Prehistoric Agriculture in China: Food Globalization in Prehistory FREE

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Summary

It is commonly recognised that farming activities initiated independently in different parts of the world between approximately 12,000 and 8,000 years ago. Two of such agricultural centres is situated in modern-day China, where systems based on the cultivation of plants and animal husbandry has developed. Recent investigations have shown that between 5000 and 1500 cal. BCE, the Eurasian and African landmass underpinned a continental-scale process of food "globalisation of staple crops. In the narrative of food domestication and global food dispersal processes, China has played a particularly important role, contributing key staple food domesticates such as rice, broomcorn, and foxtail millet. The millets dispersed from China across Eurasia during the Bronze Age, becoming an essential food for many ancient communities. In counterpoise, southwest Asian crops, such as wheat or barley, found new habitats among the ancient populations of China, dramatically changing the course of its development. The processes of plant domestication and prehistoric agriculture in China have been a topic of extensive research, review, and discussion by many scholars around the world, and there is a great deal of literature on these topics. One of the consequences of these discoveries concerning the origins of agriculture in China has been to undermine the notion of a single centre of origin for civilisation, agriculture, and urbanism, which was a popular and widespread narrative in the past. It has become clear that agricultural centres of development in China were concurrent with, rather than after, the Fertile Crescent.

Keywords: agricultural origins, domestication, broomcorn millet, foxtail millet, rice, loess plateau, Yangtze-Huai River valley, multicropping

Introduction

The transition from foraging to farming was a long-lasting process in several regions throughout the world. To some extent, this process has roots as old as our species (e.g., Barker, 2006). The full process of species transition from wild to domestic forms took thousands of years, starting between 12,000 and 10,000 years ago at the end of Pleistocene. During the next 3,000 years a variety of agricultural systems based on plant cultivation and animal husbandry developed subsequently in almost every corner of the globe (e.g., Barker, 2006; Cowan, Watson, & Benco, 1992; Harris & Hillman, 1989; Zohary, Hopf, & Weiss, 2012).

Recent investigations have shown that between 5000 and 1500 cal. BCE, the Eurasian and African landmasses underpinned a continental-scale process of food "globalisation of staple crops (e.g., Jones et al., 2011; Liu et al., 2019; Stevens et al., 2016). China plays a pivotal role within the plant domestication and globalisation narrative, with its diverse forms of food products that have contributed to the agricultural system including cultivation of crop species such as broomcorn, foxtail millets, and rice (Crawford, 1992, 2006). During the Bronze Age, the cultivation of broomcorn and foxtail millet expanded geographically, dispersing across a range of environments in Eurasia, while the Southwest Asian grains (i.e., wheat and barley) moved eastward to India and China (e.g., Liu et al., 2019; Spengler, Frachetti, et al., 2014). The process of plant domestication and the development of prehistoric agriculture in China has been a topic of extensive research, review, and discussion by many distinguished colleagues around the world (e.g., An, 1989; Crawford, 1992, 2017, 2018; Jones & Liu, 2009; Lee, Crawford, Liu, & Chen, 2007; Liu, Fuller, & Jones, 2015; Zhao, 2011).

There is a lack of consensus among experts on how to define terminology concerning topics such as "domestication" or "agriculture." This article uses these terms in a broad perception. "Domestication" is used in the context of describing mutually dependent relationships between domesticator and domesticate (Zeder, 2018). The term "agriculture" defines the occupation of crop cultivation as the primary food-producing activity in a society, although hunting and gathering may continue (e.g., Price & Bar-Yosef, 2011). We also emphasise the diversity and regionally specific nature of farming practices in China.

China's vast landmass possesses contrasting environmental extremes, from tropical in the south, to sub-Arctic in the north, and alpine in the west. Seventy percent of the territory of modern China is composed of mountains, plateaus, and hills, where the continental interior remains beyond the reach of the summer monsoon. These features have led to a range of agricultural traditions that are diverse in their crop ecology and elaborate in the management of water, both in the lowlands in the east of the country under the influence of East Asian summer monsoon as well as in the mountainous continental interior beyond the reach of summer monsoons (Liu et al., 2015).

The geography of prehistoric China comprises a vital variation in monsoonal system dynamics, ranging between a warm, wet summer monsoon, and a cold, dry winter monsoon. In the Holocene, the summer monsoon brings water from the Indian and Pacific oceans onto much of the south and east of China. It has a powerful ameliorative effect on the aridity of the continental interior. The winter monsoon drives the movement of aeolian dust from the Gobi desert to the Loess Plateau. The sensitivity of that monsoonal system to fluctuations in the relative temperatures of land and ocean has rendered it the most variable component of the weather patterns in the region, critically affecting the water availability in many parts of China, particularly toward the South and East.

