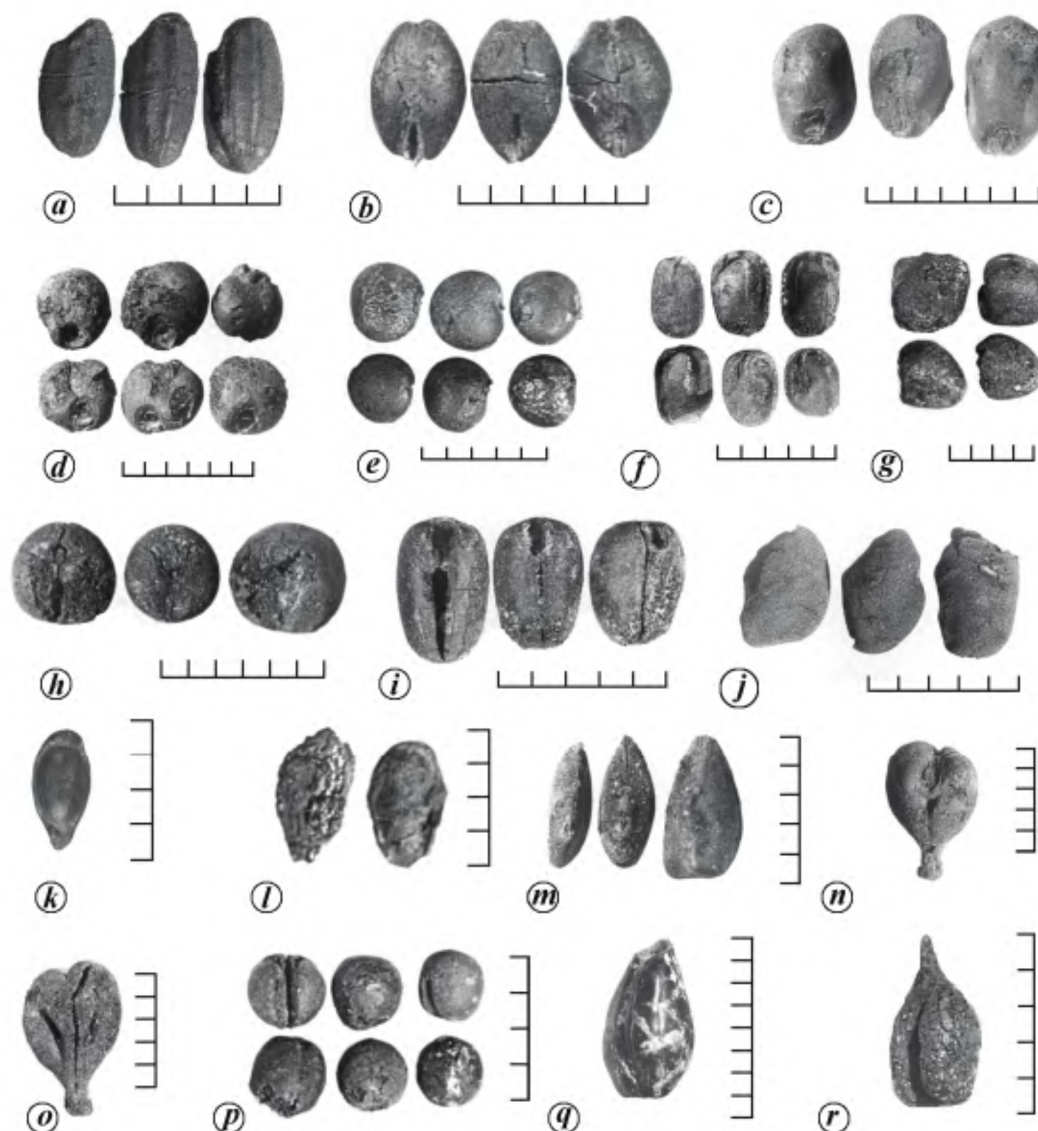
*Triticum sphaerococcum* Perc. (dwarf-wheat, Figure 3d): Twelve, broad and somewhat rounded or oval-round grains were encountered. Some of them exhibit broad and circular hump on their dorsal side.

*Lens culinaris* Medik. (lentil, Figure 3e): More than 300 seeds, either complete or partly broken were segregated from the bulk charred remains. Seeds circular and flattened with keeled margins, appear lenticular in shape. Hilum is very small and lanceolate.

