Qarakhanids on the Edge of the Bukhara Oasis: Archaeobotany of Medieval Paykend

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The urban center of Paykend was an exchange node just off the main corridor of the Silk Road in the Bukhara Oasis on the edge of the hyperarid Kyzyl–Kum Desert. The city was occupied from the end of 4 century B.C.E. to the mid–12 century C.E.; our study focuses on the Qarakhanid period (C.E. 999 – 1211), the last imperial phase of urban occupation at Paykend before its abandonment. In this study, we present the results of an analysis of archaeobotanical remains recovered from a multifunction rabat, which appears to have comprised a domicile, military structure, center of commerce, and/or a caravanserai, a roadside inn for travelers. We shed light on how people adapted a productive economy to the local ecological constraints. By adding these data to the limited Qarakhanid archaeobotany from across Central Asia, we provide the first glimpses into cultivation, commerce, and consumption at a Silk Road trading town along the King's Road, the central artery of ancient Eurasia.

Key Words: Paykend, Qarakhanids, agriculture, Silk Road, arboriculture, millet, rice.

Introduction

The archaeology and history of the Silk Road have recently received considerable attention, emphasizing the influence of the trade routes in shaping cultures across Eurasia (Frankopan 2015; Spengler 2019a; Whitfield 2019). The lasting effects of the Silk Road are visible in the food we eat (Spengler 2019b), the genes of humans across Eurasia (Damgaard et al. 2018), and the languages many of us speak (Robbeets and Savelyev 2017). The heart of the Silk Road consisted of a linked string of urban centers, including Afrasiab (ancient Samarkand), Bukhara, and Paykend (Figure 1), that stretched across ancient Sogdiana—what is now Uzbekistan and Tajikistan. Some of these oasis cities were first occupied in prehistory, but overland trade peaked between the early medieval period

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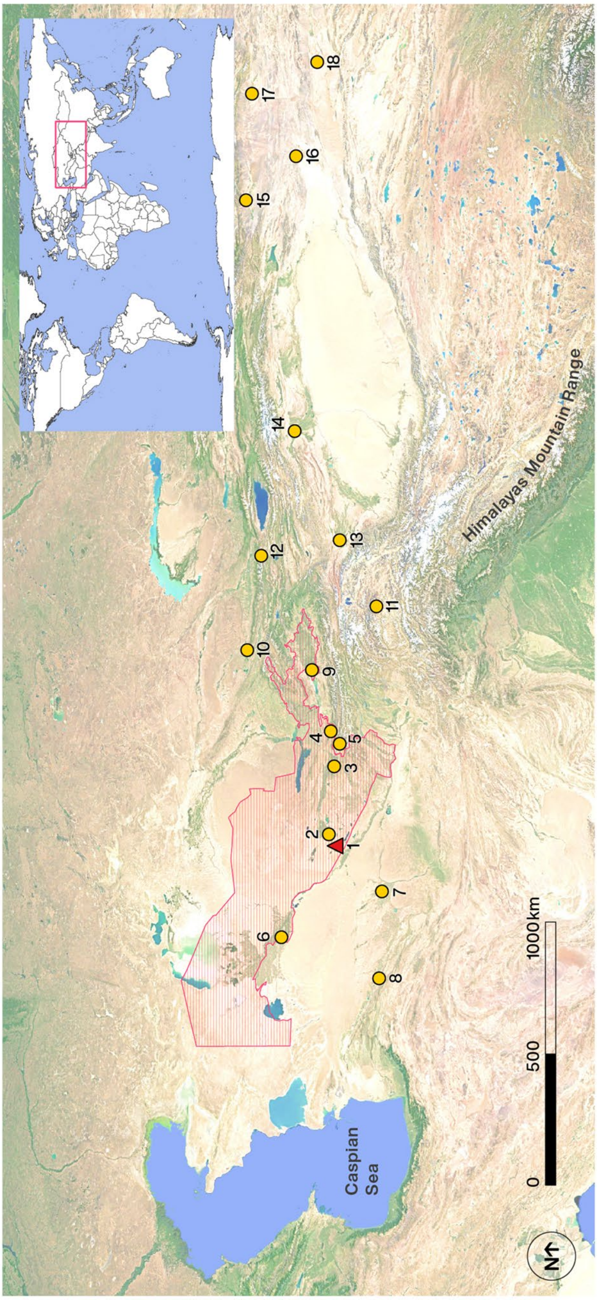

Fig. 1. Medieval cities: 1 – Paykend, 2 – Bukhara, 3 – Afrasiab, 4 – Tashbulak, 5 – Panjakent, 6 – Khiva, 7 – Merv, 8 – Askhabad, 9 – Kokand, 10 – Taraz, 11 – Bazar–Dara, 12 – Ak–Beshim, 13 – Kashgar, 14 – Aksu, 15 – Turpan, 16 – Loulan, 17 – Hami, and 18 – Dunhuang.

and continued until the Mongol Conquests in the year 1220 (Abazov 2008; Biran 2001).

As a trading hub, Paykend helped bridge imperial centers from China to the eastern Mediterranean—eastern Turkestan, Chach, eastern Sogdiana, and Margiana, as well as ancient Bactria/Tokharistan and the Indian subcontinent (Buryakov 1997; Omel'chenko 2013, 2019). Paykend was founded by Sogdians as a fortress in the 4th century B.C.E., and developed into a city at the transition period between late Antiquity and the Early Middle Ages, becoming a prominent *entrepôt* that flourished until the middle of the Qarakhanid period (Omel'chenko 2019; Semenov 2002). As an urban center, Paykend remained prosperous until the 11th century, when it was abandoned due to aridification (Narshakhi 943; Nekrasova and Torgoev 2016; Omel'chenko 2019) and a reduction in water output from the main course of the Zerafshan River on which Paykend was located (Rante and Mirzhaakhmedov 2019). Over time, the water deficit caused abandonment of numerous cities on the edges of the Bukhara Oasis. In the Tārīkh–i Bukhārā, it was claimed that Ali Arslan Khan, a Qarakhanid ruler, attempted to have a canal dug to revive the city but was unsuccessful (Narshakhi 943; Nekrasova and Torgoev 2016). Our radiocarbon dates illustrate (discussed below) that, until the end of the Qarakhanid period after the city was in decline, Rabat–4 may have continued to serve as a caravanserai or a rest stop where travelers remained for short periods before continuing their journey. It is likely that rabats in this region continued to function, due to their position at lower elevation, their economic importance, their sponsorship by the state, and the fact that they did not require as much water as a full city.