Within the summer monsoonal region, the lower reaches of the Yangtze and Yellow Rivers bound the northern and southern ranges of China's most productive stretch of lowland, the arena within which much of the dynastic history has unfolded. Zhao (2011) outlines three main areas of the origins of farming activities in China: dryland agriculture in China's northern territory (the Loess Plateau and Yellow River catchment) that is associated with the cultivation of broomcorn or common millet (*Panicum miliaceum*) and foxtail millet (*Setaria* *italica*); the middle and lower Yangtze River Valley, which is associated with the domestication of rice; and the tropical region of southern China (south of the Nanling Mountains) where a variety of tubers and fruits were the primary dietary resources.

Macrobotanical evidence from the Pleistocene indicates that people in the present territory of China were likely exploiting grasses long before they were intensively managed (Bestel et al., 2014). In addition to millets and rice as essential domesticated staple grains, past peoples in the region subsisted on a wide range of other plant and animal resources. Microbotanical evidence has shown that since the terminal Pleistocene, a variety of plants, including acorns, beans, tubers, and grasses (Triticeae and Paniceae) were used in the Loess Plateau (Liu, Bestel, Shi, Song, & Chen, 2013). Throughout the Neolithic (c. 8000–1500 BCE), new plant foods were introduced into human diets, including soybean (*Glycine max*), adzuki bean (*Vigna angularis*), buckwheat (*Fagopyrum esculentum*), and hemp seed (*Cannabis sativa*; Hunt, Shang, & Jones, 2018; Lee, Crawford, Liu, Sasaki, & Chen, 2011; Liu et al., 2015), just to list a few examples among a rather long list of plant resources (Crawford, 2018). Recent research shows that in the Yangtze-Huai region, rice cultivation emerged in the context of a broad spectrum foraging for tree nuts, especially acorns (*Quercus* spp.), fruits such as peaches and apricots (*Prunus* spp.), and wetland nuts and tubers, including water chestnuts (*Trapa natans*), foxnuts (*Euryale ferox*), lotus root (*Nelumbo nucifera*), Job's tears (*Coix lachrymal-jobi*), and barnyard grasses (*Echinochloa* spp.; Yang et al., 2015; Zhao, 2010; Zheng, Crawford, & Chen, 2014). Animal resources, including pig (*Sus scrofa*), also significantly contributed to the Neolithic diets (Barton et al., 2009; Cucchi et al., 2016; Jing & Flad, 2002).

The last two decades have witnessed the widespread application of flotation techniques and, consequently, the rapid growth of archaeobotanical data in China. Archaeobotanical sampling using the water flotation technique has become a routine part of the archaeological excavations. This development has significantly changed our understanding of the farming practices in ancient China. The potential use of flotation systems in archaeological investigations was discussed among Chinese scholars in the 1980s (Huang, 1986) and first applied in the excavation of Liluo in 1992 (Liu et al., 2015). Meanwhile, Gary Crawford brought flotation machines modified from those originally designed by Patty Jo Watson in America (the SMAP type) to East Asia, first to Japan and Korea and subsequently to China, and trained many archaeobotanists on their use (Crawford, 2006; Liu et al., 2015). Zhao Zhijun from the CASS Institute of Archaeology in Beijing has played a pivotal role in encouraging the application of flotation in China. In 2011, Zhao (2011) reported on flotation-based archaeobotanical results from more than 80 sites across China: about 7,000 sediment samples were processed, and a significant quantity of charred plant remains recovered. This rapid growth in archaeobotanical evidence has been accompanied by qualitative improvements in the analysis and interpretation of early crop domestication and food dispersal evidence.

In light of previous reviews on the topic of prehistoric agriculture in East Asia, this article focuses on recent advances in the origins and spread of plant domesticates. We emphasise the role of early food production of staple grains: broomcorn and foxtail millet in the Loess Plateau and rice in the Yangtze-Huai River region. We also consider farming practices in ancient China in the context of trans-Eurasian exchange of food and foodways, emphasising the importance of the Fertile Crescent cereals in the prehistoric diets in China. The prehistory of the cultivation of staple grains has played a vital role in the development of many aspects of Chinese cultures from past to present. Globally, this process employs millions of people feeding a large proportion of the world's population (Bray, 1984). This article discusses the origins and dispersal of domesticated crop species in China and extends a discussion on the history of the arrival of southwest Asian crops that eventually became an essential integral part of the Chinese subsistence and its culinary heritage, contributing immensely to the ancient cultures in China.

