2 Origins and Spread of Agriculture in China

2.1 Introduction

Searching for the origins of agriculture was an important topic of Chinese archaeology even before the introduction of archaeobotanical practice in the country (see Ch. 1). The transition to food production is considered one of the most fundamental moments in the making of human civilisation. The domestication of plants, strictly linked with the transition from food gathering to food producing, has been among the most popular topics of archaeobotanical research in the last century. This transition was described as the ‘Neolithic Revolution’, happening rapidly and in one core area (the

DOI 10.30687/978-88-6969-935-1/003

Fertile Crescent),[1] from where it had diffused and spread to the rest of the world (e.g., Childe 1962; Diamond, Bellwood 2003). Today this view has shifted in favour of the transition to agriculture being a gradual, long and protracted process. Plants most likely needed millennia to evolve from their wild progenitors into their domesticated forms, and different local species were independently domesticated in multiple areas around the world.[2] The accumulated archaeobotanical evidence has showed that cereals were cultivated for millennia before they were domesticated[3] and most scholars agree that their domestication was the result of selective pressures acted through cultivation practices.[4] Scholars have also moved away from the concept of domestication happening in a core, defined area and diffusing to the surrounding regions (also referred to as monocentric view)[5] in favour of a multi-regional (poly- or multi-centric) approach. This multi-centric model outlines that plant species were domesticated following their cultivation across multiple sites within a region.[6] Finally, productive economies are seen as nuanced, with increased evidence that semi-sedentary or even mobile populations also practiced some level of plant production in the past (Spengler et al. 2021). This chapter reviews early theories about the origins of agriculture in China with a focus on those plant species that hold relevance for prehistorical and early historical Southwest China, especially Yunnan. Botanical aspects, including growing requirements, are also examined to offer an environmental and ecological framework for understanding the cultural and social development of local societies. To help readers navigate this topic, I provide definitions of key terms used in relation to early agricultural research **[tab. 1]**.

---

[1] Southwest Asia today has the earliest attested evidence of wild plant harvesting and processing, for example from Ohalo II, where wild plant collection is presumed to start 23,000 years ago (e.g., Snir et al. 2015; Maeda et al. 2016; Weide et al. 2018) and domesticated plant remains are documented at several sites in the region dating to about 10,000 years ago onward (e.g., Willcox 2012; Tanno, Willcox 2006, 2012; Arranz-Otaegui et al. 2016).

[2] See Larson et al. 2014 for an overview of some of the main centres of domestication in Eurasia; other recent works on the topic include Fuller et al. 2014, 2016; Allaby et al. 2017; Allaby et al. 2022; Fuller, Denham, Allaby 2023.

[3] Fuller 2007; Purugganan, Fuller 2009; 2011; Purugganan 2019.

[4] Helbaek 1960; Harlan 1975; Harris 1989; Stevens, Fuller 2024.

[5] The core-area hypothesis was put forward in the context of the beginning of agriculture in Southwest Asia, where scholars initially suggested that agriculture started in a 'golden triangle' where all of the 'eight founder crops' were brought into cultivation at the same time (e.g., Lev-Yadun, Gopher, Abo 2000; Kozlowski, Aurenche, 2005). The most recent research has brought into questions both the core-area and the founder crops concepts (i.e. Fuller, Willcox, Allaby 2011a; 2011b; Arranz-Otaegui, Roe 2023).

[6] Fuller, Willcox, Allaby 2011a; 2011b; see also Asouti 2013; Larson et al. 2014; Boogard et al. 2017.

Table 1 List of key terms used in plant domestication studies (Fuller, Denham 2022, 182)

Term	Definition	References
Domestication	“A coevolutionary process that arises from a mutualism, in which one species (the domesticator) constructs an environment where it actively manages both the survival and reproduction of another species (the domesticate) in order to provide the former with resources and/or services”.	Purugannan 2022, 664
Cultivation	Set of activities involved in the production of plant resources; can include: - Tilling - Sowing - Weeding - Manuring - Harvesting - Threshing - Winnowing	Fuller et al. 2014
Agriculture	A specific production economy of a society, characterised by reliance on the cultivation of (usually, but not exclusively, domesticated) plant species as the primary mode of subsistence. Agricultural societies are typically sedentary, but semi-mobile societies may engage in seasonal food production.	Stevens, Fuller 2017
Domestication traits (domestication syndrome)	Characteristics that differentiate a plant species from it wild ancestors. For cereal and legumes these can include: - Loss of natural seed shattering - Loss of seed dormancy - Increase of seed size - Thinning and lightening of the seed coat These morphological, morphometrical and life cycle changes are driven by specific genes which change under selective pressure exerted by recurring human behaviours (such as cultivation). These are influenced by competing pressures, environmental conditions, and gene inheritance mode in plants.	Fuller, Allaby 2009; Purugganan, Fuller 2009; Brown et al. 2009; Allaby 2014
Landrace	“A dynamic population(s) of a cultivated plant that has historical origin, distinct identity and lacks formal crop improvement, as well as often being genetically diverse, locally adapted and associated with traditional farming systems”.	Villa et al. 2005
Mono-centric domestication	“Domestication occurred in the Near East, in a ‘core area/golden triangle’ where the whole package of eight ‘founder crops’ were brought into cultivation at the same time. From here, cultivation of these species spread, and if the same wild species was brought into cultivation elsewhere it was under the influence of the earlier traditions of cultivation in this core region”.	Fuller, Willcox, Allaby 2011a, 618 (see also Fuller, Willcox, Allaby 2011b)
	“Domestication is a ‘discovery’ driven by human conceptualization of the domesticated as distinct from the wild”.	Fuller, Denham 2022, 182
(Poly)/ Multi-centric domestication	Parallel processes of early plant cultivation emerging independently in multiple areas within a region that lead to the domestication of that plant species.	Fuller, Willcox, Allaby 2011a; 2011b

2.2 Early Debates on the Origins of Agriculture in China

2.2.1 The Theorisation of Agriculture Before the Study of Archaeological Plant Remains

Given the scarcity of ancient plant remains before the development of archaeobotany, most early theories relied on ancient textual evidence. A seminal work for this was *The Origin of Cultivated Plants in Southeast Asia* by Li Huilin 李惠林 (1911-2002; Li 1970).[7] Li was a Harvard PhD graduate, who taught Biology and Botany at several institutions both in China and the United States, including at Suzhou University, the National Taiwan University, and University of Pennsylvania. Li also chaired the editorial committee of the *Flora of Taiwan* (1975-79). In *The Origins of Cultivated Plants in Southeast Asia*, Li called 'Southeast Asia' the vast region comprising the Gobi Desert, North China, the Korean Peninsula, modern continental China to the southern Tibetan Plateau, modern mainland and insular Southeast Asia **[fig. 4]**. Li based his hypotheses in large part on the agricultural treatise *Qimin Yaoshu* 齊民要術 (Essential Arts for the People), attributed to Jia Sixie 賈思勰, an official of the Northern Wei Dynasty (sixth century CE). The treatise was possibly completed around 533-544 CE. In 1979, Li published the translation and commentary of an earlier botanical treatise, *Nan-fang ts'ao-mu chuang* 南方草木狀 (Plants of the Southern Regions), a written text dating to 304 CE and attributed to botanist Ji Han 嵇含 (263-307 CE).[8] In this translation-commentary Li further expanded his hypotheses, especially in relation to Belt 3 (1979) **[fig. 4]**. Li's publications summarise well the state of early agriculture and plant domestication research in this region at the time, as well as setting the scene for subsequent research until a more widespread implementation of archaeobotanical methods allowed for a review of his hypotheses. Li had divided East Asia into four main belts **[fig. 4]** and listed which plants species were domesticated in each of these four areas, on the basis of historical accounts and modern ethnobotanical and phytogeographical information **[tab. 2]**. Belt 1 included the area from the Yellow River Basin northward; a region with Loess soil and a cold and temperate climate, homeland of millet, soybean, cabbage and other vegetables, hemp and several fruit trees, including peaches, apricots, apples and pears (Li 1970, 9). Belt 2 indicated the area south from the Qinling Mountains to the current borders of mainland China, with a strong emphasis on the Yangzi River Basin. Compared to Belt 1, a warmer and wetter climate characterised this region. Here, people domesticated tea, many vegetables including Chinese kale and scallion, *Citrus* fruits (sweet orange, mandarin orange, kumquat, wampee) and some aquatic root crops such as water chestnut and lotus roots, but many plant were introduced from Belt 1. Belt 3 indicated modern mainland Southeast Asia, with the exclusion of the Malay

---

[7] An earlier version was first published in Chinese; Li, Huilin 李惠林 (1966). *Tung-nan-ya tsai-p'ei chich-wu chic ch'i-yuan* 東南亜栽培植物之起源 (Origins of the cultivated plants in South and East Asia). Hong Kong: Chinese University of Hong Kong 香港: 香港中文大學出版. This version, however, is not easily accessible; therefore, through this book I refer to the 1970 edition.

[8] Li had titled this work *A Fourth Century Flora of Southeast Asia*, keeping in line with the regional divisions of his earlier work. The text is now usually referred to with the more accurate translation of *Plants of the Southern Regions* (Li 1979).

Peninsula. Here there are year-long mild temperatures and great abundance of water thanks to seasonal monsoons.

