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ORIGINAL ARTICLE

Ancient plant use at the site of Yuergou, Xinjiang, China: implications from desiccated and charred plant remains

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Abstract Archaeobotanical studies were undertaken at the Yuergou site, which is located in the Turpan basin in Xinjiang, China, and which has been dated to around 2300–2400 years B.P. Altogether 21 taxa were identified. Four cereal remains were identified, *Triticum aestivum*, *Hordeum vulgare* var. *coeleste*, *Panicum miliaceum* and *Setaria italica*. The first three were probably cultivated while the last one may not have been grown deliberately, but probably grew together with plants of *P. miliaceum*. A fruit stone of *Ziziphus jujuba* (Chinese date) was discovered, which showed that this may have been cultivated around the site during that time. Charcoal of *Picea* sp. was found, from wood which must have been used as fuel by the indigenous people. Fifteen taxa of wild plants were also identified, most of which can be considered as weeds, and which grew near the site. Burs of *Xanthium strumarium* were discovered. As nearly all of them were broken, the seeds may have been used by the ancient inhabitants. Since most of the cereal remains consisted of chaff, they must represent by-products. Furthermore, grains of *Echinochloa crus-galli* may also have been exploited as complementary food resources. All the above indicate that both cultivated and wild plants were used for cereals, fuel, or other purposes, and plant resources played important roles in the daily life of the ancient inhabitants of the Yuergou site.

Keywords Ancient agriculture · Central Asia · Cereals · Millet · Wood charcoal · Crop processing

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Introduction

The ancient civilization around the Turpan basin of Xinjiang can be traced almost as far back as 10,000 years ago. Chipped stone implements such as scrapers and choppers were discovered at the Gouxi site at Turpan. Furthermore, stone flakes, internal casts, stone spheres as well as microblades were unearthed at the Astana site, which is nearly 5,000 years old (Wang 1992). Later, the Turpan basin became a paradise for the ancient Gushi people from 3000 to 1900 B.P., as this and the adjacent areas fell under the influence of the Subeixi Culture (Lü and Zheng 2002). According to the sparse information to be found in the ancient written record, these fair-haired people had a nomadic lifestyle, but they also cultivated cereals as a food supplement.

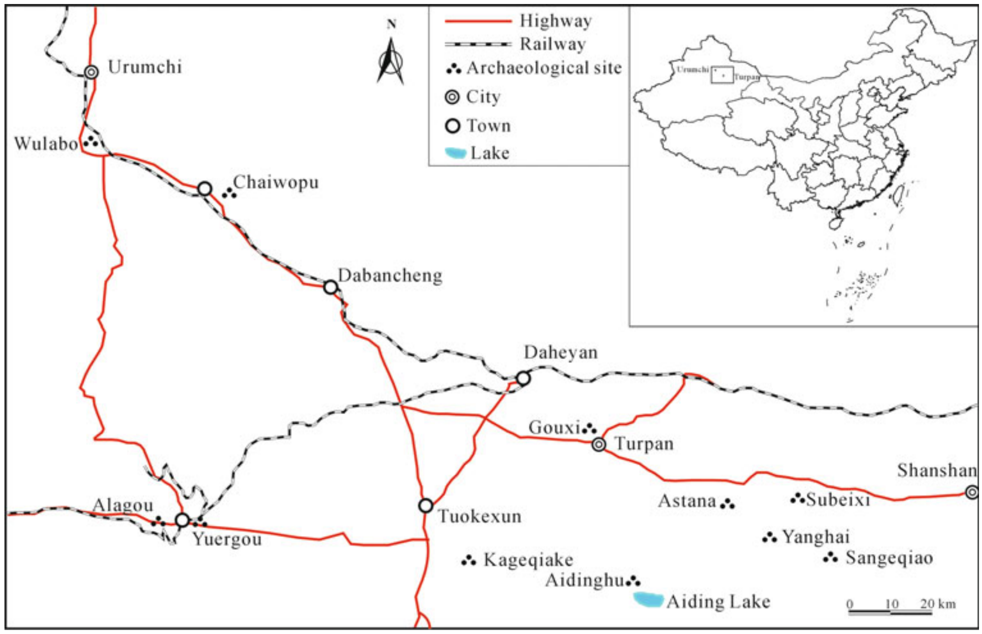

Fig. 1 Map showing the sites referred to in the text (prepared by H. Jiang)

During the past 30 years, a series of archaeological excavations has been undertaken, in which a significant number of artefacts were unearthed, which have enriched our knowledge of the lifestyle of the Gushi people. To date, tombs belonging to the Subeixi Culture have been discovered at the Aidinghu, Yanghai, Alagou, Yuergou, Sangeqiao, Wulabo as well as Subeixi, etc. (Fig. 1; Lü and Zheng 2002; XIA and BCRTP 2004). Studies on the shape of the tomb, pottery, cloth and other funereal objects have increased our knowledge of the Subeixi Culture. However, human behaviour and nutrition are difficult to elucidate from typological structures and artefacts. In the past ten years, a multi-disciplinary approach, including archaeobotanical aspects, has been implemented by archaeologists.