The ancient road from Amul/Amuya/Firabr to Bukhara would have been widely traveled, fostering long–distance commerce and providing incentive for the broader empire to continue protecting caravans along the eastern edges of the oasis. The heart of the ancient city would have been located a few thousand meters from the caravanserai, and would have already been in ruins by the time the Mongols arrived in Bukhara (Semenov 2002). The fact that the city has been desiccated since its abandonment provides a unique glimpse into life before the Mongol Conquests. The region itself was suitable for farming until the later part of the Qarakhanid phase, due to a complex system of lakes and canals (Omel'chenko 2019); whereas, historical sources discuss the local branch of the oasis as a microecological pocket, suggesting that between 400 and 1,100 ha of the city was located in the rural hinterland (Naymark 1992).

Historically, the Qarakhanids are thought to be the first Central Asian Islamic dynasty with rulers who had Turkic origins and a court that was run in a Turkic language (Biran 2015, 2016; Duturaeva 2016; Hua 2008; Kochnev 2006; Paul 2001; Pritsak 1951, 1953; Umnyakov 1927). At the end of the 10th century, the Qarakhanids displaced the Samanid elites, and most of the resulting multiethnic empire lived in cities in the lowlands or towns in the foothill or desert–grassland ecotones, where people actively carried out irrigated agriculture and trade (Maksudov et al. 2019). Taking over Samarkand and Bukhara, the Qarakhanid rulers invested in irrigation and urban infrastructure building. Qarakhanid rulers (khan/khagan), such as Ali Aslan Khan, supported the construction of palaces (sarai) in and around Samarkand and Bukhara; in addition, considerable reconstruction work was undertaken at Paykend (Karev 2013). Many mausoleums, minarets, madrasas, and mosques were constructed throughout the Qarakhanid territory (Arapov 2013). During the Qarakhanid period, irrigation canals were built for farming in northern Central Asia (Golden 2011). Clarke et al. (2005) stated that irrigation systems were expanded onto the floodplains and deltas between C.E. 950 and 1200; while people in Fergana and Transoxiana appear to have continued a sedentary farming lifeway (Golden 2011). Despite extensive investment in infrastructure and agriculture, the empire experienced problems before the Mongol Conquests, possibly due to the pluralistic system of government common among most of the steppe empires. Historians state that the Qarakhanids divided land among siblings, a practice historically typical of mobile pastoralists. As a result, the empire rapidly splintered and four capitals formed: Kashgar, Samarkand, Uzgen, and Balasagun. According to Starr (2013), this increasing expansiveness and decentralization was the Achilles' heel of the Qarakhanids.

Early archaeological investigation at Paykend focused on cultural artifacts and architecture (Baratova and Omel'chenko 2013; Mirzaakhmedov 2016; Mirzaakhmedov et al. 2016; Mukhamedzhanov et al. 1988; Omel'chenko 2013, 2019; Semenov 2002), and a dearth of data on floral and faunal remains persists from Qarakhanid sites in the region. In this study, we ask the following: 1) how did agriculture develop in the hyperarid desert during the Qarakhanid reign—a period when some historians envision an agricultural decline (e.g., Bartol'd 1963:62–63); and 2) what was the role of arboriculture and cash crops at this nodal city of the Silk Road. We present an archaeobotanical assemblage from the Qarakhanid period to test assumptions about agricultural development or decline and to explore the introduction of crops into the core of the trade routes.

Paykend and Its Environment

The site (39.586244°, 64.008709°; 233 masl) is located in the southwest of the Bukhara Oasis on the lower course of the Zerafshan River (Omel'chenko 2019) on the edge of the desert zone (Rante and Mirzaakhmedov 2019). Finds of 9th/10th century, exfoliated and easily breakable ceramic sherds in a depression to the southeast of Paykend, indicate that the ceramics were long exposed to water suggesting that there might have been water reaching the Paykend area from the lower Kashka–Darya River as late as the 9th/10th centuries (Stark et al. 2017). Despite an average annual rainfall ranging from 114–125 mm (Mavlyanova et al. 2005) to 160 mm (Rante and Mirzaakhmedov 2019), most of the oasis is currently under cultivation of fruit orchards and wheat and cotton fields (Kurbonovich 2016). The pumping of underground aquifers, loss of mountain glaciers, and heavy diversion of water from the river has dramatically changed the boundaries of the oasis over the past century and lowered the water table. However, detailed studies of botanical remains and cultivation practices can inform us as to what the local ecology would have looked like in the past.

Materials and Methods

We collected 22 sediment samples (412.5 L) from Paykend in 2019, where 20 samples were from Rabat–4 (357.5 L) and two samples were from two middens (55 L) in Shakhristan II (Figure 2). Cooking ovens, tandyrs (cylindrical clay ovens that are typical for Central Asia), and burnt deposits were sampled at Rabat–4, the urban center of the 9th/10th centuries at Paykend (Semenov 2002). The midden samples from Shakhristan II are ideal complements to the hearth and oven contexts, which would have been regularly cleaned. We floated the samples using an overflow machine with a catchment tank system, which allowed for more rapid field processing and the reduction of water waste. All macrobotanical remains were recovered in a carbonized state. Following established protocols for archaeobotanical studies in Central Asia (Motuzaite Matuzeviciute et al. 2019; Spengler et al. 2018), light fraction was collected down to 0.355 mm, and the heavy fraction was collected down to 1.4 mm. Heavy fraction samples were sorted in the field and all carbonized macrobotanical remains were separated and packaged for transport. All cultural artifacts were returned to the archaeologists, while the light fractions and macrobotanical remains from the heavy fraction were sent for analysis to the Paleoethnobotany Laboratory at the Max Planck Institute for the Science of Human History in Jena, Germany.

In the laboratory, carpological remains were examined under low magnification and identified using seed identification keys (e.g., Cappers and Bekker 2013; Cappers et al. 2012; Jacomet 2006, 2012; Neef et al. 2012). The identifiable seeds and fruit parts were quantified and have been presented in the Electronic Supplementary Material (ESM) 1. Fragmented grains of free–threshing wheat (*Triticum aestivum* L.) and hulled barley (*Hordeum vulgare* var. *vulgare* L.) were quantified based on Minimum Number of Individual (MNI) estimates, whereas three fragments were counted as one grain. Fragmented grains of wheat or barley that were too small to properly identify (usually less than one third of the original mass) were categorized as Cerealia. Fragments not assigned to a taxon were classified as unidentifiable. Seed fragments and