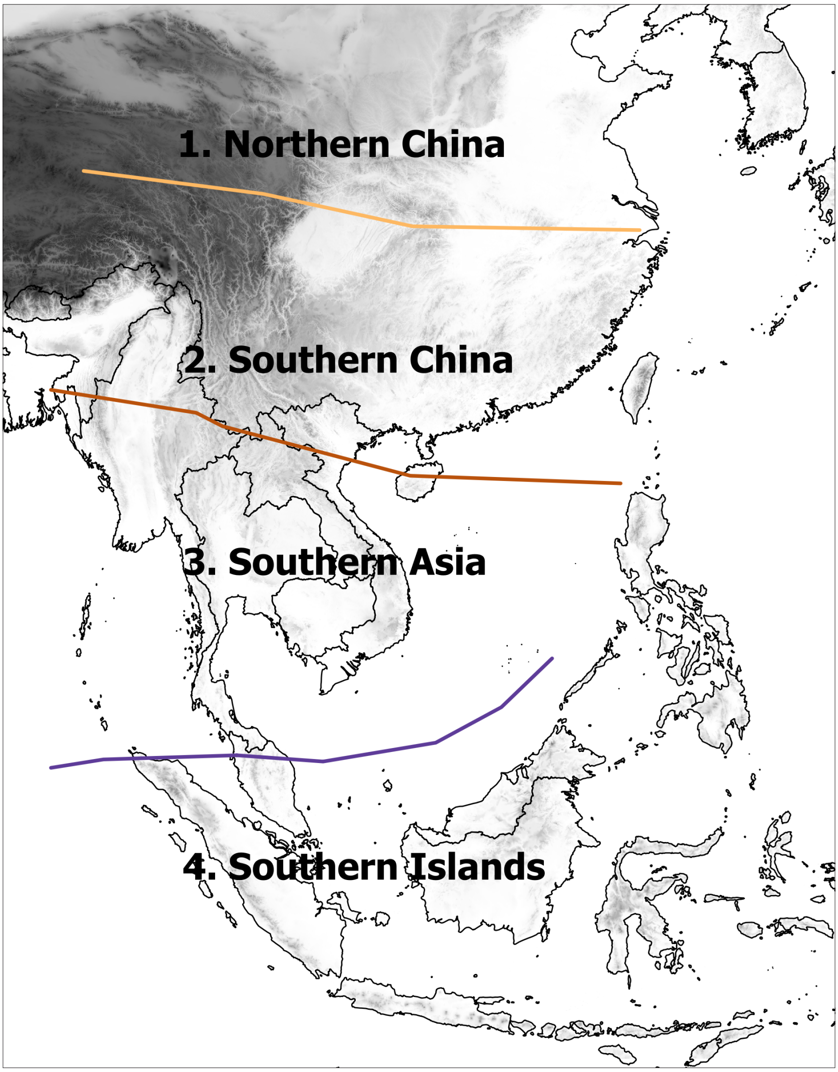

Figure 4 Map showing latitudinal belts of domesticated plants in 'Southeast Asia', according to divisions proposed by Li 1970. Redrawn from Li 1970 (fig. 1). Made by the Author with QGIS 3.28.5. Firenze, Natural Earth and Earth Resources Observation and Science (EROS) Digital Elevation basemap, U.S. Geological Survey

According to Li, rice originated here (Belt 3 was also the main region expanded upon in Li's 1979 commentary of Ji Han's botanical treatise) **[fig. 5]**. It is curious to note that Li stated that there was no archaeological evidence in support for this hypothesis, but given the importance of rice in modern agriculture, it must have originated here

> Although this view is not substantiated by archaeological evidence, the extreme importance of rice cultivation on the economy of this region is obvious. (Li 1970, 12)

Li theorised that rice was almost the only component of the native subsistence of this latitudinal belt, with ancient people still relying heavily on other types of resources or external influences (Li 1979). Finally, Belt 4, comprising of modern-day Malay Peninsula and insular Southeast Asia, was the homeland of tropical fruits and relied on the northern belts for other types of crops. Modern-day distribution of wild population is not necessarily a true reflection of the original distribution of a plant species (Fuller 2011a); therefore, the analysis of ancient plant remains from archaeological sites provides the best evidence for discussing the domestication of plant species in the past. Appendix 1 provides an updated list of plant species originally listed in Li's work and their currently known region of origin, based on the accumulated archaeological and archaeobotanical evidence.

Table 2 Main plant species and their latitudinal belt of origin according to Li (1970). The table was adapted from Chang 1986 (80). Please note that North China, South China/Southeast Asia are meant by the definition given in Li (1970), and do not correspond to modern regional divisions; see text for details. See Appendix 1 for a full list of plant species listed in Li's publication and their currently accepted region of origin, as evidenced by recent archaeological and archaeobotanical work

	North China	**South China/Southeast Asia**
Cereals	Broomcorn millet Foxtail millet	Rice Job's tear
Legumes	Soybean	Red beans
Vegetables	Garlic Mallow Knotweed Welsh Onion Chinese Cabbage	Amaranth White gourd Luffa Water spinach Lily Manchurian waterrice
Fruit trees	Peach Chinese plum Apricot Hawthorn Persimmon Chinese jujube	Oranges Kumquat Loquat Litchi Longan Chinese olive
Roots/tubers	Chinese artichoke	Chinese yam Taro Greater Yam Yam
Fiber crops	Hemp	Ramie Chinese jute
Other industrial crops	Mulberry Varnish tree	Tea oil Tung oil tree
Beverages		Tea

K.C. Chang in the fourth (and last) edition of his publication *The Archaeology of Ancient China* noted

> to understand and demonstrate the transformation into agricultural life in China, the archaeologists will have to investigate in detail the faunal and floral changes that took place in the several millennia before and after the beginning of the Holocene. A beginning has been made in the studies of domesticated pigs and dogs and their wild ancestors in China,

> but botanical studies toward and understanding of the cultivation of native grasses, roots and tubers have not yet begun. (Chang 1986, 79)

This sentence summarises well the fact that, until the introduction of archaeobotanical methods at the end of the 1980s, plant finds from archaeological sites in China were rather sporadic; K.C. Chang himself refers to the work by Li (1970) in his book. The scarcity of archaeobotanical evidence hindered the understanding of the beginning of agriculture in the country, despite it being a major topic of interest especially among prehistorical archaeologists who sought archaeological evidence to support theories derived from mythological[9] and historical records.

Grain impressions on ceramic sherds were among the first type of archaeological evidence used to theorise about the origins of agriculture in China. One often cited example is that of possible rice grain impressions from the Yangshao site, in Henan, found during its 1929 excavation (Ho 1977). Andersson, who excavated the site at that time, proposed that 'Rainy Southern Asia'[10] was the centre for rice domestication (Andersson 1934; Li 1970; Ho 1977). In these early decades of archaeological research, plant presence at a site was taken as indication of local cultivation, regardless of the quantity and type of context where the plant remains were retrieved and, most importantly, whether the plant growing requirements were in line with the ancient climate of the time of occupation of the site. Chance finds of large quantities of millet remains such as those from Cishan (Handan, Handan 1977; Hebei, Handan 1981) and rice remains such as those from Hemudu (Zhejiang, Zhejiang 1978; Hemudu 1980; see § 1.2.1) gave support to a dual view of early agriculture in China, based on millet in the north and rice in the south (e.g., Yan 2000) **[fig. 6]**. This view was initially postulated based on early textual evidence, such as that in the *Shijing* 詩經 (Classic of Odes, dated to the Zhou Dynasty, ca. 850 BCE), which contained descriptions of botanical varieties of ca. 150 plants, including indications of their cultivation practices and uses (Ho 1969; 1975). Scholars suggested that millet and rice farming were originally divided along the boundary of the Qinling Mountains and Huaihe River (Yan 1987; 2000; Zhao 2011). Millet was domesticated by Yangshao farmers in the Yellow River Valley. Ho initially postulated that thanks to the richness of loess soil, there was no need to practice fallow (Ho 1969),[11] however, he later suggested that agriculture followed a four-year cycle; land would be clear from pre-existing vegetation in the first year, cultivated for two successive years, and left to fallow on the fourth year (Ho 1975, 49-54). It was thus hypothesised that the earliest agricultural systems

---

[9] The most well-known myth on the origin of agriculture in China is about Shennong 神農 (the Divine Farmer), a legendary king who invented the plough (Sterckx 2018) and taught his subjects to sow 'ancient five grains' (*wugu* 五穀), for which he is also sometimes referred to as the *Wugu Xiandi* 五穀仙帝 (the Divine Emperor of the Five Grains); see records in the *Shiji* 史記 (The Grand Scribe's Records) by Sima Qian 司馬遷 146-86 BCE; Ch'ien, Nienhauser 1994-2019). According to Bray (1984, 432), the five grains usually include rice (*dao* 稻), broomcorn millet (*shu* 黍), foxtail millet (*su* 粟; in ancient text millet is also referred to with the generic term *ji* 稷), wheat/barley (*mai* 麥), and (soy)beans (*shu* 菽). In some texts hemp (*ma* 麻) is indicated instead of rice, such as in the *Liji* 禮記 (The Classic of Rites; Legge 1885). These five grains are sometimes still referred as the basis of traditional Chinese agriculture (see for example He et al. 2022c, 2).

[10] 'Rainy Southern Asia' in opposition to 'Dry Central Asia'.

[11] Recent research has demonstrated that loess soil does indeed have high fertility potential when well-watered, which would reduce fallow needs (Stevens, Zhuang, Fuller 2024).

were similar to modern slash and burn practices, with people clearing a patch of vegetation with fire, cultivating the cleared land for one or two years and then moving to another patch of land, which would be cleared with fire and cultivated while the previously cultivated land was left to fallow. This was based upon scrutiny of Zhou Dynasty (1046-246 BCE) textual sources and Shang Dynasty (1250-1046 BCE) oracle bone inscriptions[12] which indicated that the land left to fallow was used for hunting (Peng 1989). Mythological accounts gave great importance to millet, indicating that Lord Millet (*Houji* 后稷) was the legendary divine ancestor of the Zhou clan's kings (Smith 1957; cf. Legge 1861-72). Finds of ancient millet grains such as that from Cishan thus gave support to the fact that millet was indeed the staple crop that sustained the formation of the earliest Chinese States (Zhao 2011).

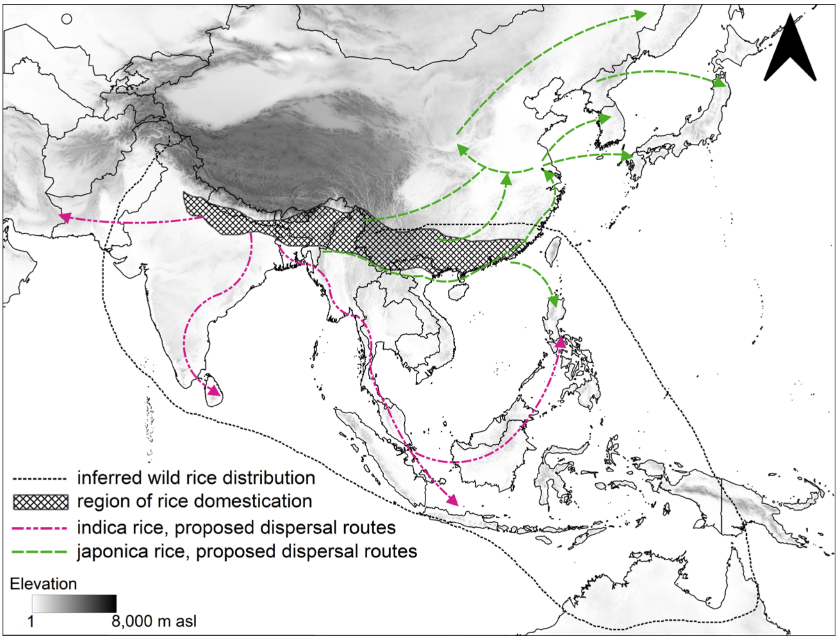

Figure 5 Map showing inferred wild rice distribution, proposed region of rice domestication and hypothesised spread routes according to early theories of rice domestication and dispersal. Redrawn from Li 1970. Made by the Author with QGIS 3.28.5-Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

Observation of modern centres of wild plant diversity was a common approach to individuate possible plant domestication centres, a method adopted and popularised by Vavilov in the early twentieth century (Vavilov 1951), itself developed on conclusions put forth in the late nineteenth century by De Candolle (1885). This was particularly relevant in the early theorisation of rice domestication. Among the first theories it was proposed that rice was domesticated somewhere between Northeast India, Southwest China, upper Myanmar, northern Thailand, Laos, and north Vietnam (Rozheviz 1931; Ramiah 1937). The discovery of extant wild rice populations in modern

---

[12] Inscriptions indicating plants, especially cereals, such as possible cultivated rice, wheat, barley, millets, and hemp were identified from Shang oracle bones recovered from archaeological sites in Henan (Ho 1969; Lu 1999).