The first systemic archaeobotanical study was conducted on the macroremains of seeds/fruits, leaves, wood, etc. which were excavated in a Subeixi Culture cemetery named Yanghai Tombs. It showed that the ancient people of Turpan knew how to take advantage of plant and animal resources, especially the former. Cultivated plants like *Hordeum vulgare* var. *coeleste* (syn. *Hordeum vulgare* var. *nudum*) (naked barley) and *Panicum miliaceum* (common millet) were used as cereals (Jiang et al. 2007b), while *Vitis vinifera* (grape) was cultivated for its fruit (Jiang et al. 2009). Some wild plants, such as *Cannabis sativa* (hemp) and *Lithospermum officinale*, were exploited for medicinal/psychoactive and decorative purposes respectively (Jiang et al. 2006, 2007a). Based on microremains of phytoliths and starch, a palaeodiet study of the Subeixi site indicates that noodles and cakes were made from *P. miliaceum* (Gong et al. 2011). However, in order to obtain more information and gain a clearer picture of the Subeixi Culture, it became necessary to study one more related site or tomb. Fortunately the newly excavated Yuergou site supplied more materials, and also provided an opportunity to improve our understanding of the ancient Gushi people of Turpan, including their agriculture, horticulture, crop processing and use of the indigenous wild plants.

Site description

The Yuergou site (87°52.096′, 42°49.877′, and 778 m asl) is situated on the western edge of the Turpan–Shanshan–Tuokexun Basin (Turpan Basin). It is located near the confluence of the Aiweiergou River, which flows from north to south with the Alagou River, which flows from west to east. These merge to form the Yuergou River, which flows eastwards to Aiding Lake (154 m below sea level), the lowest part of China (Fig. 2). The Yuergou District is characterized by a typical continental arid climate. The climate is dry due to a shortage of precipitation. The dominant trees are *Ulmus*, *Salix* and *Populus*. In the oasis nearby, drought-adapted shrubs and scattered grasses such as *Alhagi pseudalhagi* (Bieb.) Desv. (camel thorn), *Haloxylon regelii* (Bunge) Korovin, *Halimodendron halodendron* (Pall.) Voss., *Phragmites australis* (Cav.) Trin. ex Steud., *Achnatherum splendens* (Trin.) Nevski, *Chondrilla piptocoma* Fisch. et Mey., *Karelinia caspica* (Pall.) Less., *Anabasis* sp., *Artemisia* sp., *Caragana* sp., *Seriphidium* sp., as well as *Tamarix* sp., etc., are to be found.

The Yuergou District was once a crossroad in ancient Xinjiang. The Alagou valley was one of the main routes of the ancient Silk Road. During the 1970s, the Alagou–Yuergou tombs, belonging to the Subeixi Culture, were

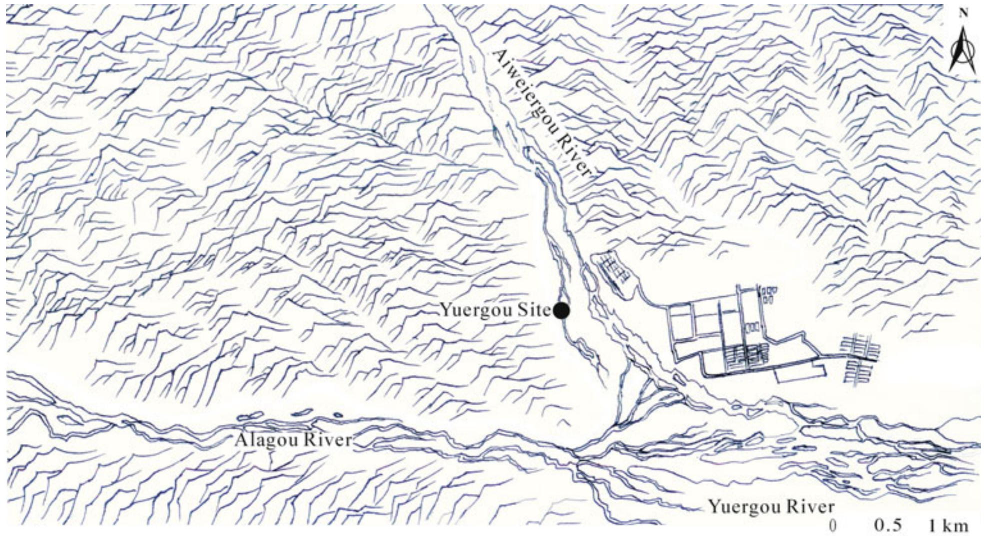

Fig. 2 Map showing the geography around the Yuergou site (prepared by X. Ren)

Fig. 3 **a** Overview of the site. **b** Detailed structure of F1a–d. **c** H. Jiang at work on the site. **d** Bottom of the earthenware pot was broken, and replaced by muddy material. Finger showing dung of sheep/goat (photos **a**–**b** by Y. Wu, **c**–**d** by C.-S. Li)

discovered. Nearly 80 tombs were excavated and many artefacts of great significance were unearthed (Wang 1981). In 2008 the Yuergou site was discovered during the construction of the Turpan–Kuqa multiple track railway. A salvage excavation was carried out by a working group from the Xinjiang Institute of Archaeology, under the direction of Professor Yong Wu, one of the authors of the present paper.

As the site is located on the floodplain, there are many huge boulders, and very little vegetation could be found nearby (Fig. 3a). The whole site is nearly 200 m in width from north to south and 400 m in length from east to west. The northern part of the site was destroyed during construction of the railway, emplacement of a water pipe and the erection of modern houses. The original site consisted of three stone houses and ten stone walls. During the excavation, two houses and five walls were uncovered (Fig. 3b). The remnants of these houses, made of huge boulders, were numbered as F1 and F2. F1 is located in the western part of the site. It had four rooms, which were