Early Use of Broomcorn and Foxtail Millet

The cultivation of millet marked the beginning of a process of social and material transformations in northern China, allowing the formation of the Neolithic cultures, such as Xinglongwa, Luoguantai, Houli, and Peiligang, and subsequently widespread cultural groups such as Yangshao, where sedentary populations relied on millet-based agriculture (Liu & Chen, 2012). Two types of millet were domesticated in China: broomcorn millet and foxtail millet (Crawford, 2014; Fukunaga, Ichitani, & Kawase, 2006; Hunt, Rudzinski, et al., 2018; Liu, Hunt, & Jones, 2009). These minor cereals are not very well known in the Western world, as their status as human food is often obscured. However, millets used to play an highly important dietary role in the past across Eurasia, representing one of the most expansive food crops in geographical terms (Jones, 2004; Liu, Motuzaite Matuzeviciute, & Hunt, 2018). Due to unique physiological responses to thermal and hydrological conditions, both Asian millets (broomcorn millet in particular) are fast-growing crops with the highest water use efficiency among cereal crops (Baltensperger, 2002). These ecological merits of the two millets make them particularly important in the context of food security in modern systems in their capacity to grow in marginal environments.

The wild ancestor of foxtail millet is likely *Setaria viridis*, which is a C_4 annual grass that is widely distributed over a large part of East Asia, but with probable primary habits including north China. The wild progenitor for broomcorn millet, by contrast, remains unclear. From a genetic perspective, research on the processes that shaped patterns of intraspecific genetic diversity in *P. miliaceum* is inherently bound up with the broader evolutionary context (Liu et al., 2018). Recent genetic research has clarified the geographic pattern for the origin of broomcorn millet, offering two parsimonious explanations for the phylogeographical output (Hunt et al., 2011, 2013). Broomcorn millet has undergone selection for starch quality, specifically for a high frequency of varieties with waxy or glutinous starch in those areas of East Asia (central-eastern China, Korea, and Japan) where this trait is valued in the cuisine (Fuller & Rowlands, 2009; Hunt et al., 2013). Regardless, our knowledge of how domesticated forms of broomcorn and foxtail millet evolved from their wild ancestors is limited.

Evidence from phytoliths and starch granules places the first use of broomcorn and foxtail millet in the early Holocene. In the case of foxtail millet, the oldest claim—inferred from starch granules—is from the Nanzhuangtou (c. 9500 BCE) and followed by the Donghulin (c. 7500 BCE) sites (Yang, Wan, et al., 2012). In the case of broomcorn millet, the earliest claim related to phytoliths is from the Cishan (c. 8000 BCE; Lu et al., 2009; Yang, Zhang, et al., 2012). However, there is considerable disagreement among scholars on these early microfossil records, regarding both the lack of species specificity from starch grains and phytoliths (Liu et al., 2013) and the controversial radiocarbon dates from Cishan (Zhao, 2011). Compared with microfossil evidence, macrofossil identification is less contentious. The earliest charred grains of broomcorn and foxtail millet in an archaeological context date to the turn of the 7th or 6th millennia BCE. Eight localities report charred broomcorn and foxtail millet grains before 5000 cal. BCE.

Concerning the consumption of millet, palaeodietary research based on the isotopic approach has been growing at a fast rate, with hundreds of studies featuring stable isotopic compositions in human and animal remains (e.g., Lightfoot, Liu, & Jones, 2013; Liu & Reid, 2020). Stable isotopic values from archaeological skeletons reflect long-term consumption practices of individuals, and isotopic studies provide direct proxies to understanding past human diets. Carbon isotope compositions, for example, vary primarily according to the photosynthetic pathways employed by plants at the base of the food chain. The potential for using carbon isotopic values to differentiate between different types of cereal and plant diets was first realised in detecting maize consumption and recently extended to the discussion of Asian C_4 domesticates, including millet. Both broomcorn and foxtail millet utilise the C_4 (Hatch-Slack) photosynthetic pathway, and recent isotopic studies have capitalised on the different isotopic signatures among various food plants, including rice, wheat, and barley; vegetables, tubers, and fruits (C_3 plants); and broomcorn and foxtail millet (C_4 plants). These studies show that human consumption of millet as a staple food is surprisingly old in north China, but variable both among sites and among individual consumers. Human skeletal remains have been analysed isotopically from several northern sites predating 5000 BCE where stable isotope values of human collagen varied significantly between sites, from no millet consumption as a staple food to a mix of C_3 and C_4 diets (Hu, Ambrose, & Wang, 2006; Hu, Wang, Luan, Wang, & Richards, 2008; Liu, Jones, Zhao, Liu, & O'Connell, 2012; Wang et al., 2019), and two sites (Xinglonggou and Xinglongwa) have carbon isotope values indicating millet consumption on a significant scale around 5000 BCE (Liu et al., 2012). Therefore, Xinglongwa cultural sites in the Xiliao River region provide evidence for the oldest millet consumption on a large scale (Liu & Reid, 2020). After 5000 BCE, almost all northern populations of China are consistent with C_4 diets producing enough millet to provision their animals, including pigs (e.g., Barton et al., 2009; Chen, Yuan, Hu, He, & Wang, 2012; Pechenkina, Ambrose, Ma, & Benfer, 2005).