Guangdong, Guangxi, and Yunnan during the surveys conducted by the Chinese Geological Society in the 1920s and 1930s (Xia 1960; Ho 1969, 23) gave prominence to the view that rice was domesticated somewhere in the Yunnan-Nepal belt, from where it spread north and eastward, either through the Yangzi River or along a coastal route from modern Vietnam to the Yangzi Delta **[fig. 5]**. This was substantiated by the higher concentration of wild rice varieties in Yunnan compared to other areas in the region, where at least 3,000 rice varieties were documented at altitudes ranging from 40 to 2,600 m asl (Chen 1989, 90). Several scholars suggested this indicated rice was most likely domesticated there.[13] This view was further elaborated upon by scholars studying the Austroasiatic languages, most of which supported a rice origin in the region (see § 2.2.1.1). Ancient rice findings gave further support to this theory, including the silicified rice grains that were found at Baiyangcun, northwest Yunnan, during the 1972 excavation (Yunnan 1981).[14] Recent archaeobotanical research across China coupled with direct dating of ancient rice seeds has disproved this theory (see § 2.3.1.2). For Yunnan, the current earliest domesticated cereal remains date to several millennia later than those from the mid- and lower Yangzi Basin (Dal Martello et al. 2018; Ma et al. 2024; see Ch. 4).

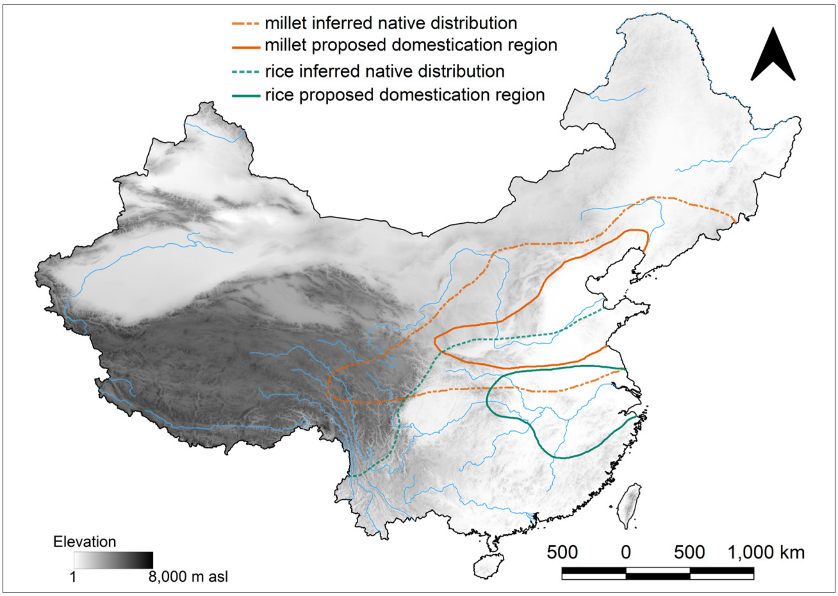

Figure 6 Centres of domestication and inferred native distributions of rice and millet according to early theories of agricultural origin in China. Based on Yan 2000 (fig. 1). Made by the Author with QGIS 3.28.5. Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

---

[13] See for example Chatteerjee 1951; Chang 1964; Li 1970; Liu 1975; Chang, Bunting 1976; Wang 1977; Li 1981; 1984; Dubu 1982; Xu 1998.

[14] The Baiyangcun rice later gained prominence in the context of the farming/language dispersal hypothesis which linked the domestication and spread of rice to proto-Austroasiatic speakers, whose homeland was possibly Yunnan and from where rice spread outward (e.g., Bellwood 1995; Higham 1996a, 1996b; Benedict 1999; Higham 2004; Sagart 2008; Van Driem 2012). This view was supported by some scholars until quite recently and only the increased application of archaeobotanical methods has finally confuted it (see Ch. 4).

Based on rice finds from archaeological sites in the lower Yangzi (see § 1.2.1), other scholars suggested that rice was domesticated in the Yangzi River Basin or possibly further south. Finally, some scholars suggested that rice was domesticated by millet farmers as they migrated south and found that millet cultivation was less successful than in the north (e.g., Barrau 1966; Ho 1969; Chang 1970).

This dualistic component of early Chinese agriculture **[fig. 6]**, albeit with nuances, is still generally considered accurate and has been substantiated by successive archaeological and archaeobotanical work (see below). Scholars, however, have moved away from a monolithic view of an individual centre of domestication, in favour of a cluster area or mosaic view of domestication of plant species (e.g., Stevens et al. 2020), a shift in archaeobotanical research that reflects general trends towards multi-centric approaches in archaeological research worldwide.

2.2.1.1 Linguistics and the Domesticators of Rice

An important theory related to the beginning of rice agriculture in China, which proposed Yunnan as a probable centre of domestication, arose following comparative and historical linguistic studies on Austroasiatic languages. Today, this is one of five major language phyla that exist in East Asia, the others being Sino-Tibetan (referred by some scholars as Trans-Himalayan), Tai-Kadai (also known as Kra-Dai), Hmong-Mien (previously referred to as Miao-Yao), and Austronesian (see Sagart 2022; Enfield 2021 for recent overviews on these language families). The aim of linguistics studies is to reconstruct language phylogeny by tracing similarities and shared innovations in vocabulary, often examining terms related to animals, plants, food, and agricultural activities. As a result, such studies attempt to individuate the ancient homeland and dispersal routes of those language families. Geographical origins of language families are often identified where the greatest modern diversity of those languages is attested today.[15] Within Archaeology, linguistics reconstructions gained prominence in past discussions on ancient plant domestication in the framework of the language/farming dispersal hypothesis. This theory links the dispersal of major world language families to the development of agriculture, based on the assumption that demographic expansions (and, consequently, the spread of languages) are driven by the increased availability of food surpluses derived by stable agricultural production.[16] Scholars postulate that the demographic growth, driven by food surpluses, would have placed pressures on available resources (as per Rindos 1980; 1984), pushing part of the population outward in search of new arable lands, while at the same time displacing pre-existing hunter-gatherer

---

[15] Some scholars have recently raised questions about the suitability of this method, highlighting for example that, although modern Sino-Tibetan languages today have the highest level of diversity in Nepal-Northeast India-Myanmar (see Blench, Post 2014), however, scholars agree that they originate from the Yellow River Basin (see Sagart et al. 2019; Wu, Bodt, Tresoldi 2022; Jacques, Stevens 2024).

[16] See Renfrew 1992, 1996; Bellwood 1996; 2001; 2005; 2006; Bellwood, Renfrew 2003.

populations (Ammerman, Cavalli-Sforza 1971).[17] According to proponents of the farming/language dispersal hypothesis, in tracing the homeland of language phyla, we can individuate where plants were domesticated. Noting that Austroasiatic languages today have the greatest diversity in vocabulary for rice and related cultivation activities compared to other East Asian languages,[18] numerous scholars suggested that rice was domesticated among ancient Austroasiatic speakers. These languages today are most prevalent in continental Southeast Asia, extending from Northeast India (where the Munda languages sub-group is found) to Malaysia, although their distribution is highly fragmented. The other major Austroasiatic subfamily is Mon-Khmer, occupying fragmented territories in mainland Southeast Asia and Yunnan. There is yet no consensus among scholars about the original homeland of Austroasiatic languages, but Yunnan has often been suggested as the possible homeland for this language phylum.

Some scholars postulated that rice was domesticated among Austroasiatic speakers in the region where modern Munda languages are distributed (southern Yunnan-Myanmar).[19] It was further suggested that the presence of different ecotypes in the region led to the domestication of different rice cultivars (*ahu*, *indica*, and *japonica*), resulting in the development of dry and wet rice cultivation systems before these dispersed west and eastward.[20] Other scholars proposed that Austroasiatic and Austronesian languages had a common ancestor, Austric, whose speakers domesticated rice, and the population growth resulting from rice cultivation drove their expansion and later divergence into what are now Austroasiatic and Austronesian languages.[21] The most likely area for the Austric homeland was individuated in the *Sanjiang* 三江 (Three Rivers, or Three Parallel Rivers) region of Yunnan, where three major Asian rivers run parallel to each other for 300 km and would have provided routes of dispersal (Blust 1996). These rivers are the Nujiang 怒江/Salween, Langcang 浪沧/Mekong, and the Jinsha 金沙 section of the Changjiang 长江/Yangzi River. Further west, the N'Mai River, a tributary of the Irrawaddy River, also runs parallel to the Three Rivers, but by being in modern Myanmar is usually not included **[fig. 13]**. This theory was favourably received among proponents of a single origin of agricultural spread from China to Southeast Asia.[22] Today, the existence of Austric has been refuted, including by proponents of the theory themselves (e.g., Blust 2013), due to the lack of shared vocabulary for rice agriculture between

---

[17] Ethnographic studies have documented this kind of agricultural driven demic diffusion in Borneo, where native Iban swidden rice cultivators would periodically spread to neighbouring areas following demographic increase (Freeman 1970).

[18] Diffloth (2005) for example illustrates eleven reconstructible Austroasiatic roots: *(kə)ɓaːʔ 'rice plant', *rəŋkoːʔ 'rice grain', *cəŋkaːm 'rice outer husk', *kəndək 'rice inner husk', *pheːʔ 'rice bran', *təmpal 'mortar', *jənreʔ 'pestle', *jəmpiər 'winnowing tray', *guːm 'to winnow', *jərmuəl 'dibbling stick' and *kəntuːʔ 'rice complement', i.e. accompanying cooked food other than rice; indicating that Austroasiatic has the high diversity in rice agriculture related terminology.

[19] e.g., Sagart 2008; Sagart 2011a; 2011b; 2019; van Driem 2011; 2012; Bellwood 2011.

[20] e.g., Van Driem 2017, 2012, 2011; Donegan, Stampe 2004.