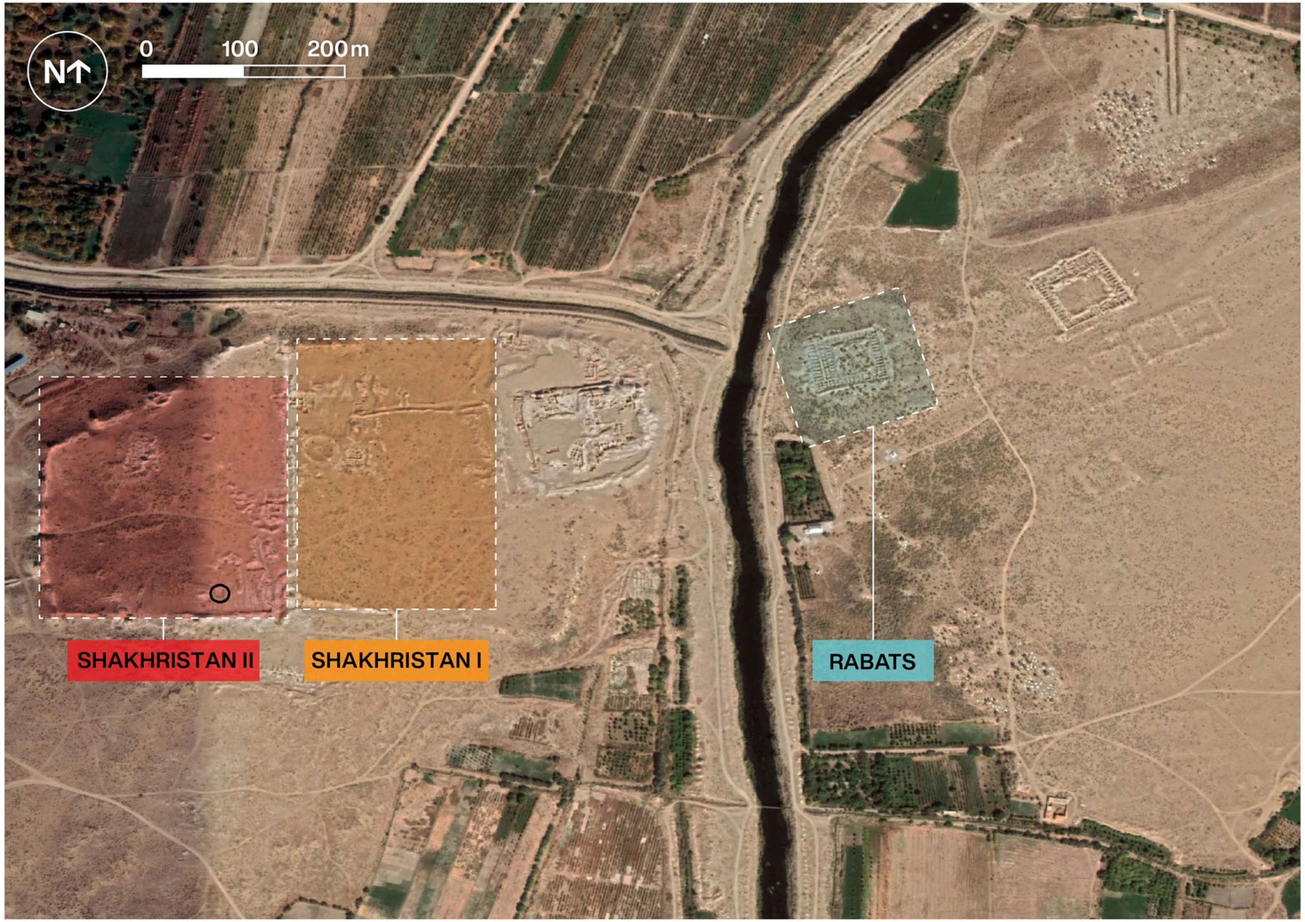

Fig. 2. A map showing the occupation divisions of Paykend; our study focused on the circled area in the upper right, i.e., Rabat–4, and the midden located to the southwest encircled in Shakhristan II.

Cerealia were not added to the total counts. Nuts were represented mainly by fragmented shells, and minimum numbers estimated due to their small number and were presented as fragments in ESM 1.

Length, width, and thickness measurements were made for all whole wheat, barley, and millet grains. Grape (*Vitis vinifera* L.) measurement parameters were length, stalk length, chalaza position, and width (Table 1); measurements were made digitally with a Keyence VHX 6000 microscope. After identification and measurement, six samples were chosen and sent for radiocarbon dating. Barley, wheat, and broomcorn millet (*Panicum miliaceum* L.) grains from Rabat–4 and wheat and barley from Shakhristan II were directly dated (AMS) at the Scottish Universities Environmental Research Centre (SUERC) Radiocarbon Dating Laboratory and calibrated using OxCal v4.4.2 software (Bronk Ramsey 2009, 2020) and the IntCal 20 curve (Reimer et al. 2020).

Results

Radiocarbon Dating

The results of the radiocarbon dating are provided in Figure 3. The possible occupation range spans cal. C.E. 897–1223, resulting from the 2–sigma calibration. The mean (μ) of the two dates from Shakhristan II ranged from cal. C.E. 992 to 1106. A wheat grain from FS 8 dated

Table 1. Average seed measurements for the most prominent crops

	Total	Whole	Not measurable	Average length (mm)	Average width (mm)	Average thickness (mm)	Scutellum length (mm)	Stalk length (mm)	Chalaza position (mm)
Barley	327	165	162	5.14	2.56	2.06			
Wheat	368	178	190	3.9	2.48	2.07			
Small wheat	86	40	46	2.92	1.79	1.53			
Rice	3	3		4.59	2.73	1.97			
Broomcorn millet	151	68	83	1.88	1.61		0.67		
Foxtail millet	68	25	43	1.65	1.47		1.09		
Grape	31	14	17	4.95	3.09			1.16	2.45

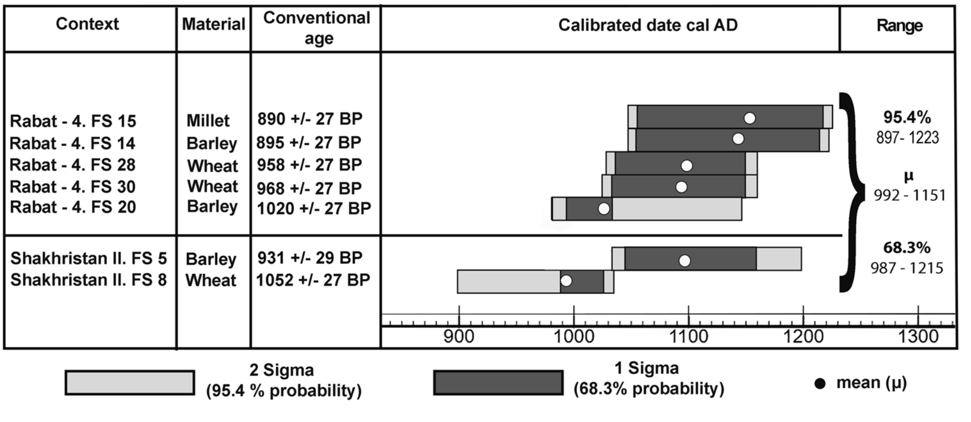

Fig. 3. Radiocarbon dates obtained on carbonized grains recovered from Rabat–4 and Shakhristan II