The early millet-growing sites in China are geographically concentrated along a chain of low mountains broadly running northeast-southwest, extending along a 2,500 km boundary between the Loess Plateau and the eastern China floodplains, a pattern echoing the “Hilly Flanks of the Fertile Crescent” in southwest Asia (Liu, Hunt, & Jones, 2009; Ren et al., 2016). This early association of millet sites with foothill locations is also helpful to understand some later geography of the dispersal of millet cultivation. Out of all cereals domesticated in China, broomcorn millet is a pioneering cereal that dispersed out of China, reaching Europe already during the Bronze Age (Jones, 2004; Motuzaite Matuzeviciute, Staff, Hunt Liu, & Jones, 2013).

Domestication of Rice

Rice (*Oryza sativa*) is one of the most important cereal grains in the world, serving as a staple food source for more than half of the world's population. The first use of rice and its domestication is a subject of many discussions, debates, and reviews (e.g., Crawford & Shen, 1998; Fuller, 2011b; Fuller et al., 2010; Gross & Zhao, 2014).

The analyses of phytoliths recovered from Pleistocene caves on the southern margins of the Yangtze basin have led to suggestions of Pleistocene rice domestication in the region (Yasuda & Negendank, 2003; Zhao, 1998). However, we still lack a full understanding of the significance of wild rice to the hunter-gatherer societies identified from sites older than 15,000 years.

More recent results obtained through improvements in archaeobotanical recovery methods have indicated that rice domestication was underway and only completed after the Hemudu cultural phase (7,000–6,000 BP) in the Lower Yangtze Valley (Fuller et al., 2010; Fuller & Qin, 2009, 2010). For example, rice spikelet bases from Huixi in the Lower Yangtze are dated to between 9,000 and 8,400 years ago. They are documented to consist of the intermediate and nonshattering forms, indicating that a very early stage of nonshattering rice selection was underway (Zheng, Crawford, Jiang, & Chen, 2016). Data from Kuahuqiao, Tianluoshan, Majiabang, and Liangzhu also indicate that rice underwent a continuing selection for reduced shattering characteristics (Fuller et al., 2009; Zheng et al., 2016). This evidence points to a start of cultivation in this region on the order of c. 10,000–9000 years ago; the situation in the Middle Yangtze Valley could be somewhat earlier but may represent a parallel process to the Lower Yangtze. Indeed, sites in the Huai River and other northern tributaries of the Yangtze, such as the Han River, could indicate additional centers of early rice cultivation. Yet, the evidence for the very earliest cultivation and the start of the rice domestication process remains obscure: current archaeological evidence makes the end of the rice domestication process clear, rather than its beginnings.

By about 6,000 years ago (the Daxi period in the Middle Yangtze and the Late Majiabang in the Lower Yangtze), domesticated rice had become established as the critical dietary staple for Neolithic societies and the staple food in subsequent periods, contributing to the emergence of increasing social complexity and population growth. In the Middle Yangtze Valley, the increased productivity and reliance on rice supported the growth of populations, as seen in the large-scale settlements of the Qiujialing and Shijiahe cultures dated to the 3rd millennium BCE. The Liangzhu society (3300–2300 BCE) in the Lower Yangtze basin, based on an intensely managed landscape for rice cultivation, started to develop an urban character with elaborate jades and other craft objects. The central site of Liangzhu included impressive city walls, canal systems for transport, artificial platforms for occupation, and elite burials (such as Mojiashan site). The nearby site of Maoshan has produced extensive paddy field systems that would be familiar to a modern rice farmer with long walkways and embankments defining square to rectilinear fields that could be flooded from local streams (e.g., Liu et al., 2015). Pigs, melons, and bottle gourds were the only other documented domesticates aside from rice. Cultivation of fruit trees like persimmon and peach, and fiber crops like ramie and mulberry for silkworms, is also probable (e.g., Liu et al., 2015). The first preserved textiles come from Liangzhu contexts and indicate the production of ramie and silk. Still, spindle whorls suggest that textile traditions extend back to the early rice cultivators of Kuahuqiao and Hemudu, as well as in the Neolithic Middle Yangtze (e.g., Liu et al., 2015).