*Vigna radiata* (L.) R. Wilczek (green-gram, Figure 3f and i): Complete seeds are somewhat cylindrical, with rounded to angular ends. Elliptical hilum is about 1.00 mm long and is more or less flush with the seed coat surface.

*Lathyrus sativus* L. (Grass-pea, Figure 3g): Seeds, somewhat squat and wedge-shaped in outline. Rough-textured seeds coat has partly been rubbed off. The small oval hilum has been noticed in few seeds.

*Pisum arvense* L., syn. *P. sativum* var. *arvense* (L.) Poir (field-pea, Figure 3h): Complete as well as broken seeds, spherical to somewhat hemi-spherical in shape have been recorded. Seeds measure 3.50–4.00 mm in diameter. Seed coat is blurred and rubbed off at places



**Figure 3.** *a*, *Oryza sativa* (rice); *b*, *Hordeum vulgare* (hulled barley); *c*, *Triticum aestivum* (bread-wheat); *d*, *Triticum sphaerococcum* (dwarf-wheat); *e*, *Lens culinaris* (lentil); *f*, *Vigna radiata* cotyledons (green-gram); *g*, *Lathyrus sativus* (grass-pea); *h*, *Pisum arvense* (field-pea); *i*, *Vigna radiata* (green-gram); *j*, *Macrotyloma uniflorum* (horse-gram); *k*, *Sesamum indicum* (sesame); *l*, *Linum usitatissimum* (linseed); *m*, *Emblica officinalis* (anwala); *n*, *Vitis vinifera* (grape) showing chalazal scar on dorsal side; *o*, *Vitis vinifera* (grape) showing two narrow and deep furrows on ventral side; *p*, *Vicia sativa* (common vetch); *q*, *r*, *Coix lachryma-jobi* (Job's tear) (scale in mm).

due to carbonization. Hilum is ovate and flush with the seed coat surface.

*Macrotyloma uniflorum* (Lam.) Verdc. (horse-gram, Figure 3j): Seeds roughly trapezoidal and flattish, with thin cotyledons have been encountered. Hilum is small and linear and positioned laterally in a small depression.

*Sesamum indicum* L. (sesame, Figure 3k): Single flat-ovate seed, having one end narrow and the other one rounded. Carbonization has blurred the appearance of characteristic faint central and marginal lines. However, the smooth surface seed can be placed under the cultivated *S. indicum*.

*Linum usitatissimum* L. (linseed/flax, Figure 3l): Two elongated seeds relatively narrower at one end, with

characteristic hooked tip in one of the specimens have been encountered. However, the characteristic hooked tip got devoured during handling.

*Emblica officinalis* Gaertn. (anwala, Figure 3m): In all, four trigonous seeds identified as of emblic myrabolan have also been encountered. Owing to its use in medicine, it is very important.

*Vitis vinifera* L. (grape vine, Figure 3n and o): Single pyriform seed, representing practice of viticulture has been identified in the bulk carbonized samples. Seed has elongated stalk. Ventral side of the seed has two narrow and deep furrows flanking a central longitudinal ridge. Whereas, on the dorsal side, an oval-circular and somewhat discoid shield like structure 'Chalazal scar' can be

seen. *V. vinifera* is the most important and universally cultivated species.

*Vicia sativa* L. (common vetch, Figure 3 p): In all 25 seeds, more or less globular to somewhat cubicular, measure 1.90–2.10 mm in diameter. Small, ovate hilum is raised along the median groove.

*Coix lachryma-jobi* L. (Job's tear, Figure 3 q and r): The evidence is furnished by involucre and seed. Involucres, false fruits or pseudocarps connote the bead-like oval-cylindrical structures of *Coix* grass, formed from hard shell-like bracts or metamorphosed leaf sheaths which enclose the female spikelets<sup>18–20</sup>. *C. gigantea*, *C. aquatica* and *C. lachryma-jobi* are three species of this grass, commonly occurring in the regions of Bihar and Orissa<sup>19</sup>. The involucre are hard and polished, and conform to those of the var. *lachryma-jobi* of *C. lachryma-jobi*. In other variety, involucre show striations. Both the varieties of this species grow commonly in wild state, along the water-courses, ditches, etc. and also cultivated by hill-tribes in the eastern region of India.

