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The southern Central Asian mountains as an ancient agricultural mixing zone: new archaeobotanical data from Barikot in the Swat valley of Pakistan

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Abstract

The mountain foothills of inner Asia have served as a corridor of communication and exchange for at least five millennia, using historically documented trade routes such as the Silk Road and the Tea-Horse Road. Recent research has illustrated the important role that this mountain corridor played in the dispersal of crops and farming technology between northeast and southwest Asia 5,000 to 1,000 years ago. However, the role of the mountain valleys along the southern rim of the Pamirs and Himalaya in facilitating crop dispersals has not yet been fully explored. Notably, ongoing debates over secondary dispersals of *Hordeum* (barley) and *Triticum* (wheat) into China and the routes of dispersal for the East Asian crops *Oryza sativa* (rice), *Prunus persica* (peach) and *P. armeniaca* (apricot) into northern India are continuing topics of inquiry. In this article, we add to these discussions by focusing on archaeobotanical remains from the Barikot site (ca. 1200 BCE–50 CE) in the Swat valley of northern Pakistan. The Swat valley is an ancient settlement zone in the Hindu Kush-Karakoram foothills, whose cultural features have always had a strong link with inner Asia. The archaeobotanical assemblage illustrates that a diverse array of crops, with origins across Asia, were cultivated around the same settlement. Additionally, these farmers likely implemented seasonal cropping cycles and irrigation that required various labour inputs and water management regimes.

Keywords Crop rotation cycles · Archaeobotany · Swat valley · Irrigation · Rice · Northern Pakistan

Introduction

Human populations around the world congregate in biologically rich ecotonal zones; as such, mountain foothills often represent cultural hotspots (Turner et al. 2011).

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Archaeological research across inner Asia has consistently shown high human population density throughout these ecotones between hills and lowlands, especially in river valleys or alluvial floodplains (Spengler et al. 2013; Frachetti et al. 2018). These river valleys have served as agricultural experimentation zones for millennia (Spengler 2019). Farmers grew both southwest and northeast Asian crops in these foothills for the first time in the late 3rd millennium BCE, representing some of the earliest agriculture in Central Asia (Spengler et al. 2014; Spate et al. 2017; Zhou et al. 2020).

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The even earlier first agriculture in South Asia has been identified in Balochistan, southwest Pakistan, at the sites of Mehrgarh, Sherikhan Teraki, Sarai Khola and Kili Gui Muhammad, all on alluvial fans (Petrie and Thomas 2012). The ease of irrigation along the alluvial slopes facilitated experimentation with farming practices, such as the development of crop rotation cycles (Miller et al. 2016; Spengler 2019). Over the past few years, archaeobotanical investigations along the inner Asian mountain corridor from the Pamirs north to the Altai (Kuzmina 2008; Frachetti 2012), has greatly expanded our understanding of crop diversification (Liu et al. 2016; Motuzaite Matuzeviciute et al. 2018; Spengler et al. 2018) and technological advances in cultivation (Miller et al. 2016). Yet, further south along the southern rim of the Pamirs, Hindu Kush, Kunlun and Himalaya, there are still questions regarding when and from where certain crops arrived. Historically, farmers there have grown a mixture of crops of East, South and southwest Asian origins together with North African crops, creating a unique economy across northern India and Pakistan. These crops all have

differing cultivation requirements, including water needs, growing day lengths and minimal season durations. In this paper, we contribute to the understanding of cultivation systems in the river valleys and alluvial plains of the southern Central Asian mountains, by adding archaeobotanical data from the site of Barikot (ca. 1200 BCE to 50 CE) in the Swat valley of northern Pakistan (Fig. 1). We further explore three questions: 1, what water-demanding crops were cultivated in this semi-arid region; 2, were crop rotation cycles used; and 3, what role did arboriculture play in the economy.

Sharp transitions between altitudinal ecoclines (ecological gradients determined by the elevation level on a mountain) cause greater biodiversity than the flat steppe or desert regions. The ability to access seasonally available resources at different points on the ecoclines or to shift the elevation of grazing pastures or cultivated fields allows people to adapt better to ecological changes and to use complex foraging or farming strategies. Ethnobotanical studies of wild plant foraging in the Swat valley demonstrate that people use seasonally specific plants from different ecotonal zones and are

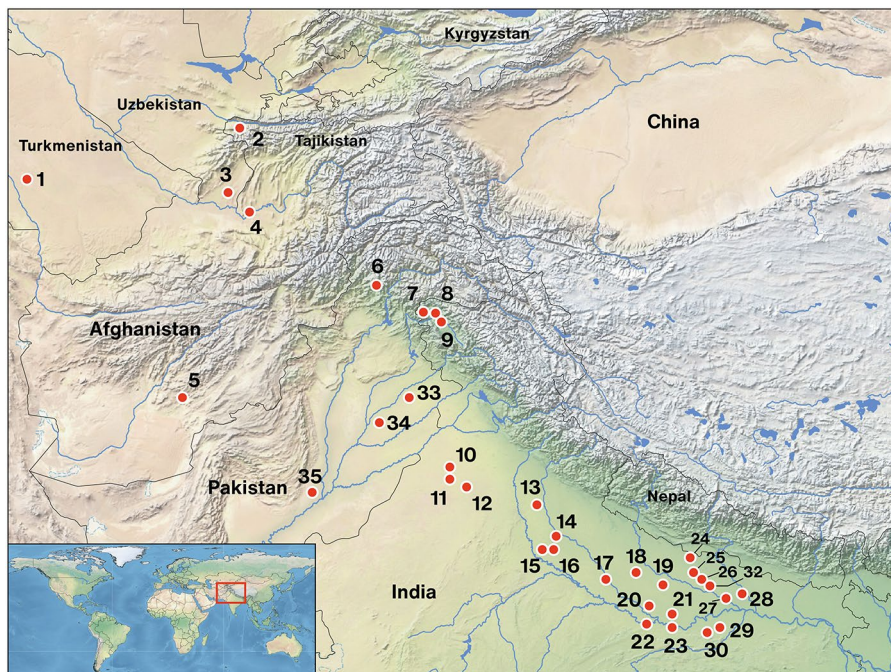


Fig. 1 A map of southern Central Eurasia, with selected agricultural villages or urban sites from the 2nd and 1st millennia BCE with archaeobotanical results. 1, Murghab sites (ca. 3000–1000 BCE); 2, Sarazm (ca. 3500–2000 BCE); 3, Djarkutan (ca. 2500–1500 BCE); 4, Shortughai (ca. 2500–1500 BCE); 5, Mundigak (ca. 4500–2200 BCE); 6, Barikot (ca. 1200 BCE–50 CE); 7, Kanispur (ca. 2700–2000 BCE) and Qasim Bagh (ca. 1800–1400 BCE); 8, Burzahom (ca. 2400–600 BCE); 9, Gufkral (ca. 2400–1600 BCE) and Semthan (ca. 1500–1 BCE); 10, Kunai (ca. 3000–2000 BCE); 11, Bhirrana (ca. 3300–2800 BCE); 12, Siswal (ca. 3800–1500 BCE); 13, Hastinapur (ca. 900–500 BCE); 14, Atranjikhhera (ca. 2000–200 BCE); 15, Indor-Khera (ca. 1300–600 BCE); 16, Lal Quila (ca. 2000–1500 BCE); 17, Radhan (ca. 2000–1000

BCE); 18, Hulashkhera (ca. 800–200 BCE); 19, Damdama (ca. 3800–2000 BCE); 20, Sringaverapura (ca. 1000–700 BCE); 21, Hetapatti (ca. 2500–1500 BCE); 22, Kausambi (ca. 600–200 BCE); 23, Jhusi (ca. 2200–1900 BCE); 24, Lahuradewa (ca. 6000–1500 BCE); 25, Imlidithkhurd (ca. 2000–800 BCE); 26, Khairadih (ca. 2000–200 BCE); 27, Waina (ca. 1600–600 BCE); 28, Chirand (ca. 2000–1200 BCE); 29, Senuwar (ca. 2200–600 BCE); 30, Raja-Nal-ka-Tila (ca. 1300–700 BCE); 31, Rajdhani (ca. 800–200 BCE); 32, Narhan (ca. 1300–200 BCE); 33, Harappa (ca. 2600–1900 BCE); 34, Jalilpu (ca. 2000–1000 BCE); 35, Mehrgarh (ca. 7000–2600 BCE); references for the sites and their archaeobotanical assemblages are provided in ESM 2

aware of resource distribution in time and space (Ahmad et al. 2011; Zeb et al. 2013). Many Central Asian mountain ranges have high glacial peaks, which can represent challenges to cross them, especially during the colder season. As a result, mountain passes have historically been areas of great attention, not only providing routes of passage, but also water and forage for grazing livestock, and they also provide useful archaeological deposits (Frachetti et al. 2018; Taylor et al. 2019). The High Terek pass historically connected Xinjiang to Central Asia through the Alay mountains of Kyrgyzstan, as the Jiptik, Torugart, and Irkeshtam passes did through the Pamir mountains. Further south, the valleys of Kashmir, Khyber and Swat in the western Himalayan Hindu Kush region of Pakistan possess dense archaeological deposits, reflecting the funnelling of human populations through them from the 3rd millennium BCE until today (Bandey 2009; Han 2012; Coningham and Young 2015; Vidale et al. 2015; Olivieri 2017; Olivieri et al. 2019). These valleys have a long history of sedentary agropastoral occupation, relying on a variety of different crops and large deep conical storage pits (Costantini 1987; Lone et al. 1993; Spate et al. 2017). They also witnessed a tumultuous succession of changing empires between ca 500 BCE and 500 CE (Olivieri et al. 2019).