between cal. C.E. 897 and 1032 (GU56000) and a barley grain from FS 5 is from between cal. C.E. 1032 and 1119 (GU56828). The mean (μ) of the four dates from Rabat–4 ranged from cal. C.E. 1023 to 1151. Barley from FS 20 dated between cal. C.E. 980 and 1148 (GU56003) and FS 14 – cal. C.E. 1045–1220 (GU56001); wheat from FS 28 is from between cal. C.E. 1028 and 1158 (GU56004) and FS 30 – cal. C.E. 1023–1158 (GU56005); and millet grains from FS 15 were dated to cal. C.E. 1034–1230 (GU56002) with 95.4% probability in Rabat–4 (see ESM 2). Based on curves on the multiple plots (Figure 3), the samples span the Qarakhanid period from the 11th and 12th centuries C.E.

Archaeobotany

The archaeobotanical assemblage presented in this article consists of 25,646 carbonized seeds and fruit parts, as well as 1,132 unidentifiable seed fragments (ESM 1). In addition to the total sum of identified seeds, there were 319 Cerealia fragments and one legume fragment. Combined, these samples yielded 75 plant taxa, including domesticated grains and legumes, fruits and nuts, and wild herbaceous plants. Some of the wild species were only identifiable to family, suggesting that the total number of represented species is greater than the number of named taxa. Of the identifiable specimens, 1,061 seeds belonged to the group of domesticated field crops, 57 were categorized as fruits or nuts, and 24,528 were placed in the group of wild herbaceous plants. In addition to seeds and nutshell fragments, 66 free–threshing hexaploid wheat rachises, 2 possible spikelet fragments, 193 hulled barley rachises, and 4 culm nodes were recovered but were not added to the final counts. In addition to carpological remains, 648.2 g of wood fragments larger than 2.0 mm in diameter were recovered.

Domesticated Crops

Five grain crops were recovered at Paykend: free–threshing wheat, hulled barley, broomcorn millet, foxtail millet (*Setaria italica* [L.] P. Beauv), and rice (*Oryza sativa* L.). Legumes included lentils (*Lens culinaris* Medik.), green peas (*Pisum sativum* L.), and chickpeas (*Cicer arietinum* L.). Furthermore, seeds of flax (*Linum usitatissimum* L.) and cotton (*Gossypium* sp.) were identified in a few Rabat–4 samples.

Of the 1,061 domesticated crops, the most dominant specimen type was free–threshing wheat (n=454); additionally, 65 hexaploid wheat rachis internodes (Figure 4e) were recovered. Out of 454 wheat grains, 86 of them were classified and counted separately, due to their unusually small, but not compact morphology. The small wheat grains were recovered from only two samples: one sample (FS 29) came from a tandyr oven on the southwestern side of Rabat–4 and one additional small grain came from Shakhristan II (FS 8). Wheat grains made up 42.3% of the total domesticated annual crop seeds, with a density of 1.21 grains per liter in Rabat–4. Wheat was the most abundant crop recovered, and its ubiquity was 65% in Rabat–4 and 100% in Shakhristan II. There were 327 barley grains recovered, which all appear to be hulled; moreover, all whole barley rachis internodes resembled hulled forms. Barley grains were only recovered from Rabat–4. Although, the relative abundance (32%) and density (0.915 grains per liter) of barley was less than wheat, its ubiquity (75%) was higher. In addition to barley and wheat, 138 broomcorn and 47 foxtail millet grains were recovered. Although, millet was recovered at a lower density (0.671 seeds per liter) and its relative abundance was only 23.4%, its ubiquity was almost 85% (Table 2). In addition, three rice grains were recovered from one Rabat–4 sample.

A single chickpea was handpicked from the midden in Shakhristan II (Figure 4i). Additionally, three lentils were identified, two of which came from Rabat–4 and one from Shakhristan II. Only one pea was recovered from Rabat–4, and was in a bad state of preservation, but was still identifiable. Due to the small number of seeds, the ubiquity, density, and relative abundances for legumes were lower than any of the grain crops. Cotton seeds (n=11) were recovered from three samples, with a ubiquity of 15%. The two samples from the tandyr ovens and the one from the hearth contained significant quantities of charcoal.

Fruits and Nuts

In addition to grains and legumes, fruit seeds and nutshell fragments were recovered,

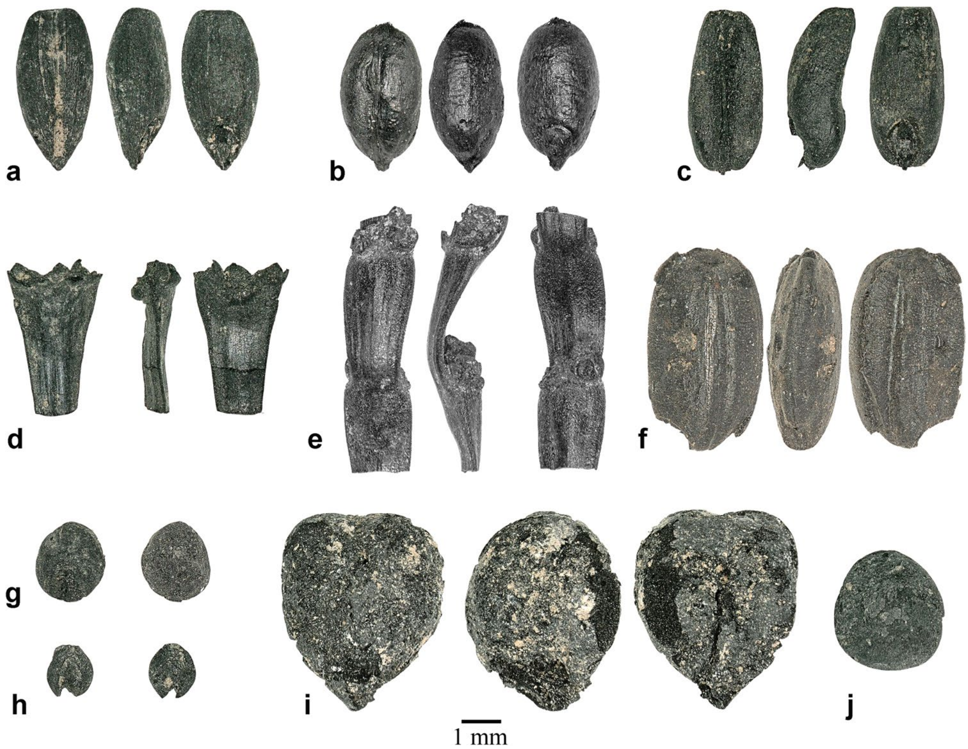

Fig. 4. a: *Hordeum vulgare* var. *vulgare* L., b: *Triticum aestivum* L., c: *Triticum* sp., d: Rachis of hulled barley, e: Rachises of free–threshing wheat, f: *Oryza sativa* L., g: *Panicum miliaceum* L., h: *Setaria italica* (L.) P. Beauv, i: *Cicer arietinum* L., and j: *Lens culinaris* Medik.