The plant and animal domestication contributed to the emergence of permanent sedentary settlements of Neolithic culture. Metal was either absent or insignificant. Farming, herding and foraging provided the subsistence base for these early farming communities. Neolithic at Jhusi is characterized by hand made pottery, cord impressed ware, rusticated ware, burnished red ware, burnished black ware and crude black-and-red ware; microliths, fragments of querns and mullers, bone arrow-heads, micro-beads steatite and semi-precious stone beads and animal bones.

In order to reconstruct the grain-based agriculture economy, systematic collection of botanical remains was made by floatation technique from this site. The remains of crop plants representing a small amount of plant resources utilized by the ancients are demonstrative of double cropping practice. Limitations in the data are inevitable as they survived the preservation by charring. The occurrence of plant remains in the deposits relies to a large extent not only upon their being present on the site, but upon the secondary process of carbonization. Therefore, plant remains inevitably provide an incomplete picture of past man-plant relationship. Taxon ubiquity<sup>21,22</sup> (represents the number of times a taxa appears in the samples of a particular period) which was used to analyse the data is given in Figure 4. The cereals in the collection comprise rice (*Oryza sativa*), barley (*Hordeum vulgare*), bread-wheat (*Triticum aestivum*) and dwarf-wheat (*Triticum sphaerococcum*). Leguminous crops in the collection are represented by the seeds of lentil (*Lens culinaris*), field-pea (*Pisum arvense*), grass-pea (*Lathyrus sativus*), horse-gram (*Macrotyloma uniflorum*) and green-gram (*Vigna radiata*). Oleiferous crops are represented by the seeds of sesame (*Sesamum indicum*) and linseed (*Linum usitatissimum*).

Rice, horse-gram and green-gram of Indian origin, were grown in the warm rainy season. Barley, bread-wheat, dwarf wheat, field-pea, lentil, grass-pea and linseed of near-eastern complex were grown in the winter season (Table 3). The evidence of barley (*H. vulgare*), bread-wheat (*T. aestivum*) and other winter crops along with summer crops like rice (*O. sativa*), etc. from early

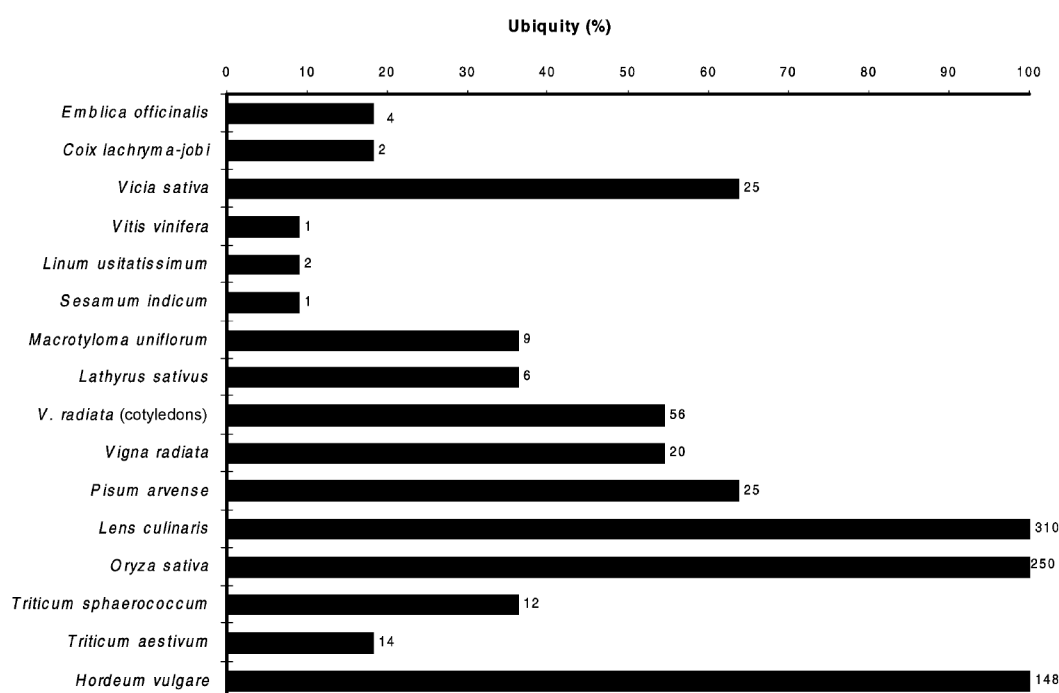


Figure 4. Abundance and ubiquity of charred seeds and grains found at Jhusi.