Interestingly, despite strong cultural dispersal through these mountain valleys, there is limited evidence for human gene flow (Jeong et al. 2016). The Swat valley in particular shows an impressive genetic continuity over three millennia from 1200 BCE to 1200 CE (Narasimhan et al. 2019), which can tentatively be read as the consequence of the exceptional stability of farming in Swat. Most of the spread of human genetic material onto the plateau came from the north, where ecoclimatic gradients are not as pronounced. In this sense, the mountains of Hindu Kush and southern Himalaya may have served as a genetic barrier to populations at low elevations, who were not physiologically adapted to the thin air and other ecological constraints of the higher land (Jeong et al. 2016). Archaeological research in the Kali Gandakhi valley and other neighbouring regions in the southern Himalaya illustrate a system of exchange that connected people in the high mountains to populations lower down, in the upper Indus and Ganges (Ganga) drainage basins (Aldenderfer and Eng 2016; Jeong et al. 2016). Evidence for systematic exchange comes from finds of carnelian and glass beads, serving vessels, cups, bamboo mats and cotton cloth in 1st millennium BCE burials (Eng and Aldenderfer 2017), textiles of cotton, linen and wool, produced in tabbies and twills (Gleba et al. 2016), metal artefacts from the mid 1st millennium CE (Massa et al. 2019) and salt (Dhungel 2002). Additionally, the well-documented Tea-Horse Road ran from the southern China lowlands, in what is now Yunnan, to the high plateau during the late 1st millennium CE (Mair and Hoh 2009). These patterns of exchange between high and low regions seem to exist for the river valleys spanning the

entire periphery of the Central Asian montane zone, and this study places the data from Barikot in this cultural context. Therefore, the Barikot site provides an ideal case study for better understanding the movement of material culture, including crops, between South, Central and East Asia.

The Barikot site

Barikot is located on a silty terrace below a rocky outcrop (34° 40' N, 72° 12' E; 799 m a.s.l.) in the middle of the Swat valley, Khyber Pakhtunkhwa Province, Pakistan, at the confluence of two tributary rivers, the Kandag and Karakar (Vidale and Olivieri 2002). The first evidence of human occupation at Barikot goes back to ca. 1700–1400 BCE (Swat Period IV; Stacul 1987), although occupation in the area dates back to the early 3rd millennium BCE, as evidenced at the nearby cave of Galeghai (Stacul 1987). From 1200 to 800 BCE, archaeological data show the presence of a large settlement (roughly 15 ha), including a hilltop acropolis (Callieri et al. 2000), an inner stronghold (Olivieri et al. 2019) and an extensive outer graveyard (Narasimhan et al. 2019). After a phase of abandonment with scarce archaeological data, the construction of an urban centre began at ca. 500 BCE (Olivieri and Iori 2020; Olivieri et al. 2019). The site was already fortified, before the construction of a long urban wall with square towers every 28 m which was built after 150 BCE at the time of the successors of the Indo-Greek ruler, Menander. At that time the city included an acropolis on the rocky outcrop and covered ca. 12 ha. The city grew in the following centuries, reaching its maximum area at the time of the Kushans around the second century CE. After a series of earthquakes combined with the collapse of the Kushan Empire, the lower city was abandoned towards the end of the third century or slightly later (Olivieri 2011, 2012) and reconstructed along the flanks of the acropolis (Olivieri 2003). The site has been excavated by the Italian archaeological mission in Pakistan, Istituto Italiano per il Medio ed Estremo Oriente (ISMEO), Italian Institute for the Middle and Far East (now ISMEO, International Association of Mediterranean and Oriental Studies), since the 1970s in sondages by G. Stacul (with important contributions by L. Costantini and other specialists) and it has been consistently excavated since 1984, under the directorship of P. Callieri and L.M. Olivieri.

Barikot is located on the highest and most strategic point in the valley. It is characterized by a rocky hill overlooking the Swat river to the north, and a vast terrace sloping down to the south. The area is marked by two tributary valleys, of the rivers Karakar and Kandak, which flow through about 100 km² of fertile silty plains surrounded by mountains. This area represents the *ager* (catchment area including agricultural fields) of Barikot (Fig. 2). The city is known in Classical sources as Bazira

Fig. 2 The site of Barikot, its ager (surrounding land), and the middle Swat valley seen from the southwest (photo by Carla Biagioli, courtesy ACT, Italian Archaeological Mission in Pakistan)



or Beira (Beira = Pakistani and Indo-Iranian *va(y)ira* and Bazira = Sanskrit *vajra*, Baums 2019) and in medieval sources as Vajirasthana (von Hinüber 2020). It was an Assakenian stronghold that was besieged and conquered by Alexander the Great in 327 BCE. The area was renowned in antiquity for its fertility; in historical sources the abundance of crops and the size of herds in this area were praised by Arrian of Nicomedia in the early second century CE (Brunt and Robson 1976–83, IV 25, 4). Curtius Rufus defined it as an *urbs opulenta* (rich city) in the first century CE (Atkinson and Yardley 2016, VIII 10, 22), the latter being a term clearly indicating agricultural wealth, which is otherwise very rarely used by the Roman historian and only applied to Tarsos, Babylonia, Persepolis and to Bactria (L. Prandi, personal communication). Previous archaeobotanical research in the Swat valley by Costantini (1987) included a section on earlier occupation layers at Barikot (ca. 1700–1400 BCE). The present work on Barikot represents the first large scale and systematic archaeobotanical study in this region; the data presented here reveal the agricultural system used across the mountain valleys and alluvial fans in the past; they also helps link ongoing discussions about South and Central Asia. By working on this site we can begin to fill in the gaps in our understanding of the spread of crops across the ancient world.

Methods

Sediment samples were collected from the site during excavations in 2016 and 2017, from all distinct features and occupation phases in two excavation trenches, 12W and 11K. The first trench was opened outside the Indo-Greek urban wall, the second roughly 100 m inside the area marked by that wall. The quantity of soil varied between samples, mostly about 7 L which was the size of the sediment bag used. Since the flotation of sediments was done during the excavation, we decided to keep the time gap between excavation and floating very short by not storing sediment samples, so to minimize the risk of contamination or mixing of samples. The samples were floated in the field using a water overflow machine, as described by Fritz (2005), Pearsall (2000) and Watson (1976). Flotation was organized by L. M. Olivieri and performed by M. Vidale, E. Iori, M. Fantoni, with Mr. Abid, ISMEO field officer at Barikot. The minimum sieve size used for the light fraction was ca. 1.4 mm, and heavy fraction material was not collected. The floated samples were then dried, packaged, and, once licensed by the archaeological authorities in Pakistan, were exported to the archaeobotanical laboratory in Jena, Germany. The export license was granted to L.M. Olivieri as director of the ISMEO mission

by the Department of Archaeology and Museums, Government of Pakistan. Similarly, the non-objection certificate was issued by the Directorate of Archaeology and Museums, Government of Khyber Pakhtunkhwa.

In the laboratory, the samples were systematically sorted and all botanical remains were identified and quantified (ESM 1). All of the identified botanical remains were carbonized except for a few mineralized *Celtis* fruitstones, which are prone to mineralization. We identified the botanical remains using a personal comparative collection of plant remains and a number of identification keys, including Cappers and Bekker (2012) and Neef et al. (2012). All domesticated crops are individually reported, with density, ubiquity and abundance counts presented in Table 1. Seeds of wild plants appeared at extremely low densities and all possible weed seeds or dung burning remains are mentioned below. Mean number of individuals (MNI) estimates are not used, but we liberally applied the category of Cerealia to include all domesticated grain fragments that were too broken or damaged to differentiate between wheat and barley. In most cases, if less than 50% of the complete grain was present, we included it in Cerealia in an attempt not to artificially inflate the abundance counts. The category of Legume was used to describe fragments of domesticated legumes that were too damaged or fragmented to assign to a type. Due to the coarse sieve mesh used, millet grains and most seeds of wild plants were lost during flotation, if they were present in the first place. The loss of any millet grains has significant implications for interpreting seasonal crop cycles and crop diversification. The limitations of these data for interpreting crop complexes and cultivation practices are discussed below.

Results

The archaeobotanical assemblage from Barikot consists of 159 sediment samples representing 140 individual layers or contexts, which were collected over two separate field seasons. These samples represent a comprehensive blanket sampling of the excavated units, and they should evenly reflect the food plants present over the duration of occupation. In total, the assemblage consists of 5,450 morphologically identified seeds; 934 of those come from the 2016 field season excavations in Trench 12W, 2,642 of them came from the 2016 excavations in Trench 11K, and 1,874 of them came from the 2017 excavations in Trench 11K (ESM 1). In addition to the total sum of identified seeds, there were 596 fragments of Cerealia, and 226 Legume fragments. We do not include Cerealia or Legumes in the total counts, so as not to artificially inflate the crop counts. Surprisingly, there were only 510 fragments of wood larger than 2.0 mm, but these were not identified to species, as there was not a suitable comparative collection of the trees in this region. Of the total 5,450 seeds, 5,301 of those were domesticated grains or legumes. There were also 49 *Gossypium arboreum/herbaceum* (cotton) seeds. Additionally, there were several fruits and nuts, including 25 *Vitis vinifera* (grape) pips, 14 *Celtis caucasica* (hackberry) pips (mostly mineralized), seven *Ziziphus nummularia* fruitstones, six possible *Prunus* fruitstone fragments, two each of *Juglans regia* (walnut) nutshell fragments, *Prunus cf. armeniaca* (possible apricot) and *cf. Daphne*, one *Rosa* sp., and a possible *Cucurbita* sp. (Fig. 3). The remaining seeds of wild plants include nine *Cannabis* seeds (a wild morphotype), nine Pooid grass seeds, two each of Cyperaceae, Poaceae, Fabaceae, and one each of *Galium* sp. and *Euphorbia*.