Rice domestication spread from China to different parts of the world at very different times. Unlike in India and the southern Himalayan belt, which contained the native wild rice species of *Ozyra rufipogon* and *Ozyra nivara* (Londo, Chiang, Hung, Chiang, & Schaal, 2006), the spread of rice is more easily identifiable in Korea and Japan because these regions have no wild progenitor of rice. In Korea, confirmed evidence for rice cultivation starts during the middle-late Chulmun period of the 1st millennium BCE. Similarly, in Japan, rice cultivation is associated with Yayoi culture and is also dated to the early 1st millennium BCE (Fuller, 2011b).

Researchers have identified rice impressions in Jamon pottery vessels that could push back the confirmed introduction of rice to Japan by millennia (Obata, 2008). India has a variety of wild rice species, and it is still under debate whether the domesticated rice species spread to India from China or had independent origins of cultivation in the Ganges Plain. Genetic research has shown that Indian forms of rice possess shared alleles of Japonica rice resulting from hybridisation (Fuller, 2011a; Fuller et al., 2009). Therefore, it has been debated that for the Indian *indica* rice to become a fully domesticated species, the Chinese *japonica* rice species would have had to arrive in India and hybridise with *indica* during the early 2nd millennium BCE.

Rice is initially a crop of monsoonal agriculture. Due to particular required cultivation technologies and climatic restraints, rice represents a latecomer to west Eurasian regions situated outside of the monsoonal range. Rice was introduced in southwest Asia during the Hellenistic times. Both Greek and Roman sources mention this cereal, which was highly prized during Roman times (Zohary & Hopf, 2000).

The Arrival of Southwest Asian Crops in China

Outside the principal region of Chinese agriculture, the Loess Plateau and Sichuan Basin are flanked by the Gobi Desert, Hexi Corridor, and the Tibetan Plateau, a combination of steppe belt and high-altitude mountainous areas. It was within this geographical range that cereal crops originating in southwest Asia were introduced into China during the 3rd and 2nd millennia BCE. First domesticated in the Hilly Flanks of the Fertile Crescent (Zohary & Hopf, 2000), wheat and barley became valuable dietary resources in China during the Bronze Age.

In the context of the trans-Eurasian exchange of cereal crops, the chronology and routes of the eastward expansion of wheat and barley—from southwest Asia to ancient China—have been much discussed by scholars (Betts, Jia, & Dodson, 2014; Dong, 2018; Flad, Li, Wu, & Zhao, 2010; Jones et al., 2016; Li, Dodson, Zhou, Zhang, & Masutomoto, 2007; Liu et al., 2017, 2018, 2019; Motuzaite Matuzeviciute, Abdykanova, Kume, Nishiaki, & Tabaldiev, 2018; Spengler, Frachetti, et al., 2014). Currently, there is a lack of consensus among scholars regarding the timing and routes of wheat and barley dispersal, particularly in the time predating 2000 BCE. From the 3rd millennium BCE onward, wheat and barley appear in the archaeological record over a wide range of dispersed regions in China, from the Shandong Peninsula on the eastern coast to the Altai Mountains in the most northwestern part of the country. In the Shandong Peninsula, at least two sites report charred wheat grains with direct radiocarbon measurements dated to between 2500 and 2000 cal. BCE (Long et al., 2018). These evidence from Shandong, together with relevant evidence from Korea, Japan, and Fujian, raises the question of whether wheat was introduced to eastern China via a maritime route (Crawford & Lee, 2003; Liu et al., 2019; Zhao, 2009). In the Altai, both charred wheat and barley are directly dated to the late 4th to early 3rd millennium BCE (Zhou et al., 2020). With the newly reported data on wheat and barley from the Altai region, the earliest wheat introduction to China is likely connected with the Inner Asian Mountain corridor (Frachetti, 2012; Frachetti, Spengler, Fritz, & Mar'yashev, 2010; Motuzaite Matuzeviciute, Mir-Makhamad, & Tabaldiev, 2020; Spengler, Frachetti, et al., 2014). The dispersal of wheat and barley into ancient China was likely distinct in time and space initially, and the process lasted over millennia and took place via several potential pathways (e.g., Lister et al., 2018; Liu et al., 2017). More substantial movements of wheat and barley took place after 2000 BCE, resulting in abundant archaeobotanical evidence across China (Liu et al., 2019; Zhao, 2009).