[21] The Austric hypothesis was originally postulated by W. Schmidt in 1906. For proponents of this theory see Diffloth 1994; Reid 1994, 1996, 1999; Blust 1996; Benedict 1999. Austronesian languages are thought to originate in modern Taiwan and from there spread to coastal China and insular Southeast Asia.

[22] e.g., Higham 1996a; 1996b; 2002; 2004; Bellwood 1995.

Austroasiatic and Austroneasian languages (Sagart 2011b, 346), and Austronesian languages are thought to originate in modern Taiwan and from there spread to coastal China and insular Southeast Asia (e.g., Blust 2013). Others indicated a tropical origin of Austroasiatic languages, based on reconstructed animal species, and located this homeland in modern continental Southeast Asia (Diffloth 2005), although, at the presumed time of rice domestication, southern China also provided tropical environments (see Ch. 3). Other scholars, in fact, pointed to southern China/the middle Yangzi River as the homeland of Austroasiatic speakers (Norman, Mei 1976), often citing that the Chinese *jiang* 江, old Chinese *kˤroŋ, used to refer to the Yangzi River, is an Austroasiatic borrowing.

Finally, some scholars refuted the hypothesis of Austroasiatic being rice domesticators altogether, indicating instead that proto-Austroasiatic speakers were hunter-gatherers that lived in a tropical environment, relied on fishing, and practiced vegeculture of tubers (e.g., taro). Known as the ‘Southern Riverine Hypothesis’, this view postulates that proto-Austroasiatic homeland was along the Mekong Basin (described by Blench as the phylum geographical ‘centre of gravity’; Blench 2015, 1). Those groups, after the adoption of rice, spread rapidly following riverine routes (Sidwell, Blench 2011; see also Heine-Geldern 1917).

Language/farming dispersal hypotheses still weigh heavily in early agricultural dispersal debates, but the assumption that wet rice cultivation was the main driver of demic diffusions has recently been challenged. Archaeological and archaeobotanical evidence demonstrate that the high yields derived from wet rice cultivation (see below) cause population packing rather than dispersing, as demonstrated by the establishment of large urban centres sustained by wet rice cultivation during the Liangzhu Culture, in the lower Yangzi region (Qin, Fuller 2019). It has been suggested that millet cultivation, or dry rice cultivation, cause demic diffusion and may have been the driver of major population dispersals (Qin, Fuller 2019; Stevens, Zhuang, Fuller 2024).

2.3 The Domestication of Rice and Millets

Ancient plant remains from archaeological sites in China have accumulated steadily in the past decades, thanks to the continued improvement and implementation of archaeobotanical methods in the country (see Ch. 1). This has allowed enormous steps forward in our understanding of past plant domestication and use in China. This section provides information on the growing requirements of each species, a summary of the evidence regarding their early cultivation, and an overview/outline of the potential areas and timing for their domestication.

2.3.1 Rice

2.3.1.1 Rice – Growing Requirements and Domestication Criteria

Rice (*dao* 稻) – *Oryza sativa* subsp. *japonica* (the rice species domesticated in China) derives from the wild progenitor *Oryza rufipogon* (Choi et al. 2017). The history of domestication of rice is complex, genetic evidence is increasingly supporting multiple wild population origins with a single domestication process, indicating that modern diversity in rice derives from later introgression of wild populations with domesticated *japonica* rice. More specifically, *indica* rice is thought to derive from the hybridisation of domesticated *japonica* with a proto-*indica* rice, itself evolved from the wild *Oryza nivara*. Archaeological evidence has shown that *O. nivara* was cultivated in the Ganges Valley around the tenth-ninth millennium BCE.[23] *Indica* rice has similar growing requirements to *japonica*, with the advantage of having a shorter growing season. Today, both varieties are cultivated, with *indica* preferred in South China, where favourable climatic conditions allow for the double cropping of the cereal (a second harvest sown in June and harvested until November; Yoshida 1981). However, since all prehistorical rice evidence identified so far in China belongs to the *japonica* type, *indica* rice is not discussed further here.[24]

Rice is a summer crop sown in conjunction with the warming of temperatures in the spring and harvested after summer, or slightly later. It has a long growing season of at least three months or more **[tab. 3]**. Depending on water management practices, rice can be divided in upland (dryland or rainfed) and lowland (wetland or irrigated) rice. Dryland rice relies solely on rainfall for its water intake, rice fields are established after clearing the forest through fire (slash and burn practice; Fuller, Weisskopf 2011), and there is no creation or maintenance of irrigation structures and therefore no surface water accumulation. Today, upland rice is cultivated in marginal hilly areas (mostly in tropical regions) where there is a minimum precipitation of 800/1,000 mm per year (Jaquot, Courtois 1987). Wetland rice is characterised by the construction of embankments, water reservoirs and other irrigation structures to allow water retention on the fields surface. Fields are either seasonally or permanently flooded. Dryland rice is less labour intensive than wetland rice, however, it also yields a much lower harvest.

---

[23] Choi et al. 2017; Fuller 2011a; 2011b; Fuller et al. 2010; Fuller, Qin 2010.

[24] For discussions on the origin of *indica* rice, readers are referred to Fuller 2011a; Choi et al. 2017; Ishikawa, Castillo, Fuller 2020; Bates 2022.

Table 3 Main growing requirements of domesticated rice. Sources: Jaquot, Courtois 1987; Yoshida 1981; Mutert, Fairhurst 2002; Maclean et al. 2002; Fuller, Weisskopf 2011; Qin, Fuller 2019

Growing requirements	Upland (rainfed) rice	Lowland (irrigated) rice
Water requirements	Rainfall higher than 800/1,000 mm	Grown in a spectrum of water systems: irrigate, flooded, fully submerged
Variety according to latitudinal region of growing	Japonica temperate	Japonica tropical
Sowing	February-May	June-July
Minimum temperature to germinate	10°C	
Optimal temperature to flower	20-35°C	
Days to maturity	120/130-150	Up to 200
Harvest	June-October	December
Yield/ Hectare	578 kg/ha ~ 1062 kg/ha (229 kg/ha)	1897 kg/ha (historical data: 1000-1300 kg/ha; Neolithic est. data: 800~900 kg/ha)
Photoperiod sensitivity (changes in day lengths)	High	Low

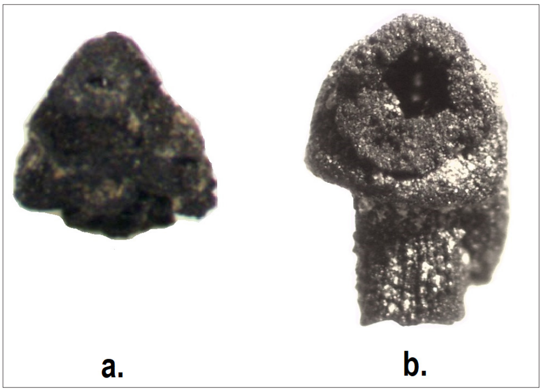

Figure 7
Rice spikelet bases from Baiyangcun, Yunnan, showing different morphology: a. wild type; b. domesticated-type.
© Author

Initially, phytoliths were the widest employed method to assess the domestication status of rice. This was undertaken through the morphological and metrical study of rice husk phytoliths, specifically double peak phytoliths and fan-shaped bulliform phytoliths (Zhang, Wang 1998). Fan-shaped bulliform phytoliths are still widely employed to establish the domesticated status of the rice plant that deposited them, through the measuring of the overall size of the phytolith, the length of the fan 'handle', and the count of the scales in the scalloped margin of the fan.[25] However, not all scholars agree on the reliability of this methodology citing the still unclear processed behind the increase of facets in the scalloped margin of bulliform phytoliths produced by domesticated rice plants. Moreover, the application of this methodology to assess wild vs. domesticated rice in areas outside of China has proved unreliable. Contradictory results within China (for example the

---

[25] See for example Wang et al. 1996; Lu et al. 2002; Huan et al. 2015; Ma et al. 2016.

presence of allegedly domesticated rice from very early periods, well before any other archaeological evidence for the exploitation of this plant) have raised further questions regarding the applicability of this methodology to investigate the domestication of rice. Interpretations derived from rice phytoliths push back rice domestication by several millennia compared to inferences made on macro-botanical remains alone. For example, rice phytoliths have been reported from limestone caves in South China at several sites along the Nanling Mountains dated by cultural association to the eleventh millennium BCE (Hung 2014). Their retrieval gave rise to the hypothesis that they represent the initial stage of rice domestication in China; however, phytoliths lack the possibility of ascertaining their antiquity via direct dating, and some scholars have pointed out that the remains from these limestone caves may represent wild rice as there is no clear indication of human collection or consumption of rice.

More reliable evidence of the early management of wild rice, leading to its domestication, is provided by charred macro-remains, as these can be directly dated through radiocarbon dating. Additionally, they can reveal changes in the spikelet morphology, which indicate whether the rice plant exhibited seed shattering or non-shattering behaviour. Non-shattering is a key trait of rice domestication, effectively making the plant dependent on humans for its successful reproduction. The examination of the spikelet base morphology is a recent development within archaeobotanical analyses,[26] which emerged following the refinement of flotation techniques and subsequent recovery of very small macro-botanical remains. Rice spikelet bases often measure just over 0.5 mm or between 0.5-0.3 mm and are thus washed out from the archaeobotanical record if the mesh size used during flotation is not small enough for their retrieval.[27]

Wild-type spikelet bases present a smooth and round scar in the abscission zone, which is mostly flat when examined from its profile angle; domesticated-type spikelet bases, instead, show a deeply ripped, rough and irregular scar in the abscission zone, which appears concave from profile **[fig. 7]**. The ripped scar in the spikelet base is an indication of a non-shattering rachis and can therefore identify domesticated rice. Other domestication traits in rice include a more erect plant growth, a compact panicle, a white grain pericarp, and an increase in grain size, especially width (Fuller 2007; Ishii et al. 2013; Ishikawa, Castillo, Fuller 2020). Archaeobotanical studies on rice domestication have also focused on grain size, another measurable trait in the archaeobotanical material (e.g., Fuller et al. 2009; 2010). These changes altogether have been estimated to account for an increase in yield per hectare of 366% compared to yields from wild rice collection (from an estimated harvest of 232 to 850 kg/ha).[28]

---

[26] The first study of rice spikelet bases can be said to be that of G.B. Thompson in the late 1990s from archaeobotanical materials from Khok Phanom Di, Thailand (Thompson 1996; 1997). In China, early work was conducted on ancient rice remains from the lower Yangzi area (Fuller, Harvey, Qin 2006; 2007; Fuller et al. 2009).

[27] Recommended mesh size for the recovery of rice spikelet bases is between 0.25-0.3 mm.

[28] Qin, Fuller 2019; Fuller 2020, 94, tab. 1; Stevens, Zhuang, Fuller 2024.