Table 1 The main crops at Barikot, ubiquities, densities and abundance measurements by phase

| Phase measurements | 1 | | | 2 | | | 3 | | | Total counts |
|------------------------------|--------------|-------------------|--------|----------|---------|--------|----------|---------|--------|--------------|
| | Ubiquity (%) | Density (seeds/L) | Counts | Ubiquity | Density | Counts | Ubiquity | Density | Counts | |
| <i>Triticum</i> sp. | 48.94 | 0.034 | 83 | 64.56 | 0.033 | 301 | 54.55 | 0.006 | 26 | 410 |
| <i>Hordeum</i> sp. | 85.11 | 0.340 | 833 | 88.61 | 0.127 | 1,154 | 87.88 | 0.055 | 248 | 2,235 |
| <i>Oryza</i> sp. | 89.36 | 0.239 | 586 | 89.87 | 0.078 | 705 | 63.64 | 0.026 | 115 | 1,406 |
| <i>Lens culinaris</i> | 42.55 | 0.052 | 128 | 68.35 | 0.055 | 499 | 51.52 | 0.011 | 51 | 678 |
| <i>Lathyrus sativa</i> | 2.13 | 0 | 1 | 1.27 | 0 | 1 | 0 | 0 | 0 | 2 |
| <i>Pisum sativum</i> | 25.53 | 0.016 | 39 | 60.76 | 0.022 | 196 | 42.42 | 0.012 | 52 | 287 |
| <i>Vigna</i> sp. | 23.40 | 0.012 | 29 | 50.63 | 0.012 | 110 | 15.15 | 0.002 | 11 | 150 |
| <i>Macrotyloma uniflorum</i> | 8.51 | 0.06 | 15 | 26.58 | 0.05 | 47 | 6.06 | 0 | 2 | 64 |
| <i>Gossypium</i> sp. | 2.13 | 0.001 | 2 | 13.92 | 0.002 | 15 | 42.42 | 0.007 | 32 | 49 |
| <i>Vitis vinifera</i> | 6.38 | 0.001 | 3 | 16.46 | 0.002 | 22 | 0 | 0 | 0 | 25 |
| Cerealia | 51.06 | 0.095 | 232 | 62.03 | 0.032 | 294 | 39.39 | 0.016 | 70 | 596 |
| Legumes | 31.91 | 0.019 | 47 | 43.04 | 0.015 | 140 | 42.42 | 0.009 | 39 | 226 |

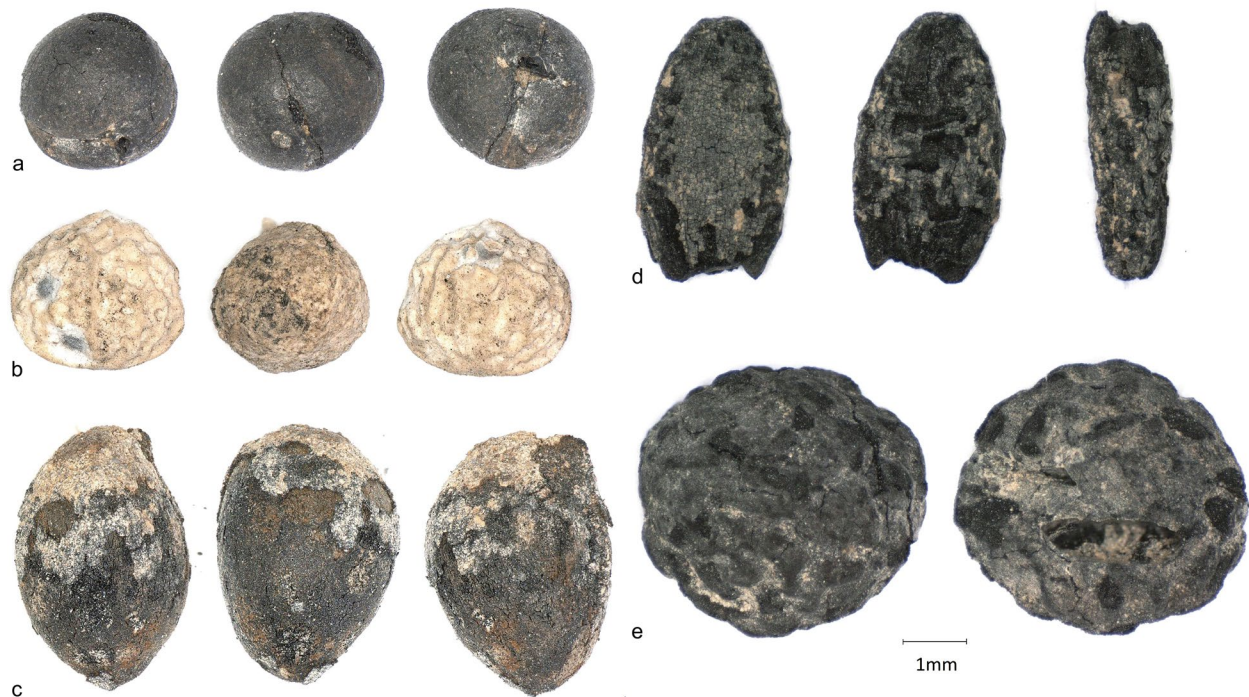


Fig. 3 A few key non-grain crops from the Barikot assemblage. **a** three views of a *Pisum sativum*; **b** mineralized *Celtis caucasica* fruitstone; **c** *Gossypium* sp. seed; **d** the single possible cucurbit seed from the assemblage; **e** *Ziziphus nummularia* fruitstone

Of the 5,350 grains and legumes, the most dominant crop in the assemblage was *Hordeum* (barley) ($n=2,235$). It appeared to be primarily *H. vulgare* var. *vulgare* (a hulled six-rowed form), which is typically found in Central and South Asia for this time period (Spengler 2015). Some naked barley morphotypes may have been present, but we did not systematically quantify them. There were also 410 *Triticum* (wheat) grains, which all appeared to be a free-threshing form—presumably *T. aestivum* ssp. *aestivum* (bread wheat). Some of these were highly compact, similar to modern sphaerococcoid types, but, as with most wheat landraces, a wide range of variation was present. The wheats mostly appeared to be hexaploid, but there were a few that might be tetraploid durum wheats. As crops spread north from India and northeast from the Iranian plateau into Central Asia, the hulled wheats were left behind, although, *T. turgidum* ssp. *durum* (free-threshing tetraploid wheat) from the 3rd millennium BCE has been reported from Kashmir (Stevens et al. 2016). Therefore, the possibility should be considered that the few morphologically distinct grains from Barikot could be from glume wheats.

The lack of millets in the assemblage is most likely a result of the coarse sieve meshes used during recovery in the field, although future research will possibly modify this assumption. There were also 1,406 *Oryza sativa* (rice) grains, which varied immensely in morphology and range from elongated to compact, but mostly overlapped with

measurements for *O. sativa* ssp. *japonica* (Chen et al. 2020). The most prominent legume is *Lens culinaris* (lentil). There were 678 lentils or lentil fragments that were intact enough to clearly differentiate them from other legume crops. There were also 287 *Pisum sativum* (pea) or pea fragments and 60 cf. *Vicia sativa* (vetch/pea). The possible *V. sativa* seeds can either represent minor secondary crops or weeds in cultivated fields; it is also possible that they are simply immature or underdeveloped peas. Three possible *Vicia ervilia* (bitter vetch) might also be immature peas. There were 150 seeds of *Vigna mungo/radiata* (mung beans or black gram); in this study, we did not attempt to differentiate between different species of cultivated *Vigna*. There were also 64 *Macrotyloma uniflorum* (horse gram) and two *Lathyrus sativus* (grass pea). No legume fragments resembled *Cicer arietinum* (chickpea). A single cf. *Linum* sp. (possible flax) seed was recovered from Sample 2016.121; an unidentified large legume was recovered from 2016.118 and a few cf. *Avena* sp. (possible oat) were recovered, but they may have been field weeds.

Collectively, there were nine clearly domesticated field crops in the assemblage and an additional four possible minor crops or wild relatives that were not morphologically distinct enough for reliable identification. In addition, *Vitis vinifera* was cultivated. The *Ziziphus nummularia* fruitstones, *Juglans regia* and *Prunus* cf. *armeniaca* nutshell fragments may represent cultivation of local trees, or

they may represent the collection of wild resources. This is a diversity of crops and intensity of agricultural systems unlike anything that has been identified at any archaeological site further north in Central Asia at this time. Many of these crops, notably the warm-weather legumes, are absent from archaeobotanical results from Central Asia, but they are present further south in the Indus valley. The lack of many of these crops further north is likely connected to ecological limitations; legumes, such as *Pisum sativum* and *Lens culinaris*, which are more cold tolerant, spread into Central Asia earlier than other legumes. Likewise, many of these crops, notably *Oryza sativa* and *Gossypium* sp., are extremely water demanding and would have required irrigation, as they are traditionally grown in wet fields in this region.