Hexaploid free-threshing wheat (*Triticum aestivum*) with compact morphotypes and naked barley (*Hordeum vulgare* var. *nudum*) are the primary types of wheat and barley in archaeobotanical assemblages in China. An insightful question is why, for example, only naked barley and highly compact hexaploid free-threshing wheat—out of several cultivated wheat and barley varieties—were adapted in the farming system in ancient China, at least in the initial stage during the 3rd and 2nd millennium BCE. This question should be considered in the context of the viaration of landraces in response to environments and culinary practices. In the case of wheat, it has been illustrated that the introduction to China may have exerted selection for phenotypic traits adapted to the eastern boiling-and-steaming tradition (Liu, Lister, et al., 2016). Other researchers emphasised the environmental effects on plant morphology and the selection of grain types, particularly in high-altitude environments companied with monsoonal climate (Motuzaite Matuzeviciute et al., 2018; Motuzaite Matuzeviciute, Mir-Makhamad, & Tabaldiev, 2020). Future research on similar morphological traits of barley will be timely and plausible. This is particularly interesting as the potential hybridisation of domesticated barley with native wild relatives in the Tibetan Plateau may have played a role in the early development of high-altitude landraces in association of adaptive strategy (d'Alpoim Guedes et al., 2016; Zeng et al., 2018). In this context, much progress has been made in the understanding of agricultural and agropastoral systems in the broad Tibetan Plateau (Chen et al., 2015; d'Alpoim Guedes et al., 2016; d'Alpoim Guedes & Aldenderfer, 2020; Zeng et al., 2018). It has become clear that the high-altitude (>3500 masl) environments played a vital role in the process of the food globalisation, particularly in the 2nd millennium BCE, and in fixing multiple adaptive traits (in barley and millet) that were carried down and contributed to the lowland system in the 1st millennium BCE (Liu et al., 2017; Motuzaite Matuzeviciute et al., 2018). Liu and colleagues (2017) highlight the importance of spring-grown barley varieties in ancient China and the degree of genetic diversity in relation to flowering time responses that are associated with adaptive challenges in high-altitude environments. The ancient texts from the 1st millennium BCE notably document a wide range of variation in planting and harvesting times of wheat and barley, indicating the cultivation of both spring and winter varieties and the existence of multicropping systems (Liu et al., 2017). The arrival of southwest Asian crops to China (wheat and barleys) and Chinese crops (millets and later buckwheat) to Europe revolutionised local economies, enabling the cultivation of multiple seasons, thus substantially increasing food surpluses (Jones et al., 2016).

Archaeobotanical evidence indicates that barley, and to some degree wheat, facilitated the habitation of various environmental niches that were previously unpopulated, and allowed the establishment of permanent settlement sites in many geographical marginal zones of Eurasia, such as mountain regions. A good example is the expansion of human settlements in northeastern Tibetan Plateau with the arrival of barley crops during the 2nd millennium BCE

(Chen et al., 2015). There has been much insightful recent discussion concerning crop ecology and the high-altitude adaptation of wheat and barley (Newton et al., 2011; d'Alpoim Guedes et al., 2015, 2016).

While the nature of the eastern expansion of wheat and barley cultivation requires further inquiry, discussion has moved beyond the topics of routes and chronologies to consider the context in which agricultural innovation occurred. The timing of the eastern dispersal reflects a range of choices that different communities made, sometimes driven by ecological expediency in novel environments, sometimes by culinary innovations. One such example is that wheat and barley arrived in central China, bringing with it a degree of genetic diversity concerning flowering time responses and allowing farmers to choose the growing season of their crops (Liu et al., 2017). In terms of the actual consumption, it would seem that the reaction of the existing dietary systems to the adoption of novel crops is a key driver. One such reaction could be understood in the context of deep-seated East-and-West cooking preference. Early communities in East and West Asia were characterised by a difference in food processing technologies: culinary traditions based on boiling and steaming of grain in the east and grinding grain and baking the resulting flour in the West (Fuller & Rowlands, 2011). These culinary preferences had consequences for the selection of grain type and gluten/starch quality, and the dispersal of grains did not necessarily correspond with the intrinsic cooking techniques. Broomcorn millet, for example, has undergone selection for starch quality, specifically for a high frequency of varieties with waxy or glutinous starch in those areas of East Asia, including central-eastern China where this trait is valued in the cuisine (Hunt et al., 2013; Liu et al., 2018). As mentioned, another such example lies in the evidence of distinct morphologies (compact caryopses) of eastern wheat, potentially resulting from the adaption of eastern culinary or environmental conditions (Liu et al., 2016). Similarly, the isotopic results show a very gradual pace of the adoption of wheat and barley as a staple food in central China, contra to a rapid reception of these western cereals in human diets in the Continental Interior (Liu et al., 2014, 2016). It is likely that such initial "rejection" of wheat and barley as staple grains may be connected with their incompatibility with local culinary practice, which is consistent with both typological and isotopic evidence (Liu and Reid 2020).