including seeds of sweet melons (*Cucumis* cf. *melo* L.; Figure 5a), fragments of apricot endocarp (*Prunus* cf. *armeniaca* L.; Figure 5f), fragments of walnut endocarp (*Juglans regia* L.; Figure 5g–h), a fragment of a pistachio shell (cf. *Pistacia vera* L.; Figure 5e), a stone fragment of Russian olive (*Elaeagnus angustifolia* L.; Figure 5d), apple/pear seeds (*Malus/ Pyrus*; Figure 5b), and grape pips (Figure 5c). The most abundant fruit in the assemblage was grape (n=31 pips), making up almost 48.4% of the recovered fruit and nut remains from Rabat–4 and 61.5% from Shakhristan II. Six melon seeds were discovered in Rabat–4 samples. Most melon seeds came from the ovens, and they were not in a good state of preservation. Nonetheless, the diagnostic features of *Cucumis* sp. were visible, presumably from *C. melo* (see Figure 5a). Also, three apple/pear seeds were recovered from the same samples as the melon and grape seeds in Rabat–4 and one seed came from Shakhristan II. They express considerable morphological variation (see Figure 5b).

There were five fragments of *Prunus* endocarp, but only two of them could be confidently classified as apricot stone fragments. Three walnut shell fragments were found in one sample. The pistachio shell does not have clear distinctive characteristics, but roughly resembles the shape of a pistachio shell. Most of the nutshell fragments came from Shakhristan II. In addition to all above–mentioned fruits and nuts, half of an oblong Russian olive stone was recorded from Rabat–4.

Wild Herbaceous Plants

In addition to the cultivated crops, 53 wild seed categories were recorded, belonging to 16 families. The most abundant wild seed group came from members of Amaranthaceae, which

Table 2. Absolute number, ubiquity, relative abundance, and density measurements by context at Paykend for staple crops.

		Wheat	Barley	Foxtail millet	Broomcorn millet	Rice	Pea	Lentil	Chickpea	Flax	Cotton
Rabat-4	Ubiquity (%) (n=20)	65	75	55	85	5	5	10			15
	Density (seeds/L) (357.5 L)	1.211	0.915	0.190	0.422	0.008	0.003	0.006			0.191
	RA (%) (n=1023)	42.3	32	6.6	14.8	0.3	0.1	0.2			1.07
	Count	433	327	68	151	3	1	2			11
Shakhristan II	Ubiquity (%) (n=2)	100						50	50	50	
	Density (seeds/L) (55 L)	0.418						0.018	0.018	0.2	
	RA (%) (n=37)	62.2						2.7	2.7	29.7	
	Count	23						1	1	11	

made up almost 66% of all wild seeds in Rabat–4 and 30.9% in Shakhristan II. We subdivided Amaranthaceae seeds into several categories based on morphological characteristics. Many specimens had traits that matched *Chenopodium/Atriplex* spp., *Suaeda* spp., or *Salsola* type, but there were also seeds for which their genera were not identified, and they were classified as Amaranthaceae. We also subdivided Fabaceae into several categories, including *Medicago/Melilotus* spp., *Alhagi* sp., *Trifolium* sp., *Trigonella* sp., and *Coronilla/Trigonella* spp., which made up 11.9% of the abundance from the Rabat–4 samples and 25.5% from the Shakhristan II sample. The most ubiquitous and abundant types of the Fabaceae were camel thorn (*Alhagi* sp.) and a small herbaceous type—*Medicago/Melilotus* spp. Asteraceae achenes were present at a ubiquity of 90%. Achenes of Asteraceae type A were narrowly obovoid and biconvex with a truncated apex—an unidentified type recovered in more than half of the Rabat–4 samples. Small Poaceae type A is the most abundant category of grass recovered in Rabat–4. The seeds of this clade were small (0.6–0.5 mm), obovoid and possessed a compressed small hilum at the bottom. In addition to the small grass seeds, the category pooid was used for many of the wild grasses. The least abundant seeds were attributed to Boraginaceae; their relative abundance was <0.1, because only two mericarps of *Heliotropium* sp., five mericarps of *Lithospermum arvense* L., and 3 mericarps of the borage family were recovered. In addition to carbonized *L. arvense*, 30 mineralized seeds of this species were found in the assemblage, but they were not counted.

Discussion

Taphonomy

Spengler et al. (2013b) proposed several reasons for the presence of wild/weedy plant remains in the archaeobotanical assemblages: human/animal foraging, dung burning, natural dispersal, bioturbation, and seed rain. Although our samples are not large enough to make any conclusions regarding taphonomy of the samples coming from Shakhristan II, we speculate that recovered plant remains from the middens consist of kitchen waste as they include fragments

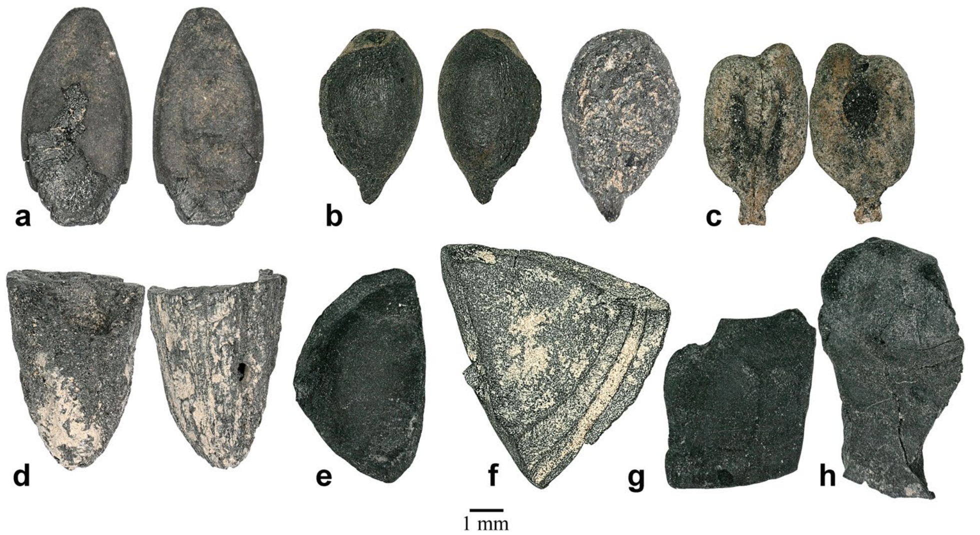

Fig. 5. a: *Cucumis* cf. *melo* L., b: *Malus/Pyrus*, c: *Vitis vinifera* L., d: *Elaeagnus angustifolia* L., e: cf. *Pistacia vera* L., f: *Prunus* cf. *armeniaca* L., and g – h: *Juglans regia* L.