Agricultural diversification

The earliest cultivation system to spread into these valleys and across northern India and Pakistan relied on cereals, notably *Triticum aestivum* and both naked and hulled forms of *Hordeum vulgare*, possibly also emmer and free-threshing tetraploid wheat (Fuller 2002; Salunkhe et al. 2012; Stevens et al. 2016). In addition to the cereals, other aspects of the southwest Asian repertoire arrived in northern India early, including *Lens culinaris*, *Lathyrus sativa*, *Pisum sativum* and *Cicer arietinum*, as well as sheep, goat and zebu cattle (Stevens et al. 2016; Petrie and Bates 2017; Bates 2020). Cereal crops arrived in the Bolan pass in Balochistan at the sites of Mehrgarh by 5000 BCE (Costantini 2008), Mundigak in Afghanistan around the same time, Sheri Khan Tarakai by 4000 BCE (Thomas and Cartwright 2010), and on the upper Punjab plain by 2500 BCE (Vishnu-Mittre 1972; Saraswat 1986; Saraswat and Pokharia 2003; Fuller 2006; Stevens et al. 2016). Liu et al. (2016) recently published direct dates from *Hordeum vulgare* grains at Damdama (2500–2400 BCE) and Lahuradewa (2300–2000 BCE), both on the Ganges plain (Saraswat 2005) and from sites along the Indus dating to 2850–2450 BCE. Both *Triticum aestivum* and *T. turgidum* ssp. *dicoccum* have been reported from sites in northern India and Kashmir (Lone et al. 1993; Fuller 2002; Salunkhe et al. 2012). As these cereals spread further north and east, the glume wheats were grown less and there is currently no evidence for *T. turgidum* in Central Asia until the Islamic period (see discussion in Spengler et al. 2018). Farmers integrated other southwest Asian crops into the cultivation system in Kashmir, including *Lens culinaris* and *Pisum sativum* (Saraswat and Pokharia 2003).

The Swat and Kashmir valleys are corridors of exchange and communication through the Hindu Kush mountains and they have dense archaeological remains, including farming village sites that date back to roughly 2500 cal BCE (Vidale and Olivieri 2002; Bandey 2009). Historically, the Jhelum river valley in Baramulla District served as a key corridor

connecting the Kashmir valley to Punjab. Interestingly, this region has many rivers and can easily provide irrigation, but it sits in a rain shadow outside the effects of the Indian summer monsoons. At this time in Kashmir, the southwest Asian crops were grown together with crops that were domesticated in India, such as *Vigna mungo* and *V. radiata* (Saraswat 1986; Saraswat and Pokharia 2003; Fuller 2006; Stevens et al. 2016). Archaeologists have argued that occupation and farming intensified in the Swat valley in the 2nd millennium BCE, and geometric rock art depictions have been interpreted as field cultivation scenes (Vidale and Olivieri 2002; Vidale et al. 2011).

Archaeologists have noted that early sedentary occupation in northern India and Pakistan is culturally distinct from that of the Indus valley and further south (Mani 2008). Much of the current interpretation of what this cultural system looked like comes from the sites of Burzahom and Gufkral in Kashmir (ca. 3000–1500 BCE), where cereal grains and sheep and goat bones were recovered (Sharma 2000, 2013; Bandey 2009). *Oryza sativa* and *Prunus* fruitstones, likely almonds, have been reported in the archaeobotanical assemblages from the later phases at these sites dating between 1800–1000 BCE (Kajale 1982; Lone et al. 1993). Although Pokharia et al. (2018) do note that there is some question about the exact stratigraphic context of the *Oryza sativa* grains, they do mention directly dated *T. aestivum* (2290–2051 cal BCE) and *H. vulgare* (2467–2236 cal BCE) grains from Kanishkapura (Kanispur). Other southwest Asian crops appear to have spread into Kashmir at this time as well, attested by the finds of *T. turgidum* ssp. *dicoccum*, *Lens culinaris*, *Lathyrus sativa*, *Pisum sativum* and *Vicia sativa* from Kanispur. A later occupation layer at Kanispur, between 100 and 300 CE, showed that East Asian millets, *Panicum miliaceum* and *Setaria italica* (and possibly *Echinochloa* sp.), as well as *Oryza sativa*, had spread into the region by this period (Mani 2008). The site of Qasim Bagh, in the same area, provided direct dates on wheat and millet grains spanning 1800 to 1400 BCE (Spate et al. 2017). The site is located at about 1,500 m, tucked into the Kashmir valley with the Himalaya to the east and the Pir Panjal mountains to the west. Also, single specimens each of *Vitis vinifera* and *Sesamum indicum*, and two specimens each of *Linum usitatissimum* and *Macrotyloma uniflorum* collectively indicate the increasing diversity in cultivated crops through time (Pokharia et al. 2018).

While this paper is primarily focused on the ancient connected cultural realm of the Swat and Kashmir valleys, it is important to acknowledge the interconnected nature of the broader region. Archaeobotanical research on the northern Ganges plain, from cultural contexts spanning 2500–200 BCE, has led to the identification of many of the same domesticated crops as we see in the Barikot assemblage. Ancient farming systems along the Indus utilized an astonishing

Table 2 Summary of crop introductions and geographical areas of origin, covering southern Central and South Asia from the 3rd millennium BCE to the 1st millennium CE

| Origin/taxa | 3rd mill. BCE | | | | 2nd mill. BCE | | | | 1st mill. BCE | | | | 1st mill. CE | | | |
|-------------------------------|----------------|-------------|---------|-----------------------|----------------|-------------|---------|-----------------------|----------------|-------------|---------|-----------------------|----------------|-------------|---------|-----------------------|
| | Northern Indus | Ganga Plain | Kashmir | Southern Central Asia | Northern Indus | Ganga Plain | Kashmir | Southern Central Asia | Northern Indus | Ganga Plain | Kashmir | Southern Central Asia | Northern Indus | Ganga Plain | Kashmir | Southern Central Asia |
| Southwest Asia | | | | | | | | | | | | | | | | |
| <i>Hordeum vulgare</i> | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| <i>Triticum aestivum</i> | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| <i>T. aestivum</i> (compact) | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| <i>Lens culinaris</i> | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| <i>Pisum sativum</i> | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| <i>Lathyrus sativum</i> | | X | X | | X | X | X | X | X | X | X | X | X | X | X | X |
| <i>Cicer arietinum</i> | | | | | X | X | | X | X | X | | X | X | X | | X |
| <i>Vicia</i> spp. | | X | | | X | X | | X | X | X | | X | X | X | | X |
| <i>Linum usitatissimum</i> | X | X | | | X | | | X | X | X | | X | X | | | X |
| East Asia | | | | | | | | | | | | | | | | |
| <i>Oryza sativa</i> | X | X | | | X | X | X | | X | X | X | | X | X | X | X |
| <i>Panicum miliaceum</i> | | | | | X | | X | | X | X | X | X | X | X | X | X |
| <i>Setaria italica</i> | | | | | X | | | | X | X | | X | X | X | | X |
| <i>Cannabis sativa</i> | | | | | X | X | | | X | X | | | X | X | | |
| South Asia | | | | | | | | | | | | | | | | |
| <i>Oryza sativa</i> | X | X | | | X | X | X | | X | X | X | | X | X | X | X |
| <i>Brachiaria ramosa</i> | | | | | X | | | | X | | | | X | | | |
| <i>Panicum sumatrense</i> | | | | | X | | | | X | | | | X | | | |
| <i>Setaria pumila</i> | | | | | X | | | | X | | | | X | | | |
| <i>Paspalum scrobiculatum</i> | | X | | | X | X | | | X | X | | | X | X | | |
| <i>Macrotyloma uniflorum</i> | | | | | X | X | | | X | X | | | X | X | | |
| <i>Vigna</i> spp. | | X | | | X | X | | | X | X | | | X | X | | |
| <i>Sesamum indicum</i> | | | | | X | X | X | | X | X | X | | X | X | X | |
| <i>Gossypium</i> sp. | | X | | | X | | | | X | X | | X | X | | | |
| <i>Cucumis melo/sativa</i> | | | | | X | | | | X | X | | | X | | | |
| North Africa | | | | | | | | | | | | | | | | |
| <i>Eleusine coracana</i> | | | | | X | X | X | | X | X | X | | X | X | X | |
| <i>Sorghum bicolor</i> | | | | | X | X | | | X | X | | | X | X | | |
| <i>Pennisetum glaucum</i> | | | | | X | | | | X | X | | | X | | | |
| <i>Citrullus lanatus</i> | | | | | X | | | | X | X | | | X | | | |
| <i>Carthamus tinctorius</i> | | | | | X | | | | X | X | | | X | | | |
| <i>Brassica juncea</i> | | | | | X | X | | | X | X | | | X | X | | |
| <i>Allium</i> sp. | | | | | X | | | | X | X | | | X | | | |
| Arboreal | | | | | | | | | | | | | | | | |
| <i>Vitis vinifera</i> | X | | | X | X | X | X | X | X | X | X | X | X | X | X | X |
| <i>Phoenix dactylifera</i> | | | | | X | | | | X | X | | | X | | | |
| <i>Ziziphus</i> spp. | | X | | | X | X | | | X | X | | | X | X | | |
| <i>Prunus amygdalus</i> | | | X | | X | | X | | X | | X | X | X | | X | |
| <i>Prunus persica</i> | | | | | | | | | | | X | X | X | X | X | X |
| <i>Prunus armeniaca</i> | | | | | | | | | | | X | X | X | X | X | X |
| <i>Juglans regia</i> | | | X | | X | | X | | X | | X | X | X | | X | |

array of crops, arguably a greater diversity than anywhere else in the ancient world (Weber 1991, 1999; Fuller and Madella 2002). Pokharia et al. (2017) summarized archaeological remains from the sites of Hetapatti (ca. 2500–1500

BCE), Raja-Nal-ka-Tila (ca. 1300–700 BCE), and Rajdhani (ca. 800–200 BCE). The abundant archaeological data from the Indus region was recently synthesized by Bates (2019), although many other syntheses have been presented

(Table 2; for example, Misra and Kajale 2003; Weber and Fuller 2008; Pokharia et al. 2014). Several studies have also illustrated shifting preference for millets over time, from primarily *Eleusine* sp. in the Mature Harappan to a mix of *Eleusine* sp., *Setaria* sp. and *Panicum* sp. in the Later Harappan (Reddy 2003). Table 2 illustrates a gradual process of increasing crop diversification through time, as crops from different regions spread into northern South Asia and cultivation systems expanded to incorporate them.