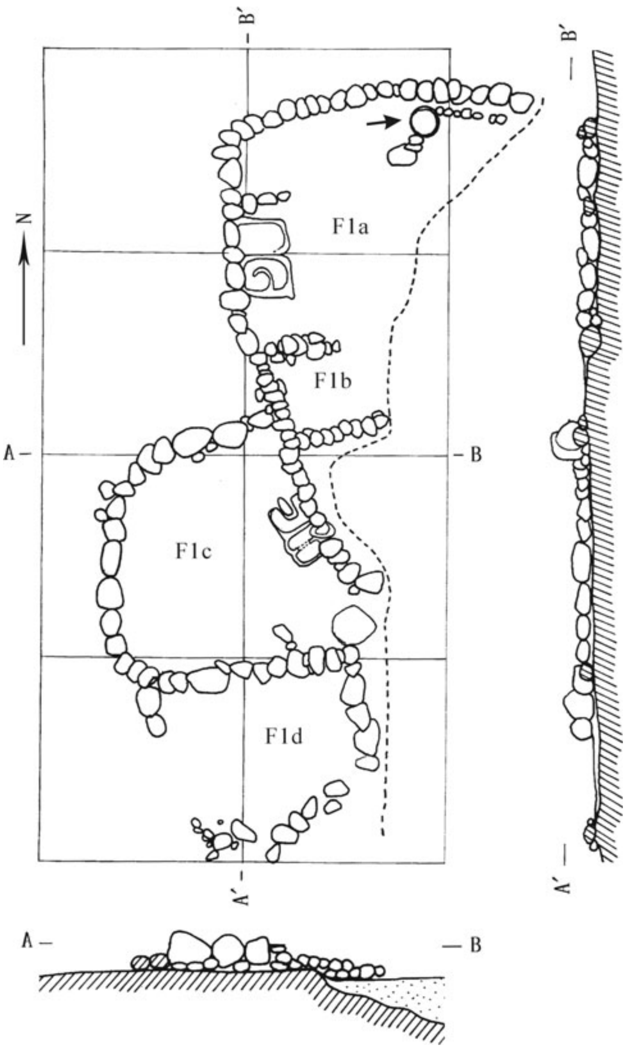

Fig. 4 Line drawing of F1, showing the four rooms (F1a–d) and the earthenware pot (*black arrow*) (prepared by X. He)

numbered F1a–d (Fig. 4). Room F1a lay to the north, with its eastern part destroyed. A line of stones lay to the northeast of the room, and near the stone line was a pottery jar, inside of which were some plant remains, mixed with earth, bones, as well as some little stones. Rooms F1b and F1c are located in the southern part and no special remains were found (Fig. 4).

Materials and methods

Plant material

The plant remains were collected from the earthenware jar in F1a (Figs. 3c, 4). The jar is 60 cm in diameter, 30 cm in remaining height. The bottom of the jar was broken and replaced by muddy material (Fig. 3d). The plant remains, mixed with a little stone, earth, bones, etc., were collected by dry sieving with 0.5 mm mesh size. Subsequently plant remains of wood, stems and dung of sheep/goat were picked out by hand, while seeds/fruits and spikelets were extracted using finely pointed tweezers and later photographed under a stereomicroscope. Transverse, radial, and tangential sections of the charred wood were prepared with a razor, and then mounted on a stub for SEM studies. The plant remains are now deposited in the Department of Scientific History and Archaeometry, Graduate University of Chinese Academy of Sciences in Beijing.

Dating

Two specimens were selected for age determination. One was a piece of charred wood, selected from the plant remains inside the earthenware jar; the other was a stem of an annual herb, extracted from the plant remains close to the bottom of the pot. The specimens were radiocarbon dated with an accelerator mass spectrometer (AMS) at Peking University, and then calibrated using IntCal04 (Reimer et al. 2004) and OxCal v3.10 (Bronk Ramsey 2005).

Terminology

Plant nomenclature follows the revised English edition of the *Flora of China* (http://www.efloras.org/flora_page.aspx?flora_id=2). The botanical terms used in the description of cereal remains and crop processing come from Jacomet (2006) and Van der Veen and Jones (2006). The botanical terms used for structural descriptions of the secondary xylem are based on the relevant references, Fahn et al. (1986), Schweingruber (1990), Lin and Hu (2000) and IAWA (2004).

Results

Radiocarbon dating

The AMS dates obtained are shown in Table 1. Judging from the cultural remains such as the pottery, the Yuergou site should belong to the Subeixi Culture, which prospered from 3000 to 1900 B.P. Furthermore, the site was considered to share a close relationship with the adjacent Yuergou–Alagou tombs, which also belong to the Subeixi Culture. The AMS data of the present study are in close agreement with previous studies, and presumably reflect the real age of the site.

Plant remains

The plant remains excavated from the Yuergou site are listed in Table 2. All of them are desiccated, except *Picea*,

Table 1 Radiocarbon dating of the ancient plant remains

Lab. no.	Sample	^{14}C age (years B.P.)	Calibrated age, 1σ-range (years B.C.)	Calibrated age, 2σ-range (years B.C.)
BA091340	Stem of an annual herb	2295 ± 50	410–350 (40.3 %)	510–460 (2.1 %)
			290–230 (27.9 %)	420–200 (93.35 %)
BA091341	Charred wood	2460 ± 35	750–680 (23.2 %)	760–680 (25.2 %)
			600–500 (27.5 %)	670–410 (70.2 %)