2.3.1.2 Rice – Centres of Domestication: The Archaeobotanical Evidence

Numerous rice macro-botanical remains have been found in the broader Yangzi Valley, especially in the middle and lower basin. Recent work has indicated three main areas as probable centres for rice domestication **[fig. 8]**:

- the lower Yangzi Basin;
- the middle Yangzi Basin;
- the Han/Huai River Valleys (tributaries of the Yangzi).

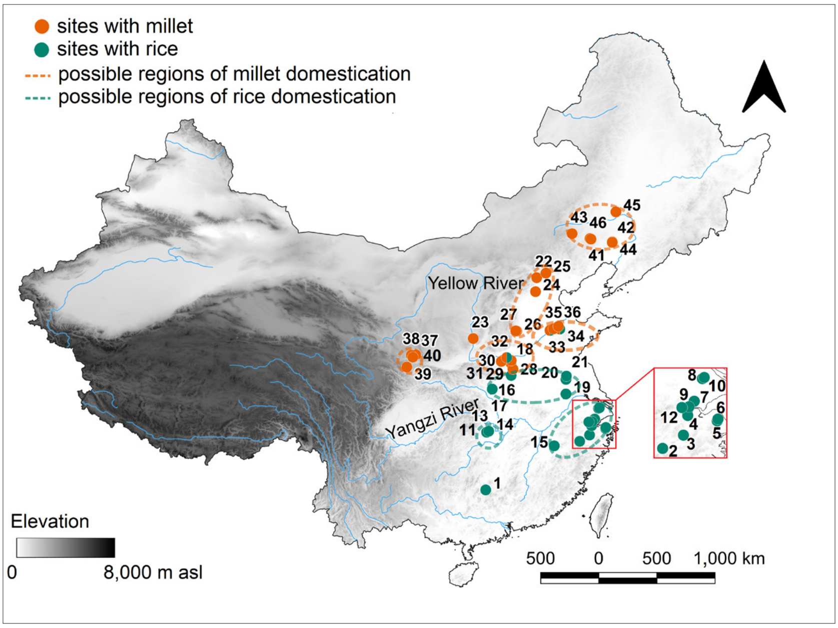

Figure 8 Sites mentioned in text in relation to rice and millet domestication in China (listed in order of first mention): 1. Yuchanyan; 2. Hehuashan: 3. Shangshan; 4. Kuahuqiao; 5. Hemudu; 6. Tianluoshan; 7. Luojiajiao; 8. Caoxieshan; 9. Maoshan; 10. Chuodun; 11. Chengtoushan; 12. Liangzhu; 13. Pengtoushan; 14. Bashidang; 15. Diaotonghuan; 16. Jiahu; 17. Baligang; 18. Peiligang; 19. Hanjing; 20. Xuenan; 21. Shunshanji; 22. Donghulin; 23. Shizitan; 24. Nanzhuangtou; 25. Zhuannan; 26. Cishan; 27. Niuwabao; 28. Dingzhuang; 29. Shawoli; 30. Wuluoxipo; 31. Fudian; 32. Zhuzhai; 33. Yuezhuang; 34. Xihe; 35. Zhangmatun; 36. Xiaojingshan; 37. Dadiwan; 38. Qin'An 1; 39. Lixian 7; 40. Huluhe; 41. Xinlonggou; 42. Jiajiagouxi; 43. Nanwanzibei; 44. Tachiyingzi; 45. Mangha; 46. Zhaobaogou. Made by the Author with QGIS 3.28.5. Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

At present, the lower Yangzi region has yielded the highest number of rice remains and is the most in-depth studied among the three regions. Here, the wet early to mid-Holocene environmental conditions provided a natural habitat for wild rice (see Ch. 3). Micro-botanical remains from the lower Yangzi region suggests rice exploitation might have started as early as the late ninth millennium BCE, evidenced for example by the find of rice husks and phytoliths from Yuchanyan 玉蟾岩 in Hunan (16300-13400 BCE; Zhang, Yuan 1998; Boaretto et al. 2009; Yuan 2013), and rice phytoliths from Hehuashan 荷花山 in Zhejiang (ca. 9400-5500 BCE; Qiu et al. 2019). However, conclusive evidence for cultivation associated with securely dated macro-botanical remains have been found only from sites dating to the seventh millennium BCE onward, exemplified by the site of Shangshan 上山 in Zhejiang (ca. 8000 BCE; Zhao, Jiang 2016). Here, fragmentary rice grains and rice spikelets have been reported.[29] These are today the oldest macro-botanical evidence recovered from the area. The majority of examined rice rachises from Shangshan are of wild-type, and only a few are of possible domesticated-type (Liu et al. 2007). The recovery of milling stones and acorns at both Shangshan and other Shangshan Culture sites (ca. 7000-6000 BCE) suggests an economy still heavily dependent on foraging. This view has been supported by a recent study on micro-botanical residue analysis on grinding stones from these sites, which revealed these were mostly used for processing acorns, inferring that Shangshan people were relying on the collection of acorns and wild rice for their subsistence (Wang, Jiang 2022). At these sites, high levels of rice husks in the pottery temper suggests people were collecting wild rice (widely available in the area at the time) and using it both for food and other purposes. Large ceramic vessels found at these sites could have been used to boil rice (Jiang 2013a), although no residue analysis was performed on the vessels to confirm this hypothesis. Although it may still represent wild rice, evidence from Shangshan Culture sites is important to trace the potential beginning of rice exploitation and later domestication in the area.

Other sites with evidence of rice exploitation date to the sixth millennium BCE onward, the most famous ones being the waterlogged sites of Kuahuqiao 跨湖桥, Hemudu, and Tianluoshan 田螺山.[30] The fact that clearly domesticated rice evidence, as we will see below, dates to a few millennia later is indicative of a long domestication process for this species. At Kuahuqiao (ca. 6200-5200 BCE) ancient plant remains recovered include several different acorn species of the Fagaceae family; possible water chestnut, Rosaceae fruits, and other species belonging to the Nymphaceae, Fabaceae and Cucurbitaceae families, as well as high quantities of rice grains and spikelet bases, recovered through flotation.[31] The majority of the spikelet bases were of wild-type (58% of the samples analysed by Zheng, Sun, Chen 2007), and samples also included a relatively high number of so-called immature-type spikelet bases, which are harvested before plants are completely ripe. Scholars have suggested that the presence of immature spikelet bases, and therefore the collection of rice panicles while still green, may represent an effort by the Kuahuqiao people to retain a higher number of grains before they would naturally shatter (Fuller, Harvey, Qin 2007). This repeated behaviour would apply a selective pressure to the plant and kick start the domestication process (Fuller, Harvey, Qin 2007). This view is not universally agreed upon (for alternative views see Liu et al. 2007; Pan 2008) and other scholars have suggested that different harvesting techniques and different stages of semi-shattering plants (plants not fully domesticated) may be possible reasons for the inclusion of immature panicles (Crawford 2011a). Due to excellent waterlogged preservation conditions, a thick layer (20-50 cm) of 'rice deposits' was found at Hemudu during excavation (ca. 5000-4500 BCE; Zhejiang 2003; Fuller, Harvey, Qin 2006; Fuller et al. 2009). The layer consisted of rice husks, ears, and straws, and some charred grains. According to the authors of the study, rice remains showed a mixture

---

[29] At the same site, foxtail millet grains have been recovered dating to ca. 4500 BCE (Zhao, Jiang 2016).

[30] Zhejiang, Zhejiang 1978; Zhejiang 2003; 2004; Hemudu 1980; Zheng, Sun, Chen 2007; Jiang 2013b; Sun 2013.

[31] Zhejiang 2004; Fuller, Harvey, Qin 2007; Zheng, Sun, Chen 2007; Pan, Zheng, Chen 2017.

of wild and domesticated-types. Other plants recovered at Hemudu include acorns, water caltrop, bottle gourd (*Lagenaria siceraria*); mountain peaches (*Prunus davidiana*), apricots (*Armeniaca vulgaris*, *P. mume*); possible sour date (*Choerospondias axillaris*); foxnut (*Euryale* cf *ferox*); Job's tears (*Coix lacryma-jobi*), and Polygonaceae nutlets (Fuller, Harvey, Qin 2007). The find of such a diverse range of plant resources implicates a general economy still largely based on foraging. High quantity of rice chaff and grains were also found at Tianluoshan (ca. 5500-3500 BCE) located only 7 km from Hemudu, and Luojiajiao 羅家角 (ca. 5000 BCE; Zheng, Sun, Chen 2007). At Tianluoshan, rice is initially only a small component of the overall the archaeobotanical assemblage, which contained the same array of wild plants as those reported from Hemudu (with the addition of horse chestnuts – *Aesculus* sp.; Fuller, Harvey, Qin 2006). However, rice became more prevalent over time, indicating that people living at Tianluoshan were sedentary foragers who grew in dependence on rice over time.[32] Phytoliths studies suggest that Tianluoshan people were managing the wetland margin of wild rice fields, therefore practicing a low-level cultivation (Weisskopf et al. 2015). Here, a slightly higher proportion of domesticated-type spikelet bases has been reported compared to wild-type ones. The archaeobotanical evidence from the above sites shows a slow but steady increase in the exploitation of rice, which resulted in an increase in domesticated-type remains over time. This has been taken as evidence to illustrate the species potential domestication pathway.

Other important sites in the lower Yangzi basin include Caoxieshan 草鞋山, Maoshan 茅山 and Chuodun 绰墩, where rice fields were excavated, providing direct evidence for the crop management and early cultivation practices.[33] At Caoxieshan (ca. 4000-3800 BCE), rice is the most prevalent crop in the archaeobotanical assemblage; of note, acorns and water chestnuts have not been retrieved. Over 70% of the rice spikelet bases reported from the site have been identified as of domesticated-type, a conspicuous increase compared to earlier sites mentioned above (Fuller, Weisskopf 2011). During the 1990s excavation of the site, ovoid fields, of an area of less than 10 m^2 and about 0.2-0.5 m deep, were found dug directly on virgin soil.[34] These have been interpreted as rice paddy fields, at present the second earliest recorded evidence of this kind in China after those found at Chengtoushan 城头山 (see below). Of note, phytolith studies undertaken at the site have identified a shift to drier conditions through time (Weisskopf et al. 2015; Fuller et al. 2016). It has been argued that drier conditions might have been the initial trigger of increased grain productivity, acting on wild rice in-built stress response to drought to produce more grains instead of shoots and leaves (Fuller 2020). Scholars have also postulated that the small creeks connecting the Caoxieshan fields were a strategy to control the water flow and dry the fields at need in order to stress the plants and cause them to produce more grains (Fuller, Qin 2009; Fuller 2011a). At Maoshan (ca. 3000-2300 BCE), located about 20 km from the walled Liangzhu 良渚 site, complex rice paddy field systems were found (Zhuang,

---

[32] Fuller, Harvey, Qin 2007; Fuller et al. 2009; Fuller, Qin 2010; Weisskopf et al. 2015.