There have been a handful of archaeobotanical studies of the Kushan period, ca. in the first 300 years CE, after organized trade routes and reliable markets were fully established across inner Asia (for instance, Pokharia and Saraswat 1999). As an example, biological remains from a trench in the northeastern part of the Balaji temple at Naimisharanya, in Sitapur District of Uttar Pradesh, illustrate that there was a complex cultivation system. As in other areas of Central Asia at this time, barley continued to dominate the cultivation system (Srivastava and Tewari 2011) and both hulled and naked forms were present – likely all six-rowed (Saraswat 1980, 1992). Four types of pulses were also reported from Naimisharanya (Srivastava and Tewari 2011). While *Echinochloa crus-galli* is a common agricultural weed, it was also grown as a crop in parts of Central Asia, likewise, seeds of *Vicia sativa* at the site could either represent a minor legume crop or weeds in winter crop fields. Interestingly, ancient remains of *Azadirachta indica* (neem) fruits were also recovered from Naimisharanya (Srivastava and Tewari 2011).

The cultivation system

Water-demanding crops

Much of northern Pakistan lies in the rain shadow of the Pamirs and receives limited precipitation, with the majority coming during the winter months. The cultivation of water-intensive crops would have required ways of managing water resources. In exploring the prominence of crops such as *Gossypium* sp. and *Oryza sativa*, we can understand better the labour investment needed in farming. Additionally, *T. aestivum* and most legumes can be water-demanding if they are grown in open fields rather than small gardens.

Traditionally, rice cultivation across West Asia relied on wet paddy fields; but in some cases, this highly water-demanding crop is/was grown in very arid regions. By the late medieval period, it appears to have been present across West Asia (Spengler 2019; Chen et al. 2020). Understanding the role of rice in the cultivation system of the Swat valley helps illustrate how the crop rose to significance across areas further north and west, despite the evident ecological constraints. The origins and timing of its cultivation in South Asia and the process of hybridization

between East and South Asian rice varieties have been topics of debate for roughly a decade (such as Fuller and Madella 2002; Fuller 2005, 2006, 2011; Saraswat 2005; Tewari et al. 2008; Fuller et al. 2010; Petrie et al. 2016). There is evidence for people collecting wild *O. sativa* across northern India for several millennia before the introduction of East Asian domesticated *O. sativa* ssp. *japonica* (Saraswat 2004, 2005; Pokharia et al. 2017). While there is a considerable range of morphological variability among *O. sativa* grains from Barikot, and there is a significant range of overlap between *O. sativa* ssp. *indica* and ssp. *japonica*, the Barikot grains are generally more compact, resembling more closely ssp. *japonica*. Following this rule of thumb, the *O. sativa* at Barikot, like early examples of rice in the southern Himalaya and Central Asia, may have had East and not South Asian origins (Chen et al. 2020). Vidale et al. (2011) suggest that East Asian rice originally dispersed into northwest India through the mountain passes, referencing early *O. sativa* in pottery impressions reported by Costantini (1987). The prominence of rice in the Indus valley seems to have largely arisen after the introduction of East Asian varieties, which hybridized with local cultivated *O. sativa* (Stevens et al. 2016). For example, at the site of Hetapatti, on the Ganges plain, in the 2nd millennium BCE, *Hordeum vulgare* is the dominant crop, but by the 1st millennium BCE at the site of Rajdhani, rice grains are 250 times more abundant than barley (Pokharia et al. 2017).

Gossypium arboreum/herbaceum is a second water-demanding crop recovered from Barikot, with a total of 49 seeds identified. While *Gossypium* production in most of Central Asia and India is for commercial purposes today and therefore extremely water demanding, cotton growing was originally for small-scale consumption. Hirth (2009) notes that small-scale *Gossypium* cultivation for domestic craft production does not require major water or labour inputs. Most reports of early *Gossypium* remains from archaeological sites prior to large-scale irrigation and organized cultivation strategies in the medieval period, are restricted to the moist tropical or semitropical zones of South Asia (Brubaker et al. 1999). The dispersal of *Gossypium* into more northern regions is often linked to the Islamic Green Revolution (Watson 1983), and there may have been photo-period sensitivity constraints to its northern dispersal (Brite and Marston 2013). The Barikot *Gossypium* sp. illustrates that cotton at least started dispersing north well before the Islamic period. Likewise, Brite and Marston (2013) report *Gossypium* sp. seeds from Kara-tepe in Uzbekistan dating to 300–500 CE. Interestingly, traces of *Gossypium* sp. fabric and threads were identified from inside two reliquaries from the Buddhist sanctuary of Butkara I in Swat, roughly 20 km north of Barikot, belonging to a first and second century CE archaeological context (Costantini et al. 2002). *Gossypium*

sp. was clearly a prominent crop across the Indus region from the mid 3rd millennium BCE onwards (Fuller 2008; Bouchaud et al. 2011).

Crop rotation cycles

South Asia, broadly speaking, provides an exceptional region for studying human adaptation to variable and dynamic environments. Within the area of northern India and Pakistan there are widely differing rainfall patterns, with some areas receiving summer monsoonal rains and others better suited for sowing in autumn (Petrie et al. 2016, 2017; Petrie and Bates 2017). A myriad of possible ancient cultivation strategies have been proposed to accompany these differing ecological constraints (Fuller 2011; Kingwell-Banham et al. 2015). Botanical investigations at the site of Rojdi, led by Weber (1991, 1999) suggest that many of the summer crops were millets, *Eleusine* sp., *Panicum sumatrense*, *Setaria pumila* and *S. italica*. Similarly, work at Harappa has led to discussions of the nature of crop rotation cycles in the Indus valley (Weber 2003). Recently, Petrie and Bates (2017) synthesized this extensive body of literature, further illustrating how complex northern Indian cultivation systems were. The site of Barikot is located in a winter rainfall zone in the rain shadow of the Pamirs, leading to unique cultivation conditions and the ability to grow warm weather crops further north than usual.

The intensification of agricultural strategies appears to be directly connected with trans-Eurasian crop exchange (Fuller and Boivin 2009; Spengler 2019). For example, Pokharia et al. (2018) and Lone et al. (1993) suggested that the presence of East Asian millets and rice in Kashmir may represent cereal farming in two seasons, with millet sown in spring and harvested in the dry season. Miller et al. (2016) suggest that the adoption of East Asian millets in urban contexts across Central and southwest Asia may represent the introduction of summer crops into a previously winter crop system. This argument is supported by the almost complete lack of millets in big urban centres until the early 1st millennium BCE, whereas they were prominent in the foothills of Central Asia for millennia before then, likely linked to low investment rain-fed farming. Secondary crops often play key roles in crop rotation systems, notably as summer vegetables, legumes, or oil and fibre crops (Sherratt 1983). *Oryza sativa* was undoubtedly an important summer crop at Barikot; additionally, a few of the South Asian legumes could have been summer crops, including *Vigna mungo/radiata* and *Macrotyloma uniflorum*. *Pisum sativum* and *Lens culinaris* are grown most extensively in cool climates, either at high altitudes in South Asia or as winter crops in some hotter regions. The prominent summer crops across the more arid regions of southwest and Central Asia include the East Asian millets, which were not identified at Barikot,

either illustrating a largely winter crop-based cultivation system or a loss of data due to the coarse sieve. The unique geography of the Swat valley makes it particularly suitable for a double cropping system with wet and dry season crops sown on the same plot of land in spring and autumn, that was developed at much lower elevations and latitudes. Notably there is high thermal insulation in the valley, because of its unusual East–West orientation, seen in a few other valleys in this region, including Baghlan and Kapisa on the two sides of the Hindu Kush and the Nangarhar, Manshera, Kashmir, and possibly the valley of Almora (Uttarakhand) to the south of the Karakoram Himalayas. These are all examples of what has been defined by one of the authors as “double-crop economic pocket zones” as river valleys particularly good for farming, where mild conditions allow South Asian crops to be grown further north than usual and for two crops per year on a plot of land (Olivieri 2021). In this regard, drought tolerant crops, such as the millets, were less important, and rice played a more prominent role at Barikot.