**Table 3.** Cultivated plants and their cropping season

Plant taxon	Cropping season
<b>Cereals</b>	
<i>Oryza sativa</i> (rice)	Summer
<i>Hordeum vulgare</i> (barley)	Winter
<i>Triticum aestivum</i> (bread-wheat)	Winter
<i>Triticum sphaerococcum</i> (dwarf-wheat)	Winter
<b>Pulses</b>	
<i>Lens culinaris</i> (lentil)	Winter
<i>Pisum arvense</i> (field-pea)	Winter
<i>Lathyrus sativus</i> (grass pea)	Winter
<i>Vigna radiata</i> (green-gram)	Summer
<i>Macrotyloma uniflorum</i> (horse-gram)	Summer
<b>Oilseed</b>	
<i>Sesamum indicum</i> (sesame)	Summer
<i>Linum usitatissimum</i> (linseed)	Winter
<b>Fruit</b>	
<i>Vitis vinifera</i> (grape)	Winter

levels of Jhusi indicate that possibly the area was in cultural contact with the original home of winter crops right from the early phase of the Neolithic culture.

The available evidence from other sites in Ganga Plain (Table 4) shows analogous status of agriculture during Neolithic and Chalcolithic cultures<sup>10,23–27</sup>. In addition to the indigenous crops in which rice was the most important, a substantial expansion in the kinds of subsistence resources of the Mediterranean, Central Asian, Eurasian and African regions made considerable dynamism in the agricultural economy of the Ganga Plain (Table 4).

*O. sativa* (rice) dominated the other cereals in abundance at Jhusi. Rice is the most important crop in the development of agriculture in the Ganga Plain, which is a part of natural habitats of wild rice and in this zone, the domestication and cultivation must have been resulted since pre-historic times<sup>28</sup>. The Neolithic site Lahuradewa<sup>10–12</sup> in Ganga Plain, and Koldihwa and Mahagara<sup>6,13,14,16</sup> in Vindhyan region have produced the earliest finds of rice in India dating back to 7–6th millennia BC. However, the dates have not been widely accepted for the cultivated variety of rice<sup>29–31</sup>. According to Possehl<sup>32</sup>, the Koldihwa dates could be aberrations and it is more likely that they are indications of an earlier, unreported occupation at the site. However, it can be pointed out that there is no archaeological evidence at the site prior to the Neolithic culture. Radiocarbon dates from Jhusi and Lahuradewa in the Ganga Valley, and Tokwa in the Vindhyan region suggest an early beginning of agriculture in the region. If we get some more dates from fresh excavations as well as direct AMS dating of the grains, the problem of dating will be finally settled.

The oldest record of barley and wheat in the Indian subcontinent is known from Mehrgarh in Baluchistan<sup>33–35</sup>

(7000–5500 BC). Barley, wheat, rice, lentil, field-pea and grape seeds have been found in Period-III at Leobanr in the sequence of Ghaligai (ca. 2970–2920 BC) settlements of the Swat valley<sup>36</sup>. Rice, which is the crop of Gangetic plains, possibly moved in competition with these crops through the cultural contacts<sup>23</sup>. Evidence of cultivated rice in the early Harappan context at Kunal, Haryana (ca. 3000–2500 BC) is also equally important<sup>37</sup>. The presence of winter-cultivated crops such as barley, wheat, lentil, field-pea, grass-pea and flax, into the rice growing zone, spread from the early cultures in the NW regions. We still need to know what sort of cultural network led the widespread diffusion of these north-western crops in the Middle Ganga Plain and Gangetic crop in the NW direction, and how it took place at such an early date. Corridors are two-way avenues and there is no reason to suppose that the corridors of agricultural diffusion of which we are talking were not operative in much earlier times. It presents a problem to archaeological research which will surely attract attention in future. The factual remains of food-grains from the beginning in the Neolithic deposits at Jhusi, connote the stage when these crops became an essential economic staple.