[33] Zou et al. 2000; Zhuang, Ding, French 2014; Suzhou 2011; 2012.

[34] Zou et al. 2000; Fuller 2011a; Fuller, Weisskopf 2011; Fuller et al. 2009; Fuller et al. 2014; see also Qin 2012; Fuller et al. 2016.

Ding, French 2014). According to the excavation report, in the early period of Maoshan occupation (ca. 3000-2600 BCE), irregular round shaped fields ranging between 1-2 to 30-40 m^2 were found (Zheng, Chen, Ding 2014). In the later period of occupation (ca. 2600-2400 BCE), rice fields increased to about 2,000 m^2 and were connected to the river by small ditches and embankments; soil breaking cut marks were clearly visible at the margins of the embankments indicating people at Maoshan were managing the creeks and creating field boundaries. Geoarchaeological analyses of field palaeo-soils confirmed that people at Maoshan were maintaining the natural creeks across the field to cultivate the rice (Zhuang, Ding, French 2014). Wells and possibly dams located north of Liangzhu were also found during excavation, and these might have served to control the water flow or prevent floods. An intensification of rice cultivation has been inferred based on palynological evidence related to deforestation and intentional burning after 4000 BCE (He et al. 2020), which compares well with the macro-botanical evidence discussed above.

In the middle Yangzi River Basin, rice grains have been reported from Pengtoushan 彭头山, and Bashidang 八十垱 (Nasu et al. 2012; Gross, Zhao 2014), however, neither site is well dated, and the lack of rice spikelet bases makes it difficult to determine the domestication status of the rice recovered. Other plant remains retrieved from these sites include water chestnuts (*Trapa bispinosa*) and lotus (*Nelumbo nucifera*), indicating collection of wild water resources. In this region, at Chengtoushan, small rice paddy fields[35] with simple drainage structures were discovered during excavation and dated to ca. 4500 BCE (He 1999; Fuller 2011a; Qin 2012). Phytoliths from Diaotonghuan 吊桶环 have been taken as an indication of early utilisation of rice in the area (Zhao 1998), possibly pre-dating the domestication of the species to the ninth millennium BCE; however, as we have seen, scholars disagree on the reliability of this method to determine domestication status, and further evidence is needed to fully clarify the contribution of this region to rice domestication.

More recently, new data from the Han (also known as *Hanshui* 汉水 or *Hanjiang* 汉江) and Huai River (*Huaihe* 淮河) Valleys, geographically located between the Yangzi and Yellow Rivers and today both discharging into the Yangzi, suggests this region was also central for the domestication of rice.[36] Rice remains have been found at several sites belonging to the Peiligang and Yangshao Neolithic Cultures in this area.[37] Rice found at Jiahu 贾湖 (ca. 7000-6600 BCE; Henan 1999), located in Henan Province along the Upper Huai River, has been used by many as strong evidence for rice cultivation by the Yangshao people (e.g., Zhang, Wang 1998; Liu et al. 2007). Others argued that Jiahu rice remains belong to a wild variety that did not participate in the later domestication of the crop (Fuller, Harvey, Qin 2007). Flotation undertaken during the 2013 excavation revealed a high number of previously unrecorded charred rice grains and spikelet bases among other species, such as grape and wheat (Zhang J.Z. et al. 2018). According to this study, spikelet bases show an increase in domesticated-type through

---

[35] At the time of writing this is the earliest archaeological rice field excavated so far in China.

[36] Gross, Zhao 2014; Silva et al. 2015; Deng et al. 2015; Stevens, Fuller 2017; Huan et al. 2022a.

[37] See Yang et al. 2016; Wang et al. 2017; 2019a; 2019b; Cheng Z.J. et al. 2022; Huan et al 2022b; Sun et al. 2022.

time, and rice is also among the most prominent species recovered. The authors of the study suggest Jiahu inhabitants relied heavily on rice exploitation and contributed to this species domestication. However, no rice grains were directly dated; wheat and foxtail grains coming from the same contexts as rice, dated by AMS radiocarbon dating, were revealed to be either modern or dating to ca. 600-500 years ago; this raises doubts about the chronology of the rice remains recovered in this occasion and any inferences made from it. Until more conclusive evidence is found, the role of rice at Jiahu remains ambiguous; rice is a minor component of the overall archaeobotanical assemblage retrieved, suggesting it occupied a minor role in the overall economy of Jiahu, where hunting and gathering were the main subsistence strategies (Zhao, Zhang 2009). The only site where rice cultivation is well attested from the same area is the site of Baligang 八里岗 (ca. 6700-1800 BCE) in the Nanyang basin, which was occupied around the same time as Jiahu (Deng et al. 2015). The archaeobotanical assemblage here is dominated by rice, which is found alongside wild plant resources, especially acorns, for the initial period of occupation. In the later periods, wild foodstuff decreases, and rice is present alongside millets (both *Setaria italica* and *Panicum miliaceum*) constituting among the first mixed farming system in China (see § 5.1). Rice remains for the whole period of occupation are mostly of domesticated-type, with wild-type remains present in negligible quantities already by ca. 6300 BCE (Deng et al. 2015). Recent archaeobotanical data from the site of Peiligang 裴李岗 (ca. 6200-5700 BCE; Li Y.Q. et al. 2020), located in northern Henan, included rice, millet, and other fruits; while the full archaeobotanical report has not been published yet, this still suggests exploitation of rice in this area by at least the sixth millennium BCE.

In the lower Huai region, rice grains have been recovered from Hanjing 韩井, Xuenan 雪南, and Shunshanji 顺山集, all belonging to the Shushanji Culture and dating to well before 6000 BCE (Nanjing, Sihong 2016). At Hanjing, what looks like paddy structures have been discovered (Zhuang et al. 2018; Qiu et al. 2022), and this suggests rice cultivation was well underway in this area by the end of the seventh millennium BCE.

Regardless of the ongoing debates on where exactly rice was domesticated, the disagreement on the best suited type of evidence to distinguish between wild and domesticated rice, scholars agree on the fact that the domestication of rice was a long and protracted process that took several millennia. Present evidence attests that the collection of wild rice started in the ninth millennium BCE, or possibly earlier, in the Yangzi Basin. This is strongly connected to an intensification in wild acorns exploitation; some scholars have suggested that the need for processing acorns to make them edible (e.g. boiling) forced people to have longer sedentary camps, which may have laid the basis for later rice agriculture (Chang 1970). Convincing evidence, including both domesticated-type rice remains and paddy-like fields, has been attested from the fifth millennium BCE onward, both in the lower and middle Yangzi region. Intensification of rice cultivation and large-scale fields have been found connected with the Liangzhu Culture from the third millennium BCE. The Han/Huai Valleys have also recently provided data of cultivated rice from about the same time. Ancient palaeoclimate in the Yangzi region was much wetter than today (see Ch. 3); this created a natural environment for wild rice, which was distributed much further north than today, and provided abundant wild rice availability to people living in the

Yangzi Basin and north from it. This allowed for experiments with wild rice gathering and exploitation for a variety of uses, but it is possibly where drier conditions emerged that rice productivity was pushed to increase, as evidenced by shifts in ecological signatures at Caoxieshan. Predominantly domesticated rice forms have been attested from the fifth millennium BCE onward, when rice began being the main source of food of people living along the Yangzi River.

2.3.2 Millet

2.3.2.1 Millet – Growing Requirements and Domestication Criteria

Two millet species are native to China: broomcorn millet (*Panicum miliaceum*, *shu* 黍) and foxtail millet (*Setaria italica*, *su* 粟). Broomcorn millet's wild ancestor has not yet been conclusively determined. Ancestral relatives of *Panicum miliaceum* subsp. *ruderale*, found today across Eurasia, have been indicated as likely candidates (Xu et al. 2019; Li L.X. et al. 2021), but a recent morphometric study on archaeological *P. miliaceum* and *P. ruderale* grains has found that these ancient *ruderale* grains are longer than the earliest *miliaceum* grains, suggesting that *P. miliaceum* var. *ruderale* may be a poor fit as a true wild ancestor of broomcorn millet (Stevens et al. 2020). Other possibilities include *Panicum repens*; however, some scholars have suggested that broomcorn millet wild progenitor might be extinct.[38] Foxtail millet derives from *Setaria viridis* (green bristlegrass).[39] Millets are warm season crops but thanks to their high level of resilience to cold and drought they are well suited to grow in a variety of environmental conditions, including harsher climates (Weber, Fuller 2008). Compared to foxtail millet, broomcorn millet has a shorter growing season, can handle water shortages better, but is not completely frost tolerant, as foxtail millet is **[tab. 4]**. Chinese millets adaptability and ability to produce grains even with as low as 200 mm rainfall make them particularly well adapted to grow in northern China and semi-arid regions. Recent experimental data has suggested that grain yields derived from the cultivation of domesticated millets increased by 1,180% (from 50.8 to 600 kg/ha) for foxtail millet and 546% (from 109.9 to 600 kg/ha) for broomcorn millets (Stevens, Zhuang, Fuller 2024).

---

38 Sakamoto 1987; De Wet 2000; Hunt et al. 2011; Hunt et al. 2014.

39 He et al. 2023; Jia et al. 2013; Eda et al. 2013; Le Thierry d'Ennequin et al. 2000.

Table 4 Main growing requirements of domesticated Chinese millets. Sources: Kamkar et al. 2006; Weber, Fuller 2008; Liu 2009; Saseendran et al. 2009

Growing requirements	***Panicum miliaceum***	***Setaria italica***
Water requirements	200-350 mm (Optimal range 300-350 mm)	
Minimum temperature to germinate	20°C	10°C
Optimal temperature for flowering	20-25°C	16-25°C
Frost tolerance	Some	Yes
Days to maturity	45-100	60-120
Yield/ Hectare	500-700 kg/ha (Neolithic est. 600 kg/ha)	800-900 kg/ha (Neolithic est. 600 kg/ha)

Millet grains preserve well archaeologically, but their very small size (charred grains usually range between <1-1.5 mm) has resulted in a bias against their retrieval in favour of larger grains. This was even more so before the standardisation of flotation techniques and use of a small size mesh sieve during flotation at archaeological excavations (see Ch. 1). At present, seed size and a general rounder seed shape together with changes in seeds' embryo size and shape have been used as the main attestable criteria in tracing this crop domestication, as these preserve well archaeologically (Fuller et al. 2014; Stevens et al. 2020).