According to Lone et al. (1993), the East Asian millets arrived late to the southern Himalayan rim and northern India, *Panicum miliaceum* at ca 100 BCE and *Setaria italica* at 250 CE, although Spate et al. (2017) recently pushed those dates back to the early 2nd millennium BCE with the discovery of millet at Qasim Bagh. *Setaria italica* is well attested in the Indus valley by the late Harappan period (ca. 2000 BCE), at Surkotada, Ojjiyana, and Hulas (cf. Fuller 2003, 2006; Pokharia 2007), and it increases in prominence at later sites (Petrie and Bates 2017; Bates 2019). The dispersal of East Asian millets through the inner Asian mountain corridor is well known (Spengler 2019). However, a secondary spread of East Asian cultural traits into northern India and Pakistan during the early 2nd millennium BCE is also recognized. Fuller and Boivin (2009) note the appearance of *Cannabis sativa*, East Asian *Oryza sativa*, *Prunus persica* (peach), and *P. armeniaca* (apricot) in northern India as signs of a “Chinese horizon”, signs of influence from the northeast. This is present in the valleys of Kashmir and Swat by 1800 BCE (Lone et al. 1993; Stevens et al. 2016). Finds of harvesting knives, jade and other stone objects, and tripod ceramic vessels are all signs of cultural dispersal from the northeast (Fairservis 1975; Stacul 1976, 1993; Sharif and Thapar 1992; Han 2012; Coningham and Young 2015).

Arboriculture

Understanding the process of domestication of fruit and nut trees, long-generation perennials, can also provide much information on concepts of land tenure and investment in future generations. It can also inform on scheduling in the economy, resource protection practices, mobility and exchange. It is clear that people have been collecting fruits and nuts from the once-wooded foothills of Central Eurasia

for millennia (Spengler and Willcox 2013); however, we know little about when people started actively maintaining these trees and breeding them. In the northern Indus valley during the 2nd millennium BCE, the cultivation of long-lived perennials is indicated by archaeobotanical remains of *Vitis vinifera*, *Gossypium arboreum* (tree cotton), *Phoenix dactylifera* (date palm), and *Ziziphus* spp. (Fuller and Madella 2002; Bates 2020). Slightly later, *Prunus persica* and *P. armeniaca* were introduced to the Indus valley; although neither grows particularly well in such hot moist regions. Further south in India, a much wider variety of fruit trees has been archaeobotanically identified by the mid 2nd millennium BCE; however, most of these would not have been productive further north, including *Artocarpus heterophyllus* (jackfruit), *Mangifera indica* (mango), and *Citrus* spp. (oranges, lemons etc.) (Fuller 2009; Stevens et al. 2016).

Most of the fruit and nut remains recovered in the Barikot study represent plants that would have grown wild in the foothills, making it impossible to determine to what degree people were cultivating, maintaining, or manipulating them. Only 25 *Vitis vinifera* pips were recovered from Barikot, but grapes are far less likely to be carbonized than parched cereal grains, especially if the seeds were removed during wine making. Grapes are the best represented fruit of ancient Central Asia, and they played a prominent role in the economy of people in the foothills and desert oases for at least three millennia (Spengler 2019). Miller (2008) discusses the early appearance of viticulture in the Kopet Dag mountains of Turkmenistan, roughly four millennia ago, and Spengler et al. (2017) discuss the spread of *Vitis* into the northern foothills by two and a half millennia ago. A single grape pip from Qasim Bagh (Spate et al. 2017) and two from Loebanr III (ca. 1700–1400 BCE) were recovered (Costantini 1987). *Vitis* pips are also found from sites across the Indus valley dating back to the early Harappan period (Bates 2019). Wine making in Swat is archaeologically confirmed by at least as early as the early 1st millennium CE, through the discovery of several wine presses, particularly the area of Barikot (Olivieri et al. 2006), as well as several pottery devices for distillation at Barikot (Allchin 1979) and by textual evidence (Falk 2009).

Ziziphus nummularia and *Z. mauritiana* are both found at sites across northern India and Pakistan, especially in more arid regions (Bates 2019; Pokharia et al. 2017). A specific small-fruited morphotype of *Z. nummularia* grows wild throughout the hills of the Swat valley (Ahmad et al. 2011). Therefore, the small *Ziziphus* fruitstones that we recovered at Barikot may have been collected from the wild. Alternatively, *Ziziphus* trees are often planted at field edges and only lightly maintained; they often mark boundaries or protect fields, while also providing fruit. It is likely that low investment maintenance of this long-generation perennial was practised by the occupants of Barikot. Similarly, *Juglans*

regia (walnut) woods once covered much of the southern Central Asian foothills; however, these trees were eventually cultivated and the wild stands were lost. Pleistocene deposits at Karewa in Kashmir illustrate how long the walnuts have been present in the mountain foothills and that people have been collecting the nuts for tens of thousands of years (Vishnu-Mittre 1965, 1984). *Juglans regia* and *Prunus dulcis* (almond) nutshells were also recovered from Kanisapur (3000–2000 BCE), illustrating a long history of human use in the region (Pokharia et al. 2018). It is likely that these trees were planted and maintained near the settlement in the Swat valley. It is also possible that the 14 *Celtis caucasica* seeds and small fragments of nutshell all represent either foraging in the wild or the maintenance of such useful trees near the settlement. Ultimately, none of the arboreal seed/fruit remains recovered at Barikot definitively indicate the cultivation of trees. However, the possibility that people were loosely maintaining and manipulating the populations of *Ziziphus* and *Juglans regia* trees in spaces between fields is highly likely. This likelihood is further supported by the evidence of viticulture, showing that the population was already familiar with perennial crops.

Conclusions

The Barikot settlement site is located in the Swat valley of northern Pakistan and it was occupied during the 1st millennium BCE. Historically the valley represented a key pass through the mountains, and these biologically diverse passes where arable farming was possible were areas of human settlement for millennia. The archaeobotanical evidence that we present here shows the complex agricultural practices that were underway in the high mountain pass in a semi-arid ecological zone three millennia ago. The farmers at the site undoubtedly used some form of irrigation or water channelling in order to maintain water-demanding crops in the rain shadow of the Pamirs. Crops, such as *Oryza sativa* and *Gossypium* sp., are particularly water-demanding and would have required great labour and time investments. However *Gossypium* sp. can be grown on a smaller scale in restricted field plots and therefore requires less water input than modern industrial cotton production. Additionally, simple irrigation is particularly easy in mountain valleys with steep slopes and steady glacial melt streams in the summer which can be diverted for this purpose.

The Barikot data help link the archaeobotany of South and Central Asia, allowing further understanding of the processes of crop exchange across the ancient world. The farmers at Barikot grew crops that originally came from central East Asia (*O. sativa* ssp. *japonica*), southwest Asia (cereals and legumes), and central South Asia (legumes). These farmers brought together crops that had evolved in

different ecological settings and were adapted to different ecological conditions. Due to the particular evolutionary courses of the progenitors for these crops and their different growing habits, all of these crops required specific growing practices. This allowed for the formation of complex seasonal cycles of agriculture, and several summer legumes and rice appear to have complemented winter wheat and barley. Furthermore, there is reason to believe that some limited maintenance of trees for fruits and nuts was practised, although all of the identified ones represent local taxa. The Barikot archaeobotanical assemblage illustrates how complex and regionally specific cultivation practices were across South Asia. This study also adds to our understanding of the prominent role of the river valleys, and “double-crop pocket zones”, across the Pamirs, Hindu Kush and southern Himalaya in the spread of crops and cultivation technology.