of economic plants. Although there are remains of wild herbaceous plants, their density is only three seeds per one liter, which is much less than in Rabat–4 where the density of wild plants made up almost 68 plant remains per liter. In addition to kitchen waste and crop–processing, the material reported from Rabat–4 is likely too rich to represent fuel residue alone. Archaeobotanical studies and experiments in Central Asia (Miller and Smart 1984; Spengler 2019a; Spengler et al. 2013b) have demonstrated that dung burning is one of the primary sources of wild herbaceous plant seeds in archaeological contexts, as many tiny seeds withstand digestion and charring. Our data illustrate that dung was used parallel to wood as fuel sources in Paykend.

Agriculture in the Hyper–Arid Desert

Ecological Constraints

This archaeobotanical study helps answer long–standing questions related to agrarian practices and environmental context. Evidence from Paykend indicates local cultivation of barley, wheat, and millet. Barley can reliably be grown on saline soil and in arid or cold conditions (Shapiro Ledley et al. 2017), as well as in nutrient–poor soils (Zohary et al. 2012), and certain varieties can be grown at extremely high altitudes (Tang et al. 2021). These qualities make barley one of the most prominent crops, grown in antiquity from the British Isles to the Japanese Archipelago. Based on archaeobotanical data (e.g., Miller 1993; Motuzaite Matuzeviciute et al. 2020, 2021b; Spengler et al. 2017) from the third to the mid–first millennia B.C.E., barley was widely cultivated, but the ratio of wheat to barley slightly shifted in favor of wheat starting in the mid–first millennium B.C.E. across Central Asia. The shift may have stemmed from improvements in irrigation systems and the greater reliance on bread wheat (Hole et al. 1969). Wheat grains recovered at Paykend varied considerably in size. In one sample (FS 29), 85 wheat grains were particularly small (Figure 6). There are many different variables that affect grain dimensions, such as different amounts of nutrients, sunlight, differing temperatures, soil moisture, altitude, latitude, etc., which can phenotypically impact development (Motuzaite Matuzeviciute et al. 2018, 2021a). There are two possible interpretations: 1) the small wheat grains could represent a plastic reaction to short–term drought stress. Water deficits reduce the mass flow of nutrients and nutrient diffusion between soil particles and

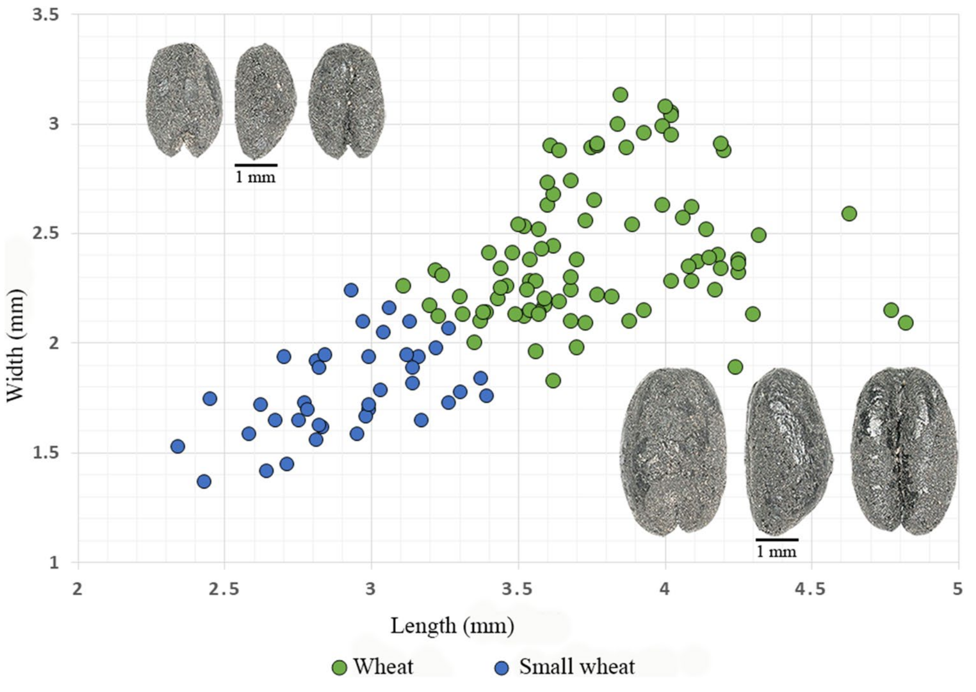

Fig. 6. Size variations of free–threshing wheat grains from sample FS29.

cause root shrinkage (Bloom et al. 1985); therefore, wheat grains might have received fewer nutrients, consequently influencing grain size. However, grain mass may vary relative to the location on the floret and immature grains can also appear either small or collapsed (Baillot et al. 2018). Therefore, 2) the small grains may represent the immature grains, possibly that might have been fed to animals and later come to the context with dung that was used as fuel.

Although wheat and rice were mentioned in historical sources as exported crops in the 5th century C.E., we argue that wheat was derived from local crop–cultivation at Paykend during the Qarakhanid period, because crop processing by–products were recovered together with grains in the samples (Fig. 4d, e). Many archaeobotanists have pointed out that "plant food that are to be traded are usually transported in a pure, fully cleaned form" (Herrmann et al. 1993:56)

Risk–Reduction Strategies

Both broomcorn and foxtail millet were present in the Paykend assemblage, despite not being identified at other Qarakhanid settlements and being rare in urban centers across Central Asia through time (Miller et al. 2016). Spengler et al. (2018) highlighted the fact that the millets were an important crop just a thousand years earlier than the samples in this study and have traditionally been associated with mobile peoples across Eurasia. Millet grains have been recovered from medieval cities further north, including Taraz (C.E. 942–1210) (Bashtannik et al. 2015), Talgar (C.E. 700–1200), Akyrtas (C.E. 900–1200), Ornok (C.E. 900–1200) (Bashtannik 2007), and in Zhuan–Tobe (9th and 10th centuries) (Bashtannik 2008). Stable isotope analysis further shows that the people living in the big cities during the medieval period were not eating considerable quantities of millet, while people in the small towns, homesteads, or living in seasonal camps were consuming the grains in substantial quantities (Hermes et al. 2018). Millet cultivation could have been beneficial for small villages and cities with poor irrigation and unreliable economies, because it would have mitigated agricultural risk and required lower labor investment than other crops.