2.3.2.2 Millet – Centres of Domestication: The Archaeobotanical Evidence

Recent debates about millet domestication in China have focused on a single vs. multiple domestication origin, as finds have been reported across separate areas in western and northeast China (Xu et al. 2019), as well as Europe (see Hunt et al. 2008; Motuzaite-Matuzeviciute et al. 2013; Filipović et al. 2020 for a critical review of that data). Millet grains were reported from Neolithic Age sites in Europe dating to as early as the seventh millennium BCE. This prompted hypotheses for either a local domestication (e.g., Jones 2004), or a very early spread of the crop (e.g., Hunt et al. 2008), which would have had implications on a possible date of origin in China. Direct radiocarbon dating on these millet grains revealed that they were intrusive from later periods and determined to be dated to the second millennium BCE (Motuzaite-Matuzeviciute et al. 2013; Filipović et al. 2020), therefore laying to rest claims of a separate European origin of these species. Within China, based on genetic analyses it was proposed that the centre of broomcorn millet domestication was in western China, possibly at the limit of the Loess Plateau (Hunt et al. 2018), but the uncertainty of its wild progenitor has made it difficult to fully investigate this issue. For foxtail millet, rDNA studies on modern *Setaria viridis* landraces have shown that the highest diversity within China is attested in the Yellow River Valley, making this area the likely centre for the domestication of this species (Huang et al. 2014; Wang et al. 2012). Archaeological finds of millets indeed appear in broader northern China along the Yellow and Wei River Basins at sites dating to at least the seventh millennium BCE.[40] Recent archaeobotanical data has individuated five possible regions involved in the domestication of Chinese millets **[fig. 8]**:

1. Southern Hebei (Cishan Culture sites, located in the north China plain east to the Taihang Mountains);
2. Northern Henan (Peiligang Culture sites, located mostly along the Jialu River valley to north of the Funiu Mountains);
3. West Shandong (Houli Culture sites, located in the Haidai alluvial plain north of the Taiyi Mountains);
4. Gansu (Dadiwan);
5. Manchuria (Xinglongwa Culture sites).

To date, the earliest macro-botanical evidence of presumably collected wild and possibly 'domesticated-shape' millet grains come from the site of Donghulin 东胡林, located less than 80 km from Beijing (Zhao C.H. 2006; Zhao et al. 2020). Flotation samples collected during the fourth excavation campaign at the site (between 2001 and 2006) included 14 grains of foxtail millet, one grain of broomcorn millet, and 11 grains of *Setaria viridis*. Additional macro-remains included seeds of hackberry (*Celtis bungeana*), possible wild grape (*Vitis* sp.) and a possible wild *Vigna* bean species. Foxtail millet grains from one context were directly radiocarbon dated to ca. 8240-7800 BCE, confirming antiquity of the grains and representing the oldest evidence of millet cultivation from China so far. *Setaria* starch grains have also been reported from lithic implements, further indicating exploitation of grasses at the site (Yang et al. 2012; 2015a). Other sites which have reported grasses starch grains evidence on stone tools include Shizitan 柿子滩, Nanzhuangtou 南庄头, and Zhuannian 转年 (ca. 9500-7500 BCE, Liu L.H. et al. 2013; Bestel et al. 2014; Wang C.F et al. 2012; 2015a). At Shizitan, grains of *Echinochloa* sp. and *Setaria* sp. have also been retrieved through flotation (Bestel et al. 2014); at Nanzhuangtou flotation samples included waterlogged water caltrop (*Trapa incisa*), and wild grape (*Vitis bryoniifolia*), and at Zhuannan charred remains of Manchurian walnut (*Juglans mandshurica*) were found (Yang et al. 2015a). These remains altogether attest to the range of wild plants exploited by late forager groups; finds of both macro- and micro-remains of grasses, including *Echinochloa* and *Setaria*, indicate that collection of wild millet might have started as early as the late ninth millennium BCE.

Further evidence comes from sites linked with Cishan and Peiligang Cultures, located in the Central Plains, dating to the late seventh and early sixth millennia BCE. At the site of Cishan (ca. 6000?-5000 BCE), 88 alleged underground storage pits were excavated during the 1970s archaeological campaigns (Tong 1984). According to the excavation reports, it was claimed that over 50 kg of millet grains had been retrieved from the pits,[41] however, these were too fragile to be further examined and were described as 'possibly' foxtail millet grains. This find has been questioned by later scholars, including whether the pits were indeed storage units and if millet was at all present at the site (e.g., Lu 1999; Cohen 2011; Liu,

---

[40] He et al. 2022a; Stevens et al. 2020; Liu et al. 2019; Shelach-Lavi et al. 2019; Stevens, Fuller 2017; Crawford et al. 2016; Fuller et al. 2016; Zhao 2011; Barton et al. 2009; Lu et al. 2009a.

[41] Yan 1992; Tong 1984; Handan, Handan 1977; Hebei, Handan 1981.

Chen 2012, 84). More recent investigations based on phytolith analyses on material retrieved from previously unexcavated pits at Cishan have reported the presence of both species, with possibly broomcorn millet more prevalent than foxtail millet (Lu et al. 2009a; 2009b). However, charring experiments also showed that broomcorn millet may be underestimated in carbonized macro-remains and overestimated in the phytolith assemblages but most importantly, the identification, chronology, and context of provenance of the material analyses in these more recent studies has also called into question (Zhao 2011), therefore, further research needs to ascertain the presence and status of millet at Cishan (He et al. 2022a). In this region, foxtail millet grains have also been reported from Niuwabao 牛洼堡 (ca. 6500- 5100 BCE, Liu, Jin, Kong 2008), not far from Cishan.

Broomcorn millet and comparatively lower quantities of foxtail millet as well as wild acorns have been found at the site of Peiligang (ca. 6500 BCE; Kaifeng 1978; 1979; Zhongguo 1984). Other sites belonging to the Peiligang Culture with evidence of cultivated crops include for example Dingzhuang 丁庄, Shawoli 沙窝李, Wuluoxipo 坞罗西坡, and Fudian 府店 where grains of *Setaria italica* have been reported, and from Zhuzhai 朱寨, and Zhuzhai B, where both grains of *Setaria italica* and *Panicum miliaceum* have been reported, all dating to ca. the mid-sixth millennium BCE.[42] At both Cishan and Peilingang there is widespread presence of agricultural tools such as stone adzes, spades, hoes, sickles, mortars and pestles. These have been interpreted as indicators of agricultural activities, especially sickles have been linked to cereal harvesting at the ear, and mortar and pestle to grain dehusking practices. Further sites with evidence of early millet grains have been mapped along the Sushui River Valley (flowing into the Yellow River from the north), dating to fifth millennium BCE (Song, Wang, Fuller 2019).

Among Houli Culture sites (ca. 6000 BCE), which are mostly clustered in modern Shandong Province, macro-botanical remains of millet cultivation have been found at Yuezhuang 月庄, Xihe 西河, and Zhangmatun 张马屯.[43] Additionally, at Xiaojingshan 小荆山 stable carbon isotope ($\delta^{13}C$) data on human skeletons showed that millet consumption contributed to less than 25% of the overall dietary protein intake ($\delta^{13}C$ average value −17.8‰ ± 0.3‰; Hu et al. 2008). This type of study estimates dietary contribution of C_3/C_4 plants based on stable carbon isotopes values measured in human (and animal) bone collagen and thus allows for inferences of potential dietary composition and its changes through time, especially when coupled with macro-botanical remains and a background vegetation baseline, to gain insights into the available plant resources at the time.[44]

---

[42] Wu 1983; Song 2011; Zhu 2013; Cohen 1999; Liu, Hunt, Jones 2009; Lee et al. 2007; He et al. 2022a; Wang et al. 2017; Wang C. et al. 2018; Bestel et al. 2018.

[43] Crawford et al. 2013; 2016; Jin G.Y. et al. 2014; Wang 2013; Wu et al. 2013; Wu, Jin, Wang 2015.

[44] C_3 plants include rice, wheat, barley, most legumes and trees; C_4 plants include millets, sorghum, and maize. This categorisation is based on the different processes plants use to fix carbon during photosynthesis. On C_3, C_4 plants see Furbank, Taylor 1995; on the application of stable carbon isotopes to infer dietary changes in Archaeology see Parkington, Sealy, Merwe 1987; Merwe 1982; 1992; Boutton, Lynott, Bumsted 1991; Schoeninger 2014; Lightfoot, Liu, Jones 2018; Katzenberg, Waters-Rist 2019. For recent syntheses of stable isotope studies to infer human diets in China see Liu et al. 2021a; Liu, Reid 2020.

At the sites of Dadiwan 大地湾, Qin'an 1 秦安 1, Lixian (LX07) 礼县, and Huluhe 葫芦河 (ca. 6000-5000 BCE) broomcorn millets have been reported in association with stone spades.[45]

In Northeast China, millet grains (mostly broomcorn millet) have been reported from Xinglongwa Culture sites including at Xinglonggou 兴隆沟 (ca. 6200-5400 BCE; Zhao 2004b, 2011a; Qiu et al. 2023), Jiajiagou West 贾家沟西 (Fuxin 12D56), Nanwanzibei 南湾子北, and Tachiyingzi 塔尺营子 (Fuxin 12D16), dating to the late sixth millennium BCE (Shelach-Lavi et al. 2019; Sun 2021). Both foxtail millet and broomcorn millet grains have been found at Hamin Mangha 哈民忙哈 (Sun, Zhao, Ji 2016) and Zhaobaogou 赵宝沟 (Yuan, Sun 2019; Zhang, Sun 2022). At other Xinglongwa Culture sites, although millet grains were not found, the stone tool assemblages bear strong similarities with the sites mentioned above. This has been interpreted as indicative of a common cultivation technology tradition continuing into the successive millennia, until at least the fourth millennium BCE (Shelach-Lavi, Teng 2013).