Table 2 Plant remains found at the Yuergou site

Taxa	Type	Utility	Plant organ	Quantity
Triticum aestivum	Herb	Cereal	Rachis	9
			Chaff	44
Hordeum vulgare var. *coeleste*	Herb	Cereal	Grain	7
			Rachis	323
Panicum miliaceum	Herb	Cereal	Sheath	15
			Intact spikelet	118
			Broken spikelet	244
			Lemma/palea	897/678
Setaria italica	Herb	Cereal	Spikelet	11
Setaria viridis	Herb	Weed	Intact spikelet	25
			Broken spikelet	20
			Lemma/palea	16/15
Setaria pumila	Herb	Weed	Intact spikelet	17
			Lemma/palea	3/7
Echinochloa crus-galli	Herb	Cereal?	Intact spikelet	156
			Broken spikelet	178
			Lemma/palea	27/47
Chloris virgata	Herb	Cereal?	Spikelet	51
Vaccaria hispanica	Herb	Weed	Seed	2
Leonurus japonicus	Herb	Weed	Nutlet	1
Phragmites australis	Herb	Fibre	Floret	4
Typha sp.	Herb	Fibre	Broken leaf	26
Polygonum sp.	Herb	Weed	Achene	13
Convolvulus arvensis	Herb	Weed	Seed	1
Cyperaceae	Herb	Weed	Utricle	2
Ziziphus jujuba	Small tree	Fruit	Stone	1
Ephedra sp.	Shrub	Medicine?	Stem	2
Xanthium strumarium	Herb	Medicine?	Bur	138
Sophora alopecuroides	Shrub	Weed	Seed	5
Lycium ruthenicum	Shrub	Weed	Fruit	3
			Stem	1
Picea sp.	Tree	Wood	Stem	–

Note Broken spikelet means the grain has been released, whereas the lemma and the palea still adhere together

which is charred. Of them, 21 taxa were identified. Aside from the cereal remains preserved as grains and/or chaff, the others were represented by leaves (*Typha* sp., *Panicum miliaceum*), stems (*Lycium ruthenicum*, *Ephedra* sp.), wood (*Picea* sp.), as well as seeds or fruits.

Description of the cereal, fruit, and wood remains

Panicum miliaceum—15 sheaths, 118 intact spikelets, as well as chaff remains (244 broken spikelets, and 897/678 lemmas/paleas) were found. All of them showed their

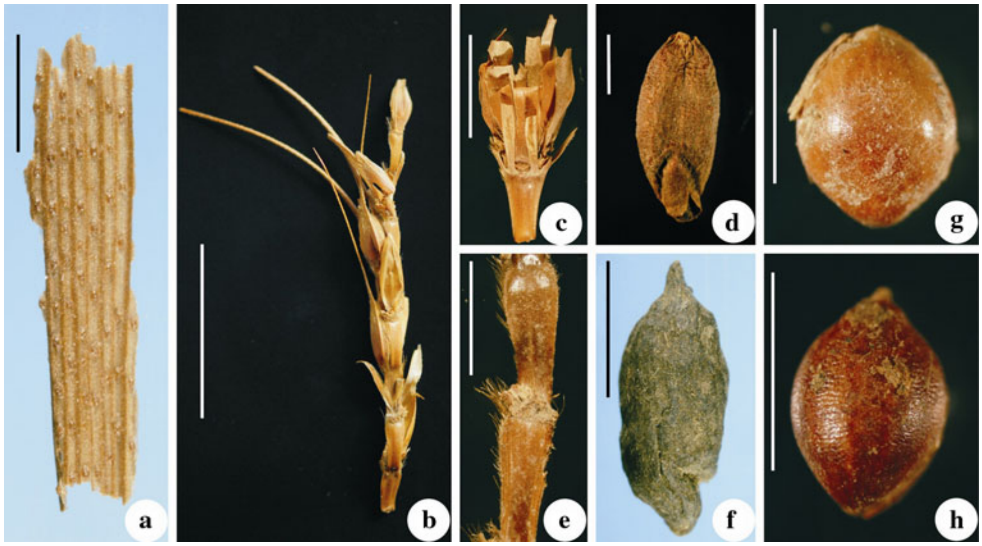

Fig. 5 **a** Leaf sheath of *Panicum miliaceum*. *Scale bar* 2 mm. **b** Multiple rachis segments of *Triticum aestivum*. *Scale bar* 2 cm. **c** Rachis segment of *Hordeum vulgare* var. *coeleste*. *Scale bar* 5 mm. **d** Grain of *H. vulgare* var. *coeleste*. *Scale bar* 2 mm. **e** Multiple rachis segment of *T. aestivum*. *Scale bar* 5 mm. **f** Stone of *Ziziphus jujuba*. *Scale bar* 5 mm. **g** Spikelet of *P. miliaceum*. *Scale bar* 2 mm. **h** Spikelet of *Setaria italica*. *Scale bar* 2 mm (prepared by H. Jiang)

natural brown colour. The epidermis of the sheath was hispid (Fig. 5a), spikelet (grain with husk) oval in shape, 2.5–2.9 mm long, 1.2–2.9 mm wide and 0.9–1.6 mm thick (Fig. 5g).

Setaria italica—11 spikelets were found inside the earthenware pot. Spikelet elliptical, 2.1 mm long, 1.2 mm wide and 1.1 mm thick on average. Husk (lemma and palea) brown in colour, lemma smooth with shallow grooves, palea papillate (Fig. 5h).

Triticum aestivum—9 rachis segments, 9 awns, 10 lemmas, 13 paleas, as well as 12 glumes, were unearthed from the earthenware pot. The plant remains of *T. aestivum* display its natural colour, and the rachis segments show typical bread wheat structure (Fig. 5b, e).

Hordeum vulgare var. *coeleste*—7 grains and 323 rachis segments were found inside the earthenware pot. Grains brown in colour, 5.8–6.1 mm long, 2.8–3.2 mm wide, and 2.1–2.2 mm thick; rachis segments compressed, triplet; glumes lanceolate (Fig. 5c, d).