Additionally, the millets could have played a key role in crop–rotation cycles as a summer–dry crop (Miller et al. 2016). Pokharia et al. (2014) pointed out that millet was an important component of dryland agriculture in South Asia. Thus, millet cultivation at Paykend may have been a response to aridity in the region, due to aridification of this part of Central Asia, or simply one component in a complex multi–cropping system of rotation, possibly seasonal.

Water–Demanding Crops

Rice is currently the most consumed cereal after wheat in Uzbekistan. The oldest rice grains recovered in Central Asia come from the ancient urban site of Khalchayan in Uzbekistan, dating to the 2nd or 3rd century C.E. (Kushan period) (Chen et al. 2020). Archaeobotanical studies illustrate that rice has been present in Central Asia since the early first millennium C.E. (Spengler 2019a). While, according to historical sources, rice was attested in Fergana since the late 2nd century B.C.E. (Spengler 2019a). Rice is the most water–demanding crop found at the site; taking into consideration the aridity of the area, especially around the tail end of occupation at Paykend, we think it is more likely that these three grains represent a trade item. Similar to rice, cotton is another water–demanding crop recovered at Paykend, but its presence in the form of seeds does not necessarily mean that it was grown around the city at this time, but it could have been brought from Bukhara where it was likely cultivated based on preliminary results from our ongoing project there.

Arboriculture and Cash Crops at Paykend

The only previous systematic archaeobotanical study of a Qarakhanid settlement was conducted on sediments from the high–elevation village of Tashbulak, in the Pamir Mountains of Uzbekistan (Maksudov et al. 2019). Tashbulak was geographically removed from the large urban centers of the political core of the empire. However, excavations at the site suggest that the occupants were directly connected into a broader Qarakhanid social network (Hermes et al. 2018; Maksudov et al. 2019). In contrast to Tashbulak, Paykend was an urban center at the political core of the empire. Moreover, Paykend and Tashbulak are located on ecologically different landscapes, but as Spengler et al. (2018) noted, fruit and nut remains found in Tashbulak had to have been cultivated at lower elevations and transported up to high elevations (ca. 2,200 masl). Spengler et al. (2018) identified seeds from stone fruits and grapes including wild capers (*Capparis spinosa* L.), wild cherries (*Prunus* subgenus *Padus* Forcke), wild hackberries (*Celtis caucasica* Willd.), as well as possibly cultivated Russian olives, sea buckthorn (*Hippophae rhamnoides* L.), walnuts, apples, and pistachios. Domesticated and non–native crops included apricots, grapes, melon, and peaches (*Prunus persica* [L.] Batsch), all of which were mainly recovered from one midden (the South unit).

Similar to Tashbulak, grapes were the most abundant fruit seeds recovered from Paykend, likely reflecting their importance in the economy (Spengler 2019b). Today, grapes are actively cultivated to the north of Paykend (Rante and Mirzaakhmedov 2019). Grapes have been cultivated in southern Central Asia since the second millennium B.C.E., and spread into the northern mountains by the mid–first millennium B.C.E. (Miller 1999; Spengler et al. 2013a, 2017; Wu et al. 2015). Although, grape cultivation is often associated with wine production (Janick et al. 2010), we can only theorize what role religions or political prohibitions may have played at the northern peripheries of the ancient Islamic world (Spengler 2019a). Additionally, grapes would have been one of the few sources of sweetness in the ancient world, also being easily stored when dried (Miller 2008).

The earliest evidence of apples in Central Asia comes from two possible *Malus* seeds, one found at second millennium B.C.E. Gonur in Turkmenistan (Miller 1999) and another from the later first millennium B.C.E. site of Tuzusai in Kazakhstan (Spengler et al. 2013a). Genetic and archaeobotanical research has illustrated that the origin of the apple is tied to human dispersal across Eurasia resulting in hybridization (Cornille et al. 2014); moreover, authors believe that the gene pool of modern apples is a consequence of the Silk Road. Genetic studies further suggest a center of origin for the modern apple within the Tian Shan Mountains of Kazakhstan (Harris et al. 2002; Spengler 2019b, c). The apple seeds from

Paykend further show the importance of this fruit tree along the trans–Eurasian exchange routes.

Today, there are more than 160 local melon varieties recognized in Uzbekistan (Androlovich et al. 2020). Unlike the grape and apple, the melon is largely absent from archaeobotanical records in Central Asia until the first millennium C.E. Its seeds were reported to have been recovered in the Khoresm Oasis from Kara–Tepe, dated to the 4th or 5th centuries C.E. (Brite et al. 2017). Melons have also been illustrated on a wall painting with banqueters, dated to the 8th century C.E., at Panjikent (Hensellek 2019). Later melon seeds have been recovered from Tashbulak (Spengler et al. 2018). There is an ongoing debate (Endl et al. 2018; Wang et al. 2020) over the origin and domestication of the melon. Wang et al. (2020), based on the published archaeological results, conclude that the sweet melon has been continuously cultivated for more than 6,000 years in China. As one example of supporting evidence, 15 wild melon (*Cucumis melo* ssp. *agrestis* Naudin) seeds were recovered at Tianluoshan in Zhejiang Province, China, from a cultural layer dated to 3640 B.C.E (Fuller et al. 2011). The melon likely spread across Central Asia from China and has been cultivated in Central Asia only since the medieval period. Later, it appears to have dispersed to Europe by a mostly overland route from Central Asia (Paris et al. 2012).