Fuller and Rowlands (2011) hypothesised that the western boundary of the boiling-and-steaming culinary tradition appears to correspond approximately to the geographic range of the summer monsoon. On a continental scope, this suggestion makes sense and has inspired insightful scholarly discussions (e.g., Fuller & Castillo, 2016). Within China, however, further considerations of the appearance of such geographically rigid boundaries could be helpful. Grinding stones, for example, are documented (often of good quantity) in central and eastern China—an assumed exclusive boiling-and-steaming zone—since the early Neolithic. It has been nevertheless noted that most grinding stones in this part of China are small and lack clear evidence of prolonged use, unlike those in west Asia (Fuller & Rowlands, 2011). Grinding grains into flour, bread making, and possibly brewing traditions date to approximately 14,000 BCE in western Eurasia (Arranz-Otaegui, Gonzalez Carretero, Ramsey, Fuller, & Richter, 2018). Conversely, a question also remains as to whether the eastern cereal boiling technique could potentially have spread westward alongside the expansion of millet cultivation in the 3rd millennium BCE.

In any case, the dietary and culinary traditions in north China by c. 2000 cal. BCE, particularly in the western Loess Plateau and the northern fringes of the Tibetan Plateau, are characterised by multiple-resource subsistence and the diversification of cooking techniques.

The oldest evidence of noodles known from the Lajia site in Qinghai (c. 2000 BCE) provides such an example. The noodles were found inside a clay bowl that was deposited upside-down beneath 3 meters or 10 feet of a sediment mudslide that instantly buried all of the Neolithic villages deep underground. The noodles were made from foxtail millet with possibly some broomcorn millet and were identified from phytoliths, starch granules, and miliacin biomarkers (Lü et al., 2014). Some of the starches were affected by a gelatinisation process showing that the noodles probably were formed by using a noodle press after heating and fermenting the millet flour. The noodles were thin (about 0.3 cm in diameter), delicate, and more than 50 cm in length (Lu et al., 2005). Experimental work has shown that they were made with a hele-type noodle press that allowed shaping noodles by extruding gelatinised flour gel, probably formed from sticky millet variety and potentially with additional wheat flour (Ge, Liu, Chen, & Jin, 2010; Lü et al., 2014). Despite some questions about the archaeological context of this evidence, the Lajia noodle can be seen as one of the oldest example of "fusion cuisine," hybridising the Western grinding tradition and Eastern boiling technique, and potentially utilising grains originating in East and West Asia, respectively.

Western Expansion of Millet Cultivation

Jones (2004) first directed attention to the appearance of very early millet records in archaeological sites in Europe. With a constellation of multidisciplinary research projects that embraced archaeobotanical, genetic, and stable isotopic approaches, Jones's research enabled a better understanding of the chronology and geography of the dispersal of these crops across Eurasia (see Liu et al., 2018, for a summary). Both foxtail and broomcorn millets have been reported at multiple sites outside China in South and Southeast Asia during the 3rd millennium BCE (Betts et al., 2019; Pokharia, Kharakwal, & Srivastava, 2014; Weber, 1998, 2003; Weber, Lehman, Barela, Hawks, & Harriman, 2010). Yet, only broomcorn millet was a preferred crop in prehistoric sites of Central Asia and Europe. The reasons for this phenomenon may or may not relate to the morphological and physiological differences between the two millets, such as grain size, water, and cold tolerance, altitude adaptation, and flexibility in growing seasons.

The timing and pathways for the spread of millet from China to Europe have been the subject of lively discussions. Extensive archaeobotanical research has been conducted at multiple sites across Central Asia, embracing a variety of geographical zones such as grasslands, mountain piedmont, high mountain valleys, and river valleys in search of cultivated plant remains in archaeological sites (Motuzaite Matuzeviciute et al., 2015, 2017; Rouse & Cerasetti, 2014; Spengler, Cerasetti, et al., 2014; Spengler, Frachetti, et al., 2014). The earliest directly dated broomcorn millet outside China was recovered from the Begash site, located on the piedmont of the Tian Shan Mountains in southeastern Kazakhstan. At this site, a direct radiocarbon date was derived from a sample that contained both millet and wheat grains and places the arrival of those crops in the southeast region of Central Asia within the second half of the 3rd millennium BCE (Frachetti et al., 2010). Stable carbon isotope compositions in sheep remains from Begash and an adjacent site (Dali) show that domesticated animals were already eating C_4 plants (possibly millets) as early as 2600 cal. BCE (Hermes et al., 2019). Yet, whether humans were consuming millet during the earliest wave of its dispersal out of China is yet to be confirmed with stable isotope investigations of human skeletal remains from the 3rd millennium BCE.