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References

- Ahmad I, Ibrar M, Barkatullah AN (2011) Ethnobotanical study of Tehsil Kabal, Swat District, KPK, Pakistan. *J Bot* 368572:1–9
- Aldenderfer M, Eng JT (2016) Death and burial among two ancient high-altitude communities of Nepal. In: Robbins Schug G, Walimbe SR (eds) *A companion to South Asia in the past*. Wiley-Blackwell, New York, pp 374–397
- Allchin FR (1979) India: the ancient home of distillation? *Man* 14:55–63
- Bandey AA (2009) Prehistoric Kashmir: Archaeological history of Palaeolithic & Neolithic cultures. Dilpreet Publishing House, New Delhi
- Bates J (2019) The published archaeobotanical data from the Indus civilisation, South Asia, c. 3200–1500 BC. *J Open Archaeol Data* 7:1–5
- Bates J (2020) Kitchen gardens, wild forage and tree fruits: a hypothesis on the role of the Zaid season in the Indus civilisation (c. 3200–1300 BCE). *Archaeol Res Asia* 21:100175
- Baums S (2019) A survey of place-names in Gāndhārī inscriptions and a new oil lamp from Malakand. In: Rienjang W, Stewart P (eds) *The geography of Gandhāran art*. Archaeopress, Oxford, pp 167–174
- Bouchaud C, Tengberg M, Dal Prà P (2011) Cotton cultivation and textile production in the Arabian Peninsula during antiquity; the evidence from Madā'in Sālih (Saudi Arabia) and Qal'at al-Bahrain (Bahrain). *Veget Hist Archaeobot* 20:405–417
- Brite EB, Marston JM (2013) Environmental change, agricultural innovation, and the spread of cotton agriculture in the Old World. *J Anthropol Archaeol* 32:39–53
- Brubaker CL, Bourland FM, Wendel JF (1999) The origin and domestication of cotton. In: Smith CW, Cothren JT (eds) *Cotton: origin, history, technology, and production*. Wiley, New York, pp 3–32
- Callieri P, Colliva L, Micheli R et al (2000) Bīr-koṭ-ghwaṇḍai, Swat, Pakistan. 1998–1999 Excavation Report. *East West* 50:191–226
- Cappers RTJ, Bekker RM (2012) A manual for the identification of plant seeds and fruits. Barkhuis, Groningen
- Chen G, Xinying Z, Jianxin W et al (2020) Kushan period Rice in the Amu Darya basin: Evidence for prehistoric exchange along the southern Himalaya. *Sci China Earth Sci* 63:841–851
- Coningham R, Young R (2015) *The archaeology of South Asia: from the Indus to Asoka, ca. 6500 BCE–200 CE*. Cambridge University Press, Cambridge
- Costantini L (1987) Appendix B. Vegetal remains. In: Stacul G (ed) *Prehistoric and protohistoric Swat, Pakistan, c. 3000–1400 BC (Reports and Memoirs 20)*. ISMEO, Rome, pp 155–165
- Costantini L (2008) The first farmers in Western Pakistan: the evidence of the Neolithic agropastoral settlement of Mehrgarh. *Pragdhara* 18:167–178
- Costantini L, Costantini Biasini L, Ferro D (2002) Sui contenuti di alcuni reliquiari da Butkara I e Saidu Sharif I, Swat. In: Callieri P, Filligenzi A (eds) *Il Maestro di Saidu Sharif Alle origini dell'arte del Gandhara*. ISMEO, Rome
- Dhungel R (2002) *The Kingdom of Lo (Mustang). A historical study*. Tashi Gephel Foundation. Lusha Press, Kathmandu
- Eng JT, Aldenderfer M (2017) Bioarchaeological profile of stress and dental disease among ancient high altitude Himalayan communities of Nepal. *Am J Hum Biol* 29:e22998
- Fairservis W (1975) *The roots of ancient India*. The University of Chicago Press, Chicago
- Falk H (2009) Making wine in Gandhara under Buddhist monastic supervision. *Bull Asia Inst* 23:65–78
- Frachetti MD (2012) Multiregional emergence of mobile pastoralism and nonuniform institutional complexity across Eurasia. *Curr Anthropol* 53:2–38
- Frachetti MD, Smith CE, Copp C (2018) Pastoralist participation (PastPart): a model of mobility and connectivity across the Inner Asian Mountain Corridor. In: Anemone RL, Conroy GC (eds) *New geospatial approaches to the anthropological sciences*. University of New Mexico Press, Albuquerque
- Fritz GJ (2005) Palaeoethnobotanical methodology and applications. In: Maschner HG, Chippindale C (eds) *Handbook of archaeological methods*. Altamira Press, Lanham, pp 773–834
- Fuller DQ (2002) Fifty years of archaeobotanical studies in India: laying a solid foundation. In: Settar S, Korisetar R (eds) *Indian archaeology in retrospect. Archaeology and interactive disciplines, vol 3*. Indian Council for Historical Research, New Delhi, pp 247–364
- Fuller DQ (2003) Indus and non-Indus agricultural traditions: local developments and crop adoptions on the Indian Peninsula. In: Weber SA, Belcher WR (eds) *Indus ethnobiology: new perspectives from the field*. Lexington Books, Lanham, pp 343–396

- Fuller DQ (2005) Ceramics, seeds and culinary change in prehistoric India. *Antiquity* 79(306):761–777
- Fuller DQ (2006) Agricultural origins and frontiers in South Asia: a working synthesis. *J World Prehist* 20:1–86
- Fuller DQ (2008) The spread of textile production and textile crops in India beyond the Harappan zone: an aspect of the emergence of craft specialization and systematic trade. In: Osada T, Uesugi A (eds) *Linguistics, archaeology, and the human past*. Research Institute for Humanity and Nature, Kyoto, pp 1–26
- Fuller DQ (2009) Recent lessons from Near Eastern archaeobotany: wild cereal use, pre-domestication cultivation and tracing multiple origins and dispersals. *Pragdhara* 18:105–134
- Fuller DQ (2011) Finding plant domestication in the Indian subcontinent. *Curr Anthropol* 52:S347–S362
- Fuller DQ, Boivin N (2009) Crops, cattle and commensals across the Indian Ocean: current and potential archaeobiological evidence. *Études Océan Indien* 42(43):13–46
- Fuller DQ, Madella M (2002) Issues in Harappan archaeobotany: retrospect and prospect. In: Settar S, Korisetar R (eds) *Indian archaeology in retrospect*. Indian Council for Historical Research, New Delhi
- Fuller DQ, Sato Y-I, Castillo C et al (2010) Consilience of genetics and archaeobotany in the entangled history of rice. *J Archaeol Anthropol Sci* 2:115–131
- Gleba M, Vanden Berghe I, Aldenderfer M (2016) Textile technology in Nepal in the 5th–7th centuries CE: the case of Samdzong. *STAR: Sci Technol Archaeol Res* 2:25–35
- Han J (2012) The painted pottery road and early Sino-Western cultural exchanges. *Anabasis* 3:25–42
- Hirth K (2009) Craft production, household diversification, and domestic economy in prehispanic Mesoamerica. *Archeol Pap Am Anthropol Assoc* 19:13–32
- Jeong C, Ozga AT, Witonsky DB et al (2016) Long-term genetic stability and a high-altitude East Asian origin for the peoples of the high valleys of the Himalayan arc. *Proc Natl Acad Sci USA* 113:7,485–7,490
- Kajale MD (1982) First record of ancient grains at Naikund. In: Deo SB, Jamkhedkar AP (eds) *Excavations at Naikund 1978–1980*. Department of Archaeology and Museums, Mumbai, pp 60–63
- Kingwell-Banham E, Petrie CA, Fuller DQ (2015) Early agriculture in South Asia. In: Barker G, Goucher C (eds) *The Cambridge World history. Vol. 2, A world with agriculture, 12,000 BCE–500 CE*. Cambridge University Press, Cambridge, pp 261–288
- Kuzmina EE (2008) *The prehistory of the Silk Road*. University of Pennsylvania Press, Philadelphia
- Liu X, Lister DL, Zhao Z et al (2016) The virtues of small grain size: potential pathways to a distinguishing feature of Asian wheats. *Quat Int* 426:107–119
- Lone FA, Khan M, Buth GM (1993) *Palaeoethnobotany: plants and ancient man in Kashmir*. Oxford & IBH Publishing Company, Oxford
- Mair V, Hoh E (2009) *The true history of tea*. Thames & Hudson, London
- Mani BR (2008) Kashmir Neolithic and early Harappan: a linkage. *Pragdhara* 18:229–247
- Massa G, Aldenderfer M, Martín-Torres M (2019) Of gold masks, bronze mirrors and brass bracelets: analyses of metallic artefacts from Samdzong, Upper Mustang, Nepal 450–650 CE. *Archaeol Res Asia* 18:68–81
- Miller NF (2008) Sweeter than wine? The use of the grape in early western Asia. *Antiquity* 82:937–946
- Miller NF, Spengler RN, Frachetti M (2016) Millet cultivation across Eurasia: Origins, spread, and the influence of seasonal climate. *Holocene* 26:1,566–1,575
- Misra VN, Kajale MD (2003) Introduction of African crops into South Asia. *Indian Society for Prehistoric and Quaternary Studies*, Pune
- Motuzaitė Matuzevičiūtė G, Abdykanova A, Kume S et al (2018) The effect of geographical margins on cereal grain size variation: Case study for highlands of Kyrgyzstan. *J Archaeol Sci: Rep* 20:400–410
- Narasimhan VM, Patterson N, Moorjani P et al (2019) The formation of human populations in South and Central Asia. *Science* 365(6457):eaat7487
- Neef R, Cappers RTJ, Bekker RM, Boulos L (2012) *Digital atlas of economic plants in archaeology*. Groningen University Library, Eelde, Groningen, Barkhuis
- Olivieri LM (2003) *The survey of the Bir-kot hill*. Archaeological map and photographic documentation. (IsIAO Memories and Reports, Series Minor 6). IsIAO, Rome
- Olivieri LM (2011) The Last phases at Barikot: urban cults and preliminary chronology: data from the 2012 excavation campaign in Swat. *J Inner Asian Art Archaeol* 6:7–40
- Olivieri LM (2012) The Last phases at Barikot: urban cults and sacred architecture. Data from the spring 2013 excavation campaign in Swat. *J Inner Asian Art Archaeol* 7:7–30
- Olivieri LM (2017) *Vajirasthāna/Bazira and beyond: foundation and current status of the archaeological work in Swat*. In: Ray HP (ed) *Buddhism and Gandhara. An archaeology of museum collections*. Routledge, London, pp 173–212
- Olivieri LM (2021) *Gandhara and North-Western India*. In: Graeco-Bactrian T, Indo-Greek world (Routledge worlds series) (eds) Mairs R. Routledge, New York, pp 386–415
- Olivieri LM, Iori E (2020) Beginnings and abandonment of an early historic town in the north-west of the subcontinent: Data from 2015 and 2016 excavation campaigns at Bir-kot-ghwandai, Swat (Pakistan). In: *Religion, society, trade and kingship: art and archaeology in South Asia and along the Silk Road (5500 BCE–5th century CE)*. (South Asian Art and Archaeology 2016, vol 1 (ed) Greaves LR, Greaves A. Dev Publishers & Distribution, New Delhi, pp 79–103
- Olivieri LM, Vidale M, Khan AN et al (2006) Archaeology and settlement history in a test area of the Swat valley: preliminary report on the AMSV project (1st Phase). *East West* 56:73–150
- Olivieri LM, Marzaioli F, Passariello I et al (2019) A new revised chronology and cultural sequence of the Swat valley, Khyber Pakhtunkhwa (Pakistan) in the light of current excavations at Barikot (Bir-kot-ghwandai). *Nuclear Instrum Methods Phys Res B* 456:148–156
- Pearsall DM (2000) *Paleoethnobotany: a handbook of procedures*. Academic Press, San Diego
- Petrie CA, Bates J (2017) “Multi-cropping”, intercropping and adaptation to variable environments in Indus, South Asia. *J World Prehist* 30:81–130
- Petrie CA, Thomas KD (2012) The topographic and environmental context of the earliest village sites in western South Asia. *Antiquity* 86 (334):1,055–1,067
- Petrie CA, Bates J, Higham T, Singh RN (2016) Feeding ancient cities in South Asia: dating the adoption of rice, millet and tropical pulses in the Indus civilisation. *Antiquity* 90:1,489–1,504
- Petrie CA, Singh RN, Bates J et al (2017) Adaptation to variable environments, resilience to climate change: investigating land, water and settlement in Indus, northwest India. *Curr Anthropol* 58:1–30
- Pokharia AK (2007) Plant remains from Kanmer excavation 05–06. In: Osada T (ed) *Linguistics, archaeology and the human past*. Research Institute for Humanity and Nature, Indus Project, Kyoto, pp 30–31
- Pokharia AK, Saraswat KS (1999) Plant economy during Kushana period (100–300 AD) at ancient Sanghol, Punjab. *Pragdhara* 9:75–121
- Pokharia AK, Kharakwal JS, Srivastava A (2014) Archaeobotanical evidence of millets in the Indian subcontinent with some