Ziziphus jujuba—Only one stone was discovered inside the earthenware pot. The stone is black in colour, 10.5 mm long, 3.5 mm in diameter. Both the apex and the base are tapered. The stone is partly broken, but still displaying a fusiform shape. No seed was observed inside the locule (Fig. 5f).

Ephedra sp.—Branchlets 2–4 mm in diameter, yellowish, bark loosely adhering to the xylem, internodes 2.5–4 mm, pith brown in colour, 1 mm in diameter. Bordered pits usually in one row on the vessels, plate perforation ephedroid (Fig. 6a–c).

Picea sp.—Transverse section: boundaries of growth rings distinct, transition from early to late wood gradual, vertical resin canals present (Fig. 6e). Tangential section: rays uniseriate to multiseriate (fusiform); uniseriate rays 1–17 cells high, while multiseriate rays with horizontal resin canals (Fig. 6c). Radial section: bordered pits usually in one row, rarely biseriate (Fig. 6e); cross-field pitting piceoid to taxodioid, 1–6 per cross-field (Fig. 6d).

Discussion

Agricultural and horticultural remains

In all, four cereal taxa were discovered, *Triticum aestivum*, *Hordeum vulgare* var. *coeleste*, *Panicum miliaceum* and *Setaria italica*. The former two are typically of western derivation, while the latter two were first cultivated in Asia. According to previous studies, there have been agricultural activities in Xinjiang since ca. 4000 B.P. For instance, caryopses of *T. aestivum* were discovered in the Gumugou tombs (around 3,800 years B.P) (Wang 1983; Yan and Yang 1999), and later spikelets of both *P. miliaceum* and caryopses of *T. aestivum* were excavated in the coeval Xiaohe cemetery (Li et al. 2011). During the period of the Subeixi Culture (1000 B.C. to 100 A.D.), agriculture was apparently well-developed as many cereal remains have been excavated. For instance, plant remains of *P. miliaceum*, *T. aestivum* as well as *H. vulgare* var. *coeleste* were excavated from the Yanghai tombs (Jiang et al. 2007b), while cakes and noodles made from *P. miliaceum* were excavated at the Subeixi site (Gong et al. 2011). In addition, dental caries was a very common complaint among the deceased of the coeval Wulabo tombs. This pathological condition shows