Broomcorn millet further expanded westward from Begash, following a series of foothill locations along similar ecological zone across central Eurasia (Miller, Spengler, & Frachetti, 2016). This scenario resonates with the location choices of the earliest millet farmers in the eastern Loess Plateau, where the grains were domesticated (Liu et al., 2009). Across Inner Asia, millet cultivation was restricted to a narrow foothill zone between 800 and 2,000 m.a.s.l., where summer precipitation is relatively high (Miller et al., 2016). Multiple sites containing broomcorn millet macrofossils have been dated to a time slightly younger than Begash. These sites stretch along the foothills of the Tian Shan, Pamir, and Kopet Dag mountain ranges (Rouse & Cerasetti, 2014; Spengler, Frachetti, et al., 2014; Spengler et al., 2016), a landscape known as Inner Asian Mountain Corridor first identified by Frachetti (2012). Stable isotope studies of human bone collagen have also identified various individuals within communities of southern Central Asia that pioneered the consumption of C_4 plants (probably millet) outside China during the 2nd millennium BCE (Lightfoot, Liu, & Jones, 2013; Lightfoot et al., 2014; Liu, Reid, et al., 2016; Motuzaite Matuzeviciute et al., 2015).

Within the scope of Central Asia, including southern Siberia, the archaeobotanical research in the higher altitude environments (above 2,000 m.a.s.l.) and in the higher latitude steppe regions has not generated any evidence of millets, until the Final Bronze Age and the Early Iron Age (Ananyevskaya et al., 2018; Bocherens, Mashkour, Drucker, Moussa, & Billiou, 2006; Brite, Kidd, Betts, & Negus Cleary, 2017; Korolyuk & Polosmak, 2010; Motuzaite Matuzeviciute, Mir-Makhamad, & Tabaldiev, 2020; Motuzaite Matuzeviciute et al., 2015; Motuzaite Matuzeviciute, Hermes, Mir-Makhamad, & Tabaldiev, 2020; Spengler, 2015; Spengler, Cerasetti, et al., 2014; Spengler et al., 2016). Isotopic analyses, performed on human skeletons from various locations across northern Central Asia and southern Siberia have confirmed that millet and other C_4 foods did not contribute to human diets until the end of the Bronze Age (Ananyevskaya et al., 2018; Lightfoot et al., 2014; Motuzaite Matuzeviciute et al., 2015; Murphy et al., 2013; Svyatko et al., 2013). The beginning of millet cultivation in Mongolia during the Early Iron Age (the 1st mill. BCE) led to the growth of the Mongolian nomadic empire (Wilkin et al., 2020), while at the same time the central Kazakhstan (Turgai region) and western Turkmenistan (Khorezm oasis) regions contain evidence for the formation of monumental architecture and elite power structures (Ananyevskaya et al., 2018; Brite et al., 2017).

The beginning of millet cultivation in Europe began no later than during the Middle Bronze Age. This chronology has been confirmed by direct radiocarbon measurements on single millet grains, with the oldest (so far) directly dated millet grain reported from Hungary (dated to c. 1600 cal. BCE) (Motuzaite Matuzeviciute et al., 2013). In tandem with the earliest directly dated grains, many sites across Europe in the late 2nd millennium report broomcorn millet grains in large quantities, providing clear evidence of the extensive use of millet as a food (e.g., Motuzaite-Matuzeviciute et al., 2013). In some places in Europe, millet remains can be found in up to 65% of all cultivated plants (Szeverényi, Priskin, Czukor, Torma, & Tóth, 2015). It has been suggested that millet in the Middle to Late Bronze Age in Europe contributed to the “third food revolution,” associated with changes in crop production strategies and increased diversity of cultivated crops (Kneisel et al., 2015). Stable isotope analyses conducted on human remains across Europe also show carbon isotope compositions that are consistent with C_4 diets starting to appear in the middle Bronze Age (Antanaitis & Ogrinc, 2000; Varalli, Moggi-Cecchi, Moroni, & Goude, 2016). In Europe, millet cultivation coincided with population rise, the formation of fortified sites, and highly increased human mobility during the Bronze Age (Kristiansen & Larsson, 2005; Motuzaite Matuzeviciute, 2018).

Conclusion

This article reviewed recent advances in knowledge in the field of ancient Chinese agriculture, which moved from being a poorly understood peripheral region to a well-charted core component of the global narratives for prehistoric agriculture in the world.

The agricultural transition in China was a slow process that took thousands of years to develop, from a long history of wild plant gathering to the established use of domesticated forms of cereals. Recent advances in the techniques of archaeobotany, stable isotope analysis, and the direct radiocarbon measurements on cereal crops have moved the timing for farming origins in China backwards, as well as clarified the role of East Asia in the formation of Eurasian foodways and cuisines.

Chinese domesticates played an important role in the development of agrarian and agropastoral systems across Eurasia, and the arrival of Southwest Asian crops made a dramatic impact on cultivation strategies, food processing, and cooking traditions in China. Like elsewhere in the world, Chinese food and foodways formed over thousands of years through the development of diverse regional subsistence and cuisines, which were further influenced by agricultural traditions from other parts of the world.

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