- observations on their role in the Indus civilization. *J Archaeol Sci* 42:442–455
- Pokharia AK, Mani BR, Spate M et al (2018) Early Neolithic agriculture (2700–2000 BC) and Kushan period developments (AD 100–300): macrobotanical evidence from Kanisapur in Kashmir, India. *Veget Hist Archaeobot* 27:477–491
- Pokharia AK, Sharma S, Tripathi D et al (2017) Neolithic- Early historic (2500–200 BC) plant use: The archaeobotany of Ganga Plain, India. *Quat Int* 443:223–237
- Reddy SN (2003) Discerning palates of the past: an ethnoarchaeological study of crop cultivation and plant usage in India. (International Monographs in Prehistory, Ethnoarchaeological series 5) Berghahn Books, Oxford
- Salunkhe A, Tamhankar S, Tetali S (2012) Molecular genetic diversity analysis in emmer wheat (*Triticum dicoccon* Schrank) from India. *Genet Res Crop Evol* 60:1–10
- Saraswat KS (1980) The ancient remains of the crop plants at Atranjikhhera (c. 2000–1500 BC). *J Indian Bot Soc* 59:306–319
- Saraswat KS (1986) Ancient crop economy of Harappans from Rohira, Punjab (c. 2000–1700 BC). *Palaeobotanist* 35:32–38
- Saraswat KS (1992) Archaeobotanical remains in ancient cultural and socioeconomical dynamics of the Indian subcontinent. *Palaeobotanist* 40:514–545
- Saraswat KS (2004) Plant economy of early farming communities. In: Singh BP (ed) Early farming communities of the Kaimur. Publication Scheme, Jaipur, pp 416–535
- Saraswat KS (2005) Agricultural background of the early farming communities in the Middle Ganga Plain. *Pragdhara* 15:145–177
- Saraswat KS, Pokharia AK (2003) Palaeoethnobotanical investigations at early Harappan Kunal. *Pragdhara* 13:105–140
- Sharif M, Thapar BK (1992) Food producing communities in Pakistan and northern India. *History of civilizations of Central Asia* 1:127–151
- Sharma AK (2000) Early man in Jammu Kashmir and Ladakh. Agam Kala Prakashan, Delhi
- Sharma AK (2013) Excavation at Gufkral (Jammu and Kashmir). BR Publishing House, New Delhi
- Sherratt A (1983) The secondary exploitation of animals in the Old World. *World Archaeol* 15:90–104
- Spate M, Zhang G, Yattoo M, Betts A (2017) New evidence for early 4th millennium BP agriculture in the Western Himalayas: Qasim Bagh, Kashmir. *J Archaeol Sci: Rep* 11:568–577
- Spengler RN (2015) Agriculture in the Central Asian Bronze Age. *J World Prehist* 28:215–253
- Spengler RN III (2019) Fruit from the sands: the Silk Road origins of the foods we eat. University of California Press, Berkeley
- Spengler RN, Willcox G (2013) Archaeobotanical results from Sarazm, Tajikistan, an Early Bronze Age settlement on the edge: agriculture and exchange. *Environ Archaeol* 18:211–221
- Spengler RN III, Frachetti MD, Fritz GJ (2013) Ecotopes and herd foraging practices in the steppe/mountain ecotone of Central Asia during the Bronze and Iron Ages. *J Ethnobiol* 33:125–147
- Spengler RN, Frachetti MD, Doumani PN (2014) Late Bronze Age agriculture at Tasbas in the Dzhungar Mountains of eastern Kazakhstan. *Quat Int* 348:147–157
- Spengler RN, Miller NF, Neef R et al (2017) Linking agriculture and exchange to social developments of the Central Asian Iron Age. *J Anthropol Archaeol* 48:295–308
- Spengler RN, de Nigris I, Cerasetti B et al (2018) The breadth of dietary economy in Bronze Age Central Asia: Case study from Adji Kui 1 in the Murghab region of Turkmenistan. *J Archaeol Sci: Rep* 22:372–381
- Srivastava C, Tewari DP (2011) Palaeoethnobotanical finds from ancient Naimisharanya, District Sitapur, UP during Kushana Period (AD 100–300). *Man Environ* 36:35–44
- Stacul G (1976) Excavation at Loebanr III (Swāt, Pakistan). *East West* 26:13–30
- Stacul G (1987) Prehistoric and protohistoric Swāt, Pakistan (c. 3000–1400 BC). IsMEO Reports and Memoirs, Rome
- Stacul G (1993) Kalako-deray, Swāt: 1989–1991 excavation report. *East West* 43:69–94
- Stevens CJ, Murphy C, Roberts R et al (2016) Between China and South Asia: A Middle Asian corridor of crop dispersal and agricultural innovation in the Bronze Age. *Holocene* 26:1,541–1,555
- Taylor WTT, Shnaider S, Spengler R III et al (2019) Investigating ancient animal economies and exchange in Kyrgyzstan’s Alay Valley. *Antiquity* 93(367):1–5
- Tewari R, Srivastava RK, Saraswat KS et al (2008) Early farming at Lahuradewa Pragdhara 18:347–373
- Thomas KD, Cartwright C (2010) The biological remains from Sheri Khan Tarakai. In: Tarakai SK, early village life in the borderlands of north-west Pakistan, Pakistan. (Bannu Archaeological Project Monographs, vol 1) (eds) Petrie CA, Khan F, Knox JR, Thomas KD. Oxbow, Oxford, pp 305–342
- Turner NJ, Deur D, Mellott CR (2011) “Up on the mountain”: ethnobotanical importance of montane sites In Pacific coastal North America. *J Ethnobiol* 31:4–43
- Vidale M, Olivieri LM (2002) Painted rock shelters of the Swat valley: further discoveries and new hypotheses. *East West* 52:173–223
- Vidale M, Micheli R, Olivieri L (2011) Iconography of protohistoric Swat and the agricultural intensification of Period IV (2nd Millennium BCE). *J Asian Civilizations* 34:97–126
- Vidale M, Olivieri LM, Micheli R (eds) (2015) Excavations at the protohistoric graveyards of Gogdara and Udegram (ACT Field School Reports and Memoirs 3). Sang-e-Meel Publications, Lahore
- Vishnu-Mittre, (1965) Floristic and ecological reconsiderations of the Pleistocene plant impressions from Kashmir. *Palaeobotanist* 13:308–327
- Vishnu-Mittre (1972) The Neolithic plant economy of Chirand, Bihar. *Palaeobotanist* 21:18–22
- Vishnu-Mittre (1984) Quaternary palaeobotany and palynology in the Himalaya: an overview. *Palaeobotanist* 32:158–187
- Von Hinüber O (2020) The name of the city. In: Callieri P, Olivieri LM (eds) Ceramics from the excavations in the historic settlement at Bir-kot-ghwandai (Barikot) Swat, Pakistan (1984–1992). ACT-Field School Project Reports and Memoirs, Lahore, pp 53–55
- Watson PJ (1976) In pursuit of prehistoric subsistence: a comparative account of some contemporary flotation techniques. *Midcontinental J Archaeol* 1:77–100
- Watson AM (1983) Agricultural innovation in the early Islamic world: the diffusion of crops and farming techniques, 700–1100. Cambridge University Press, Cambridge
- Weber SA (1991) Plants and Harappan subsistence: An example of stability and change from Rojdi. Routledge, London
- Weber S (1999) Seeds of urbanism: palaeoethnobotany and the Indus Civilization. *Antiquity* 73:813–826
- Weber SA (2003) Archaeobotany at Harappa: indications for change. In: Weber SA, Belcher WR (eds) Indus ethnobiology: new perspectives from the field. Lexington Books, Lanham, pp 175–198
- Weber SA, Fuller DQ (2008) Millets and their role in early agriculture. *Pragdhara* 18:69–90
- Zeb A, Khan SM, Ahmad H (2013) Wild plants of the Dughalgay valley, District Swat, Pakistan; traditional use and marketing. *Emirates J Food Agric* 25:1–10
- Zhou X, Yu J, Spengler RN et al (2020) 5,200-year-old cereal grains from the eastern Altai Mountains redate the trans-Eurasian crop exchange. *Nat Plants* 6:78–87