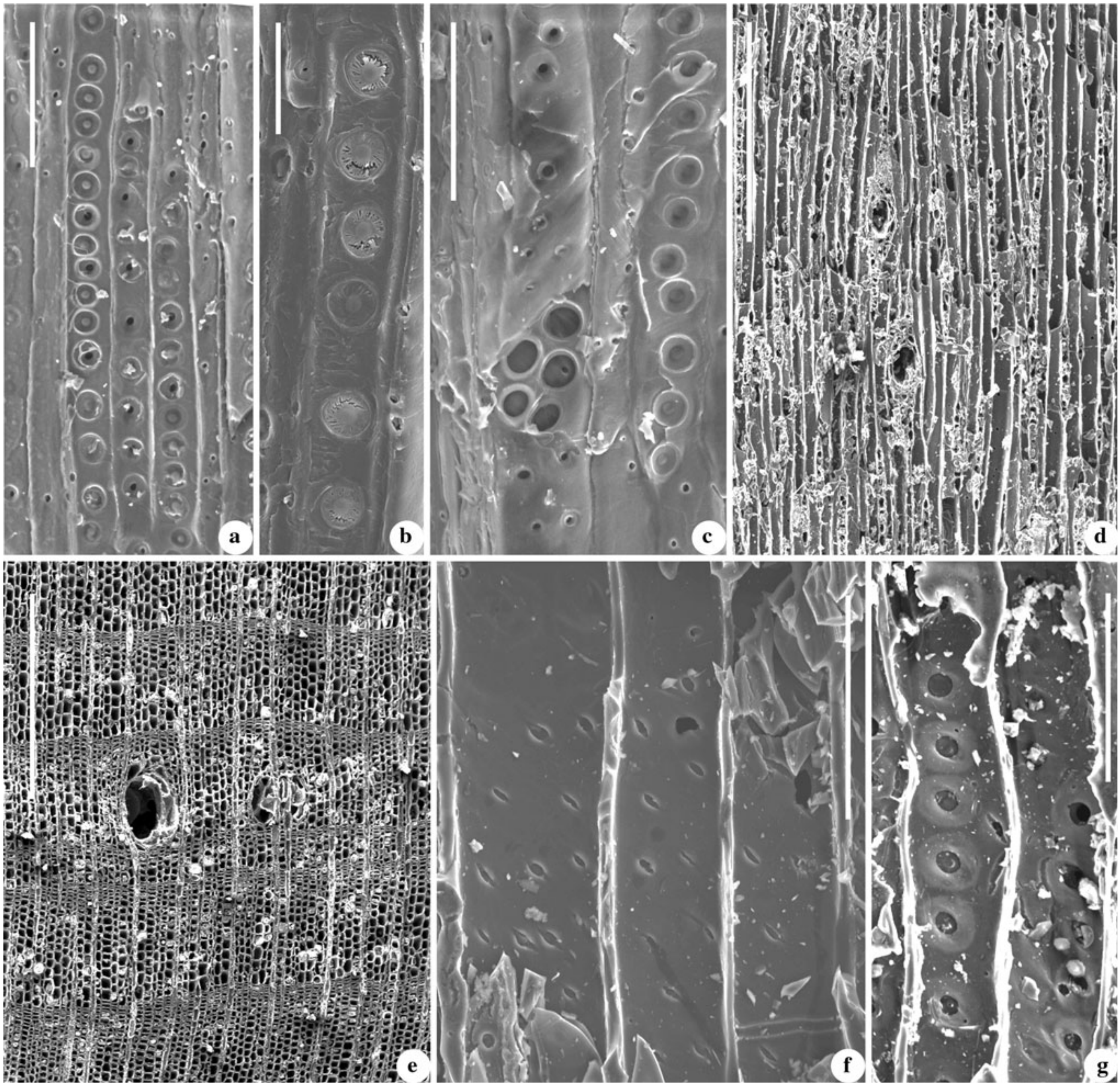

Fig. 6 **a** Radial section of *Ephedra* sp. showing bordered pits on the lateral walls of tracheary elements. *Scale bar* 50 µm. **b** Pit membrane. *Scale bar* 20 µm. **c** Structure of the compound perforation plate of vessel element. *Scale bar* 50 µm. **d** Tangential section of *Picea*, showing unseriate ray cells, and radial resin canals. *Scale bar* 30 µm. **e** Transverse section, showing growth rings and axial resin canals. *Scale bar* 500 µm. **f** Radial section showing piceoid cross-field pitting. *Scale bar* 50 µm. **g** Radial section showing uniseriate bordered pits. *Scale bar* 50 µm (prepared by H. Jiang)

that starchy food may have played an important role in their daily diet (Wang 1992). In conclusion, agricultural activities became an indispensable part of daily life for the people belonging to the period of the Subeixi Culture, although most of them still led a nomadic lifestyle.

Of the four cereals, the former three were probably cultivated around the Yuergou site, as many spikelets of *P. miliaceum*, chaff of *T. aestivum*, *H. vulgare* var. *coeleste* and *P. miliaceum*, grains of *H. vulgare* var. *coeleste*, as well as leaf sheaths of *P. miliaceum* were discovered together. Compared to the other three taxa, which are known in considerable numbers, plant remains of *S. italica* seem negligible as only three spikelets (grains with husk) were found. *P. miliaceum* and *S. italica* were the two most important cereals in the ancient Eurasian steppe, especially in East Asia. Both plants have similar edaphic requirements and life cycles, and are usually cultivated in the same area even nowadays. In this connection it comes as no surprise that these two cereals are usually found together in archaeological sites (Renfrew 1973; Marinval 1992; Hunt et al. 2008). However, the archaeological sites in Xinjiang seem to be an exception. For instance, no *S. italica* was discovered in the Xiaohe cemeteries (around 3700–3500 years B.P.) (Li et al. 2011), the Gumugou cemeteries (around 3800 years B.P.) (Wang 1983), or at the Xintala site (around 3800 years B.P.) (Zhao et al. 2012). In the Wupu cemeteries (nearly 3000 years B.P.) of Hami District, some cake, thought to be made from caryopses of *S. italica*, was found (Wang 1983). However, it is impossible to tell the ingredients by the naked eye. Without starch and phytolith analyses, the result is at best equivocal.

Plants of *P. miliaceum* are more drought resistant than those of *S. italica*, their evaporation rate being lower than that of *S. italica*, *Sorghum bicolor*, *H. vulgare* and *T. aestivum,* etc. (Dong and Zheng 2006). It is more easily cultivated in Turpan, where the precipitation is only 15 mm, while evaporation is 2,500 mm (Jiang et al. 2009). To date, there is still no physical evidence of *S. italica* in Turpan before the period of the Subeixi Culture. With ancient trade, war and human migration, the value of *S. italica* was eventually recognized by the ancient people living in Turpan. In the Astana cemeteries (around 3rd to 9th century A.D.), large amounts of *S. italica* were found, together with *P. miliaceum*, *T. aestivum*, *Cannabis sativa* and *H. vulgare* var. *coeleste*, etc. As the majority of the deceased in the Astana cemeteries were not indigenous, but had migrated from the eastern part of ancient China, and since there was a tradition for cultivating *S. italica* among the people of eastern China for countless millennia, it seems plausible that *S. italica* cultivation was introduced into Turpan, along with the migration of people from eastern China.

Apart from the cereal remains, a fruit stone of *Ziziphus jujuba* Mill. (Chinese date) was also found. *Z. jujuba* is a small, deciduous fruit tree belonging to the Rhamnaceae, which has been cultivated since the Neolithic period in northern China (Qu and Wang 1993). It contains many vitamins, sugars, and mineral substances, etc. and most cultivars can be eaten both fresh and dehydrated. Following its natural distribution, plant remains of *Z. jujuba* were mainly discovered in eastern China, such as Hebei and Henan provinces, and it was seldom found in northwestern China, especially Xinjiang. However, dried fruit and kernels were occasionally discovered in the Astana tombs in the Turpan Basin (Wang 1983). The discovery of *Z. jujuba* in the present study shows that it may have been cultivated in Turpan as early as 2,500 years ago. Fruit of *Z. jujuba* not only provided delicious food for the indigenous people, but also enriched their daily life.

Remains of trees

Among the charcoal examined, only *Picea* was identified. *Picea* is now an important forest resource in China, as it has straight timber of good quality, and is usually selected as construction material, as well as for making paper, instruments, etc. In Turpan *P. schrenkiana*, a common gymnosperm, is widely distributed on the northern slopes of the Tianshan (Heavenly Mountains) (Cheng et al. 1992). Carbonized wood of *Picea* was once found in the pits of Qin Terracotta Warriors and Horses, and was considered to have been used as pillars, crossbeams, as well as for timber (Wang et al. 2009). Desiccated wood of *Picea* was found in the Yanghai tombs, having been used for cemetery construction (Jiang 2006). In the present study, all the charred wood was found together with the other plant remains which were desiccated, in the same earthenware pot, so one cannot help thinking that these woods were explicitly selected as firewood by the ancient Yuergou inhabitants instead of being charred unintentionally.