Empirical study of data produced by archaeological excavations at Lahuradewa<sup>10,27</sup>, Imlidih-khurd<sup>28</sup>, Khairadih<sup>25,28</sup>, Waina<sup>25,28</sup>, Narhan<sup>38</sup> and Chirand<sup>39</sup>, confirms through botanical remains that the north-western crops during much earlier times, did have substantial influences in agricultural developments of far distant areas in the east and the spread of new crops, which were principal founder crops in the Pre-Harappan and the Harappan economy<sup>23,33–37</sup>.

*Vitis vinifera*, *Vicia sativa*, *Embllica officinalis* and *Coix lachryma-jobi* have been encountered as an admixture with the crop remains. *V. vinifera* is the most important and universally cultivated species evocative of practice of viticulture or horticulture in the region. Remains of grape-vine have provided unequivocal evidence of viticulture from pre-Harappan and Harappan times<sup>23,36,37,40</sup>. Before the factual evidences from archaeological sites, information on the grape and its cultivation was based on the literary and ancient sculptures. Grapes were known through the accounts of Charak and Susruta in their early medical treatises (5th century BC), and there was almost no information of their cultivation, prior to the Muslim conquest of the country<sup>41</sup>.

The evidence of grape-vine on Indian sculptures has come from Sanchi and Bharhut stupas in Madhya Pradesh, datable to 2nd–3rd century AD<sup>42</sup>. Smith<sup>43</sup> and Marshall *et al.*<sup>44</sup>, however, regarded the vine as a characteristic motif of Hellenistic art. According to Watt<sup>45</sup>, viticulture in India never at any period was regarded to have attained the proportions it assumed in the Greek and Roman ages of Europe. Now, in view of the factually evidenced viticulture since the Neolithic and Harappan times, all these opinions stand untenable. Further, evidences of onion

Table 4. Plant remains recorded from archaeological sites in Middle Ganga Plain, India

Plant remains	Lahuradewa (UP)				Imlidih-Khurd (UP)				Narhan (UP)		Khairadih (UP)		Waina (UP)	Chirand (Bihar)
	Period-IA 6400-3000 BC	Period-IB 3000-2000 BC	Period-II 2000-1500 BC	Period-I 1600-1400 BC	Transitional phase 1400-1300 BC	Period-II 1300-800 BC	Period-I 1300-800 BC	Period-II 800-600 BC	Period-III 600-200 BC	Period-I 2000-800/700 BC	Period-II 700/600-200 BC	Period-I 1600-800 BC	Period-II 800-600 BC	Period-I ca. 2500 BC
Rice ( <i>Oryza sativa</i> )	+													+
Barley ( <i>Hordeum vulgare</i> )		+	+	+	+									+
Dwarf-wheat ( <i>Triticum sphaerococcum</i> )		+	+	+	+									+
Bread-wheat ( <i>Triticum aestivum</i> )		+	+	+	+									+
Ragi-millet ( <i>Eleusine coracana</i> )														+
Jowar-millet ( <i>Sorghum bicolor</i> )														+
Kodon-millet ( <i>Paspalum scrobiculatum</i> )		+												+
Italian-millet ( <i>Setaria italica</i> )														+
Pearl-millet ( <i>Pennisetum glaucum</i> )														+
Lentil ( <i>Lens culinaris</i> )		+												+
Field-pea ( <i>Pisum arvense</i> )														+
Grass-pea ( <i>Lathyrus sativus</i> )														+
Horse-gram ( <i>Macrotyloma uniflorum</i> )														+
Green-gram ( <i>Vigna radiata</i> )														+
Black-gram ( <i>Vigna mungo</i> )														+
Moth-bean ( <i>Vigna aconitifolia</i> )														+
Cow-pea ( <i>Vigna unguiculata</i> )														+
Chick-pea ( <i>Cicer arietinum</i> )														+
Sem ( <i>Lablab purpureus</i> )														+
Til ( <i>Sesamum indicum</i> )														+
Field-brassica ( <i>Brassica juncea</i> )														+
Safflower ( <i>Carthamus tinctorius</i> )														+
Linseed ( <i>Linum usitatissimum</i> )														+
Castor ( <i>Ricinus communis</i> ) wood charcoal														+
Cotton ( <i>Gossypium arboreum</i> ) herbaceous														+
Phut/Kheera ( <i>Cucumis melo</i> )														+
Water-melon ( <i>Citrullus lanatus</i> )														+
Onion ( <i>Allium cepa</i> )														+
Fenugreek ( <i>Trigonella foenum-graecum</i> )														+
Coriander ( <i>Coriandrum sativum</i> )														+
Ajwain ( <i>Carum copticum</i> )														+
Grape pips ( <i>Vitis vinifera</i> )														+