The identification of apricots at Tashbulak, in combination with their historical importance in Central Asia, suggests that the smooth–shelled *Prunus* fragments at Paykend are likely apricots. Bukhara has a specific ancient variety of apricot that has a small, sweet pericarp and a non–bitter seed; they are often sold as nuts in the markets and added to jams. Moreover, it is a major crop in the Zerafshan region and grows around Paykend today. There is a longstanding and unresolved debate over whether the apricot originated in the Caucasus, East Asia, or both (Decroocq et al. 2016; Vavilov 1950; Weisskopf and Fuller 2014). Fuller and Stevens (2019) concluded that the "cultivated apricot originates in China" and was first dispersed outside of China during the second millennium B.C.E. (Stevens et al. 2016). But recent genetic work (Liu et al. 2019b) suggests a polyphyletic origin, with up to three independent domestication events: Southern Central Asian, European, and Chinese cultivated apricot lineages

Despite the small number of nutshell fragments at Paykend, nuts were commercially important along the Silk Road; for example, markets of pistachio nuts "Bazar of the pista–shikanan" were mentioned in historical Tarikh–i Bukhara (Narshakhi 943:54), which probably was a specialized bazaar (market) for the sale of pistachio nuts, situated just outside of the early–medieval city walls. Ecologically, it is unlikely that pistachios were cultivated in the desert near Paykend, but they could have been cultivated on the slopes of the mountains less than 100 km away (Hormaza et al. 1994; Miller 1999; Spengler 2019b; Spengler et al. 2018; Zohary et al. 2012). The Central Asian mountains, spanning from the Tian Shan, Central Pamir–Alay, and south to the Kopetdag, were likely covered in open–canopy forests of shrubby trees in prehistory (Kayimov et al. 2011; Khanazarov et al. 2009). Pistachio shell fragments were also found at the second millennium B.C.E. sites of Sarazm in Uzbekistan (Spengler and Willcox 2013), Shortughai in Afghanistan (Willcox 1991a), and Djarkutan in Turkmenistan (Miller 1999).

Wild walnut forests grow across a wide geographic range, from Xinjiang in Western China to the Caucasus (Pollegioni et al. 2017; Spengler 2019b; Zohary et al. 2012) and Southern Europe (Renfrew 1973). The center of origin for the cultivated walnut presumably covers much or all of its wild range (Leslie and McGranahan 1992; Molnar et al. 2011; Zeven and De Wet 1982), and they likely followed a hybridization pathway to domestication. Linguistic evidence suggests that walnut cultivation spread into East Asia from Southwest Asia along the Silk Road (Spengler 2019b). Paralleling the proposed domestication for the apple, a multiproxy study of genetic, historic, and linguistic data revealed that a "gene corridor" following the trans–Eurasian trade routes may be responsible for the domestication of this arboreal crop as people spread specimens across Eurasia during the first millennium B.C.E. (Pollegioni et al. 2014, 2015).

The domestication of the Russian olive remains enigmatic, due to a lack of research, but the limited archaeobotanical data suggest that it was also cultivated along the Silk Road (Spengler 2019b). The earliest archaeobotanical *Elaeagnus* pits come from the site of Aknashen in Armenia, dating to the sixth millennium B.C.E. (Badalyan et al. 2010; Hovsepyan and Willcox 2008). Other reported finds come from the third millennium B.C.E. at Sarazm in Tajikistan (Spengler and Willcox 2013), the second millennium B.C.E. in Afghanistan at Shortughai (Willcox 1991a), and in Uzbekistan at the Sapallitepa settlement (Askarov 1972). Askarov (1972) mentioned Russian olive pits recovered with grape pips from the bottom of jars found in a burial within the Sapallitepa complex; he proposed that Russian olive was added to accelerate fermentation of alcoholic drinks. Russian olive stones were also recovered from western Iran in the Chehrabad salt mines, dated to the middle of the first millennium C.E. (Aali et al. 2014) and at the medieval sites of Tashbulak in Uzbekistan (Spengler et al. 2018) and Areni–1 in Armenia (Smith et al. 2014). Wood remains from *Elaeagnus* sp. trees have been recovered from archaeological sites dating to the early sixth millennium B.C.E. (Decaix et al. 2016) and the fifth millennium B.C.E. (Berthon et al. 2013) in Azerbaijan, and in the third to second millennia B.C.E. in Syria, Tajikistan, and Afghanistan (Willcox 1991b). Wood remains have also been reported from ancient cities along the Heihe River Basin in western China, dated to the first millennium C.E. (Liu et al. 2019a) and as far west as Eastern Anatolia by the early medieval period (Willcox 1974). While Russian olive is cultivated in western China today, the native *E. pungens* grows in arid parts of the region and complicates the identification of the ancient dispersal of the crop based on archaeological wood fragments. Today Russian olive trees are not widely cultivated for commercial trade, but are grown in Pakistan (Azmat et al. 2020) and Uzbekistan.

In this paper, we focus on the presence and absence of taxa in the Paykend assemblage, and do not speculate about the importance of any of these species in the economy. Walnuts, apricots, and apples are actively cultivated in the Bukhara Oasis today, and the region is well–known for its grapes. Unlike many of these arboreal fruits, the melon is more water demanding and requires frequent irrigation (Balliu and Sallaku 2017); melons are not currently cultivated on a large scale near Paykend, but are imported in large quantities each year. We speculate that melons, as with the pistachio, were likely imported to the site from the foothills in the past. Hypothetically, pistachios could have been transported to Paykend from the slopes of the Pistalitau ridge (*pista* means pistachio in Uzbek and *tau* or *too* is a mountain in Turkic). According to Arandrenko (1889:658), Bukhara, Tashkent, and Khiva were historically supplied with pistachios from the region of Pistalitau that bordered Tuzkan Lake.

Nuts and dried fruits have been cash crops (Sherratt 1999) along the Silk Road for millennia, and we suggest that at least some of the remains found at Paykend may have been imported and historically served as commodities, capital, and tribute (e.g., Frye 2005). In the accounts of Ibn Fadlan, during his 10th century C.E. expedition across Eurasia (Frye 2005), he notes spices, millets, dried fruits, and nuts being offered as gifts at Central Asian towns.

Conclusion

Cereals and legumes, notably chickpeas, lentils, barley, wheat, and broomcorn and foxtail millet, appear to have been prominent crops during the Qarakhanid period in the Bukhara Oasis, and rice and some fruits were likely imported. Due to the hyper–arid environment, dryland farming was likely integrated into an adaptive agricultural system at Paykend during the middle of the Qarakhanid reign. The millet, a drought tolerant crop, could represent a risk–reduction strategy in response to aridity in the region. Millet cultivation could also be a response to crisis in agriculture, as described by Bartol'd (1963:62–63) and in the Tārīkh–i Bukhārā (Narshakhi 943), due to desertification. However, the wide diversity of other crops and fruit remains demonstrate that, despite the aridity, agriculture continued to be one of the most important economic activities in the Qarakhanid period. The remains of fruits and nuts could represent exchange or, in certain cases, local cultivation. Although it is well established, both historically and archaeologically, that trade of goods took place along the Silk Road, the archaeobotanical assemblage demonstrates that fruits and nuts were commodities at Paykend.

For example, pistachio nuts and possibly apples, were more likely to have been imported from the foothills than cultivated in the arid summer heat, the presence of rice and cotton also hints to links between the desert and the more humid foothills. Our data add an important component to the story of human adaptation and success in the Central Asian deserts and the globalization of the ancient world.

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