Previous studies showed that two main firewood collection strategies can generally be distinguished: collection based on either availability or selection (Out 2010). Wood of *Picea* contains resin, and is fit for burning. It also has a good combustion value like other gymnosperms. Although the possibility of natural distribution of *Picea* was rather limited around the Yuergou site during that period, the wood may have been collected during hunting or grazing activities. Selection was involved, as only *Picea* was identified among the charcoal. The ancient people may have recognized the good combustion value of *Picea*, which provided them with light, warmth, as well as safety.

Wild herb/shrub remains

Among the 15 taxa of wild plant remains, *Lycium ruthenicum*, *Ephedra* sp., and *Sophora alopecuroides* are little shrubs, while all the others are herbaceous (Fig. 7). There are several plants, *Setaria viridis*, *S. pumila*, *Chloris virgata*, *Vaccaria hispanica*, *Polygonum* sp., as well as *Convolvulus arvensis*, which should be considered as weeds. They are widely distributed on roadsides, in wild areas, as well as by riversides. All of them also usually grow together with cereals and are easily found in farmland. Plants of *Leonurus japonicus* can be used for treating menstrual problems, but as only one nutlet was discovered, it is unlikely to have been used for this purpose. Plants of *S. alopecuroides* and *L. ruthenicum* are adapted to dry environments, and all of them were widely distributed in Turpan and adjacent areas. However, they are little used even to date. For example, seeds of *S. alopecuroides* are poisonous, while *L. ruthenicum* is a thorny shrub seldom

Fig. 7 **a** Spikelet of *Setaria italica*. *Scale bar* 1 mm. **b** Spikelet of *Chloris virgata*. *Scale bar* 2 mm. **c** Spikelet of *S. pumila*. *Scale bar* 2 mm. **d** Spikelet of *Echinochloa crus-galli*. *Scale bar* 2 mm. **e** Floret of *Phragmites australis*. *Scale bar* 2 mm. **f** Seed of *Sophora alopecuroides*. *Scale bar* 2 mm. **g** Seed of *Vaccaria hispanica*. *Scale bar* 1 mm. **h** Fruits of *Lycium ruthenicum*. *Scale bar* 2 mm. **i** Seed of *Convolvulus arvensis*. *Scale bar* 2 mm. **j** Seed of *Polygonum* sp. *Scale bar* 1 mm. **k** Seed of *Leonurus japonicus*. *Scale bar* 1 mm. **l** Seed of Cyperaceae. *Scale bar* 1 mm. **m** Bur of *Xanthium strumarium*. *Scale bar* 1 cm. **n** Stem of *Lycium ruthenicum*. *Scale bar* 2 cm. **o** Stem of *Ephedra* sp. *Scale bar* 4 cm (prepared by H. Jiang)

used in modern Turpan. Neither plant is fit for human consumption or animal feeding. The occurrence of the remains would seem to indicate their presence around the site or their unintentional introduction to the site by the ancient inhabitants.

Phragmites australis and *Typha* sp. are two hygrophilous plants. As the Yuergou site is located on a floodplain, the ancient people could have obtained both of them near the Aiweiergou River. Both plants have long, flexible fibres, making them good candidates for weaving. The ancient people living in Xinjiang have known their uses for quite a long time. In the Gumugou tombs, nearly 3800 years B.P., thread made of *Typha* sp. was discovered (Jiang Hongen, unpublished data). In the Yanghai tombs, both *P. australis* and *Typha* sp. were used for mat making, while the former was also used for thread making (Jiang 2006). As only florets of *P. australis* and leaf fragments of *Typha* sp. have been discovered in the present study, while no products of the above two plants were found, their exact use is still an open question.

Ephedra is a little shrub adapted to dry environments. In the present study, as only two stems but no reproductive organs were discovered, it could only be identified to the generic level. Three species, namely *E. sinica* Stapf, *E. intermedia* Schrenk ex C. A. Meyer and *E. equisetina* Bunge, containing more ephedrine, are considered to have medicinal value. *Ephedra* is a traditional medicine in China. It was used for curing asthma, coughs as well as being used as a diaphoretic (Anonymous 2005). Plants of *Ephedra* have been excavated in the Xiaohe cemeteries (Bergman 1935) and Gumugou cemeteries (around 3800 B.P.) in Xinjiang (Wang 2009). Some scholars are of the opinion that the plants were connected with primitive religions, and thus were accredited supernatural status and revered by the indigenous people (Bergman et al. 1939; Xia 1997). However, as there is little proof that *Ephedra* was exploited in the present study, its use by the ancient Yuergou people remains uncertain.

Of the wild plant remains, *Xanthium strumarium* (syn. *X. sibiricum*) (cocklebur) is of particular interest. As an annual herb *X. strumarium* is widely distributed in the plain, on roadsides, in wild areas, etc. With its hooked thorns, it is easily disseminated by animals and mankind and has become a synanthropic plant. *X. strumarium* is poisonous (List et al. 1979), but its fruit is used in traditional Chinese medicine for curing nasal congestion, wheals, spasms, etc. (Han 2005). Although seeds of *X. strumarium* are poisonous they can be used for diuresis and diaphoresis. To date, burs of *X. strumarium* were discovered in two Chinese Neolithic sites, namely Zaojiaoshu site in Henan (LWA 2002), and Chengtoushan site in Hunan (Liu and Gu 2007). In both cases they were considered to be weeds taken to the site by the ancient indigenous people. The species has also been discovered in an early Iron Age well at Hajndl, Slovenia. However, only a few involucra were collected and the fruits were still intact (Sostarić et al. 2009). In the present study the fruits were found in great numbers (138 pieces), and all of them were broken and the seeds missing. We believe that the seeds of *X. strumarium* may have been extracted and used by the ancient Yuergou people, although they could not be eaten raw. However, the exact purpose for which they were collected and broken requires further investigation.