Lahuradewa<sup>10,12,27</sup>; Imlidih-Khurd<sup>28</sup>; Narhan<sup>38</sup>; Khairadih<sup>25,28</sup>; Waina<sup>25,28</sup>; Chirand<sup>39</sup>. +, Indicates presence.

from Waina (1600–800 BC) and sem from Imlidih-khurd (1300–800 BC) also support horticultural practice in the region of Ganga Plain.

*V. sativa* occurs as the most frequent weed in the pulse-crops. It is a forage legume of rich protein value, eaten by cattle and also used as hay. This species spread in the Indian region from Europe, through the North Temperate Zone in the Old World.

*E. officinalis* occurs throughout India, rising in the hills<sup>46</sup> to 4000 ft. Owing to its use in medicine, it is very important. It may have been in cultivation for the sake of fruits.

Job's tear (*C. lachryma-jobi*), native to South-East Asia is common throughout Middle Ganga Plain. It is common along water courses, ditches, etc. This wild grass with its hard and smooth shelled fruits is also cultivated in many parts of the tropics, particularly among the hill tribes. The grains of wild and cultivated types are used as food. Job's tear was at one time a fairly important cereal of the wet tropics in south-eastern Asia. It has been reported to be still cultivated as a cereal in the Philippines and New Guinea and by the hill tribes of Veitnam, Cambodia and Laos. Its cultivation spread to areas where rice culture was not yet penetrated. Job's tear which is at present a minor cereal has been thought to be older domesticate than rice. Its cultivation has been replaced to a large extent by rice cultivation<sup>47</sup>. The most important value of *C. lachryma-jobi* lies in its ornamental utility<sup>48</sup>. When ripe, the involucre are uniform, hard, in the shape of a tear drop, and with a porcelain-like surface. The colour varies from black, grey, white and brown.

The study of the plant remains from this site has proved to be informative and highlights the potential for problem-oriented research into the beginnings of agriculture in Ganga Plain.

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## Comparison of bulk organic matter characteristics in sediments of three Kumaun Himalayan lakes

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**Three lakes (Nainital, Sattal and Naukuchiatal) in the Kumaun Himalayan region were investigated for total organic carbon (TOC%) and nitrogen (N%), their atomic ratios (C/N) and isotopic composition ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) in their sediments. These geochemical proxies measured in 35–45 cm long cores indicate that organic matter preserved in the lake sediments is primarily derived from algal matter. Increase in TOC in all the three lakes suggests increased productivity. The sediments are anoxic in all the three lakes and show low N%. Shift in  $\delta^{13}\text{C}$  isotopic composition indicates influence of sewage input into the lakes. Likewise, increase in  $\delta^{15}\text{N}$  in surface sediments suggests nitrogen fixation by cyanobacteria.**

**Keywords:** Kumaun lakes, lake sediments, organic matter, stable isotopes.

ORGANIC matter (OM) in sediments provides a variety of geochemical proxies to understand the source and depositional history in lacustrine environments<sup>1–3</sup>. In particular, small amounts of OM preserved in lake sediments retain their original source characteristics, and reflect the environmental conditions prevailing in the catchment at the time of their deposition. This information is useful for tracing natural vs human-induced changes and their impacts on lacustrine ecosystems.

The three lakes, namely Nainital, Sattal and Naukuchiatal in the Kumaun Himalayan region are among the most frequented tourist destinations in India. Recent increase in tourist population and rapid urbanization in the watershed has resulted in various environmental issues<sup>4</sup>. Numerous studies indicate higher sedimentation rates in recent years, accumulation of heavy metals, eutrophication and occasional fish kills in these lakes<sup>4–7</sup>. It is likely that OM preserved in these lake sediments holds key information towards reconstructing these palaeoenvironmental changes in the absence of past instrumental records or water column data. Hence, in the present study, we compare the different OM sources and preservation in sediments of these Himalayan lakes.

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