Cereal processing and plant storage

Aside from ancient agriculture, the cereal remains discovered in the earthenware pot can also provide us with information on crop processing and plant storage during that period. Among the cereal remains, a total of 330 plant parts (323 rachises and seven grains) of *H. vulgare* var. *coeleste* (naked barley) were discovered. The well-developed triplets and grains indicated that they were harvested at maturity, instead of being stored in the ear. The triplets with the usually broken palea and lemma clearly indicate threshing. Of the 323 rachises, 289 were single triplets. The other 34 multiple rachis segments, which consisted of 2–4 triplets, contain 87 triplets. In total 376 triplets were discovered. Considering the fact that one triplet contains three grains, ideally 1,128 grains should have been harvested. However, only seven grains were found in the container. Similarly the nine multiple rachis segments of *T. aestivum*, containing 45 rachis segments, should have produced 135 wheat grains (rachis segment: grains ratio is 1:3, according to Alonso et al. 2008). However, no grains of *T. aestivum* were discovered. In these cases the clean grains of both the naked barley and the wheat should have been collected by winnowing or hand-sorting, and only the waste by-products would have been placed in the present container. According to Van der Veen and Jones (2006), the high ratio of free-threshing rachis internodes/grains indicates that the sample of both the naked barley as well as the wheat in the container should be by-products from an early processing stage. The seven grains of naked barley may represent accidental spillage during crop cleaning, which also occurred at the settlement mound of Tell Brak, northeast Syria (Hald and Charles 2008).

Plant remains of *Panicum miliaceum* (common millet) consisted of only 15 sheaths, 118 intact spikelets, as well as chaff (897/678 pieces of palea/lemma and 224 pieces of broken spikelets). This strongly suggests that the spikelets had been broken and the grains released after threshing. The grindstones excavated from the site may have been used for dehusking. As no clean grains (caryopses) were found, but a number of weed seeds were discovered, remains of *P. miliaceum* should be interpreted as by-products from a late processing stage according to the concept of Van der Veen and Jones (2006). The minor components of spikelets (118), which were not threshed, may represent unprocessed grain contaminants, or accidental spillage during crop processing, like those of the naked barley in the present study.

Apart from the cereal remains, there was some *Echinochloa crus-galli* in the mixture. Although 156 spikelets were still intact, it is significant that there were 178 broken spikelets as well as 27/47 lemmas/paleas. As with *T. aestivum*, no clean grains of *E. crus-galli* were discovered. That means plants of *E. crus-galli* should not be considered as weeds, but as complementary food. Plants of *E. crus-galli* and *P. miliaceum* ripen in the same season in Turpan. One possibility is that plants of *E. crus-galli* were present as weeds in a field of *P. miliaceum*, and spikelets of the former were harvested and then threshed together with those of the latter. Since spikelets of *E. crus-galli* can easily be separated by winnowing, it is also possible that spikelets of *E. crus-galli* were collected deliberately and then threshed for their clean grains. Previous studies showed that the protein, calcium and iron content of *E. crus-galli* is comparable to or greater than that of other major cereals like wheat or rice (Mandelbaum et al. 1995).

During famines, spikelets of *E. crus-galli* were collected and then threshed for their grains, even as late as the 1960s in China (Ms. Jinrong Chen, personal communication 2012). In this connection the grains of *E. crus-galli* might also have been consumed consciously or unconsciously as a component of their diet by the ancient inhabitants of Yuergou.

Except for the wood charcoal and the 138 pieces of *Xanthium strumarium*, which should have no connection with crop processing, most of the plant remains consisted of small chaff and weed seeds. In this case, the cache of plant remains could be interpreted as by-products from day-to-day processing according to Van der Veen and Jones (2006). Although *H. vulgare* var. *coeleste* and *T. aestivum* ripen simultaneously in Turpan, they cannot be harvested at the same time as plants of *P. miliaceum* and *Ziziphus jujuba*. It seems unlikely that these plant residues represent a single storage event, but instead several storage episodes in which the pot was not completely cleaned. The scenario of sequential contamination of reused stores also took place in the tomb of Tutankhamun (De Vartavan 1990). Furthermore, the earthenware jar was not a container for clean grains, but for waste by-products, which may have been used for fuel and/or fodder.

Comparisons of tomb offerings and the plant remains from the Yuergou site

Many plant remains, well preserved due to the dry environment, have been excavated in different archaeological sites in Xinjiang. In the past several years, archaeologists have paid more attention to the plant remains which were preserved in the containers. From their descriptions the tomb offerings usually represented storage products. For example, only grains (caryopses) of *T. aestivum* were preserved in the grass basket of the Gumugou cemetery (Wang 1981). A cache of florets (caryopses with husk) of *P. miliaceum* was discovered in a jar from the Yanghai tombs, which could represent storage samples, as only a few glumes and husks of *H. vulgare* var. *coeleste* were found in the same vessel (Jiang et al. 2007b). In these cases, the tomb offerings were specifically chosen for further use in another world. Unfortunately, the number of spikelets of *P. miliaceum* as well as the chaff of *H. vulgare* var. *coeleste* was not quantified in the 2007 study. In order to obtain a better scientific interpretation of the cereal remains, the concept of crop processing should be adopted and applied in future work by Chinese archaeobotanists.

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