Although millet grains have been recovered from numerous sites across broader northern China from the late seventh millennium BCE onward, at present there is a lack of conclusive evidence as whether this cereal was first domesticated in any of the regional areas outlined above and how possibly independent episodes contributed to the overall domestication of the crop. The available data supports that the domestication of millets happened over a protracted period of several millennia, and a case can be made on morphometric data for a continued increase in size in archaeological broomcorn millet grains from the seventh to at least the mid-fourth millennium BCE. This possibly attests that the domestication of the crop had fully happened by that time (Stevens et al. 2020; Stevens, Zhuang, Fuller 2024). A recent meta-data analysis of archaeobotanical reports of early archaeological millets has shown a shift from a predominantly broomcorn millet-based cultivation system for the sixth-fifth millennia BCE to a predominantly foxtail millet agriculture during the fourth millennium BCE (He et al. 2022a). This has been attested by the recovery of predominantly foxtail millet remains from sites in the Central Plains, including those located in the upper Yiluo River Valley (a tributary of the Yellow River; Lee et al. 2007; Zhang, Xia, Zhang 2014) and the middle and upper Ying River Valley (tributary of the Huai river flowing into Henan; see Fuller, Zhang 2007; Zhang et al. 2010). Foxtail millet was also the main staple crop during the foundation of the early Chinese states (Zhao 2011). Some scholars suggest that the predominance of broomcorn millet in the early Holocene was correlated to a drier climate, given the better adaptation of broomcorn millet to drought.[46] Others have also noted that foxtail millet is more common in eastern China, where there are wetter environmental conditions compared to interior regions, including Central Asia, where broomcorn millet is more predominant and has a bigger role for the species spread both westward and southward (Crawford et al. 2005; Lee et al. 2007; He et al. 2017). However, others have pointed out that, while during the wild collection stages *Panicum* grains would have provided greater yields than wild *Setaria* due to its higher grain weight (Stevens, Zhuang, Fuller 2024, 6, tab. 1), domesticated foxtail

---

[45] Liu, Kong, Lang 2004; Ji 2009; Bettinger et al. 2010; Barton et al. 2009.

[46] Feng, An, Wang 2006; Dodson, Dong 2016; He et al. 2022a; 2022b.

millet produces comparatively higher yields than broomcorn millet[47] due to greater changes in percentage of seed size increase and number of seeds per panicle. Greater yields derived from domesticated foxtail millet may have caused its predominance over broomcorn millet, as attested in the archaeological record from around 4300-3800 BCE (Stevens, Zhuang, Fuller 2024). In addition to macro-botanical evidence for grains, other scholars have noted an increase in the presence of stone 'harvesting knives' around the mid-fifth millennium BCE (Luo 2007). These are small implements characterised by a peculiar mostly half-moon or rectangular shape with holes in the middle. They are considered crop-reaping tools mostly used to harvest cereals at the ears (although other uses have also been attested ethnographically). These knives would be held with one hand and secured to the fingers through a rope going through the holes (these tools are in fact called by some scholars *xisheng shidao* 系绳石刀, corded stone knife; Luo, Li 2013). Such a use has been attested up to the 1990s among Miao people (Luo, Li 2013). Archaeologically they are a widespread find across East Asia (China, Korea and Japan) to northern India and Pakistan (Luo 2004). It has been suggested their use for harvesting millet would contribute to a predominance of non-shattering and enlarged panicle plants over time, thus contributing to the domestication of the plant (Stevens, Zhuang, Fuller 2024, 13). Finally, a synthesis of recent carbon isotope studies has highlighted the increasing importance of millet in human (and animal) diets in China over time and provides an additional line of evidence to investigate the timing and geography of the transition to an agricultural life in China (Liu et al. 2021a). It is worth pointing out that isotopic analyses are increasingly being undertaken at ancient sites across China and this may help complement and refine our understanding of early subsistence especially for those sites lacking plant remains.

2.4 Other Important Plants in Early Chinese Agriculture

2.4.1 Soybean – *Glycine max*

Soybean (*Glycine max*, *dadou* 大豆) today is the most cultivated legume worldwide, ranking among the top ten produced agricultural commodities in the last 30 years (FAOSTAT 2024). It is consumed for its seeds, for oil, and used in the production of other food products such as tofu (*doufu* 豆腐). Soybeans are planted in spring and sown before the end of the summer, have high-water requirements and a short growing season of less than three months **[tab. 5]**. Similarly to other legumes, soybeans are nitrogen fixing, meaning that, when cultivated, they compensate for potential losses of nitrogen in the soil, which can occur after the cultivation of cereals (Postgate 1998). For this reason, soybeans can be used as 'green manure', intercropped with other plants, usually cereals, in order to maintain soil nutrients balance (Zohary, Hopf, Weiss 2012). Interestingly, in many of the known agricultural centres in the world, cereals have been domesticated alongside legumes, which may indicate that legumes were in fact domesticated as a companion

---

[47] During the wild collection stages *Panicum* grains would have provided greater yields than wild *Setaria*, given its higher grain weight (Stevens, Zhuang, Fuller 2024, 6, tab. 1).

crop to cereals to compensate for soil nutrients losses derived from intensive cereal cultivation (He et al. 2022c).

Table 5 Main growing requirement of soybean. Sources: Yadav, Yadav 2002

Growing requirements	*Glycine max*
Water requirements	600-800 mm
Minimum temperature to germinate	10°C
Optimal temperature for flowering	25-30°C
Photoperiod sensitivity	Yes
Days to maturity	70-90 days
Yield/ Hectare	2 t/ha (modern)

The wild progenitor of soybean is *Glycine soja*,[48] a native species that occurs across many regions in East Asia. Given its widespread occurrence across several areas in East Asia and the scarcity of early archaeological material, there are still debates about when and where exactly soybean was domesticated. Genetic analyses have proposed often contradictory results, with some studies suggesting Japan as centre of origin (e.g., Jeong et al. 2018; Takahashi et al. 2023) and others China, either in the Yellow River Valley[49] or South China, based on high diversity in modern wild populations.[50] Interestingly, a disjunct wild population of soybean has been found in Southwest China (Dong et al. 2001), but at present it is unclear whether it contributed to the domestication of the crop. Although scholars have argued for multiple origins, with centres in China, Japan and Korea (e.g., Xu et al. 2002; Kim et al. 2012), at present the single origin is the most widely accepted theory, and a centre in the Yellow River Valley is supported by both higher genetic diversity compared to other areas in China as well as archaeological finds (Li et al. 2012; Lee et al. 2011).

Soybean, like other legumes, loses natural pod dehiscence when domesticated; however, given that pods rarely preserve archaeologically,[51] there are no reliable archaeobotanical methods to assess the non-shattering ability of legume pods. The main measurable trait to assess the domestication status of archaeological soybean has been seed size (Lee et al. 2011; Fuller et al. 2014; see also Fuller, Asouti, Purugganan 2011). Seed coat thinning has also been explored as a possible measurable trait in archaeological material (Murphy et al. 2019). Data from early sites in the Yellow River Basin have a clear trend of size increase during the fourth to third millennia BCE (Lee et al. 2011; Fuller et al. 2014). Possibly wild soybean remains have been reported from Jiahu (ca. 7000-6600 BCE; Zhao, Zhang

---

[48] Some scholars have suggested that soybean was domesticated from a *G. soja/G. max* complex that diverged from a common ancestor of these two *Glycine* species (Kim et al. 2010; Li et al. 2014).

[49] The Yellow River Valley was indicated as the homeland of domesticated soybean already by Li 1970. Archaeobotanical studies and proponents of this area include Dong et al. 2023; Li et al. 2008, 2010, 2012; Liu et al. 2020.

[50] Gai et al. 2000; Shimamoto et al. 2000; Dong et al. 2001; Wen et al. 2009; Guo et al. 2010.

[51] A paper available in pre-print at the time of writing has reported finds of charred soybean pods together with both wild (n=290) and domesticated (n=111) soybean seeds from Wangjinglou 望京楼, in Henan, dated to ca. 1600-1400 BCE (Tang et al. 2024). The authors argue that pod dehiscence develops earlier than increase in seed size, and retrieval of remains such as those from Wangjinglou might shed new light on the domestication of soybean. The pre-print is available at Research Square: `https://doi.org/10.21203/rs.3.rs-4571188/v1`.

2009), Baligang 八里岗 (6700-6500 BCE; Deng et al. 2015), and Bancun 班村 (6000-5000 BCE; Kong, Liu, and Zhang 1999). This evidence suggests that soybean may have been domesticated in northern China around the fourth millennium BCE; however, a larger dataset will be needed to confirm whether this is the result of primary, local processes or, for example, a secondary domestication of the crop following its spread from somewhere else, for example Japan.

2.4.2 Possible Minor Crops

2.4.2.1 Buckwheat – *Fagopyrum esculentum*, *Fagopyrum tartaricum*

Buckwheat (*qiaomai* 荞麦) belongs to the Polygonaceae family and for this reason is often referred to as a 'pseudo-cereal'. Of the 18 *Fagopyrum* species known globally, two are cultivated today in temperate regions: *Fagopyrum esculentum* (common buckwheat), and *Fagopyrum tartaricum* (Tartary buckwheat). These both have a short growing season (9-12 weeks) and a degree of tolerance to drought. Although they are most often cultivated during the summer, they can be cultivated in all seasons depending on the latitudinal belt of cultivation. Common buckwheat is usually grown at lower altitudes as it has no tolerance to frost, contrary of Tartary buckwheat, which is known to withstand low temperatures. Buckwheat is regarded as a suitable crop for marginal agricultural areas where other crops cannot successfully grow. Cultivations of Tartary buckwheat have been reported from as high as 4,500 m asl in some areas of the Himalayas in modern Nepal and among Drung (Dulong) villages in northwest Yunnan, where both buckwheat species were traditionally grown (Gros 2014; Luitel et al. 2017) **[tab. 6]**. Today, the main buckwheat producing countries are Russia, China, Ukraine, and Poland (Small 2017, tab. 1), however, buckwheat cultivation has declined in the past decades, mostly due to its erratic yields (e.g., Brunori et al. 2005; Pirzadah, Rehman 2021).

Table 6 Main growing requirements of buckwheat. Sources: Kalinova, Mouldry 2003; Oplinger et al. 1989; Luitel et al. 2017

Growing requirements	***F. esculentum***	***F. tartaricum***
Water requirements	100 mm	
Minimum temperature to germinate	5/7°C	
Optimal temperature for flowering	15-26°C	
Frost tolerance	No	Some
Days to maturity	70-90	
Yield/ Hectare	900 kg/ha (modern)	

Recent genetic studies on *Fagopyrum* landraces have individuated in *Fagopyrum esculentum* ssp. *ancestralis* the wild progenitor of common buckwheat, and in *Fagopyrum tartaricum* spp. *potanini* the wild progenitor of tartary buckwheat.[52] Such studies have also shown that the highest diversity in *Fagopyrum* landraces is found in Southwest China, where there

---

[52] Ohnishi 1991; 1998; Ohnishi, Matsuoka 1996; Fawcett et al. 2023; He et al. 2024.

are at least 16 endemic species, including both *esculentum*, *tartaricum* and their wild ancestors.[53] Of note, these are mostly localised at the crossroad of northwest Yunnan, southwest Sichuan, and eastern Tibet, in a rocky hilly area of only 250 km of radius.[54] This area has been proposed as the most likely region for the domestication of both species, although some recent linguistic studies implied that buckwheat was domesticated by East Bodish speakers of the Tibeto-Burman language family living in modern day Buthan, with domestication occurring around or after the first millennium BCE (Hyslop, d'Alpoim Guedes 2021). At present no archaeobotanical data is available to test this theory.

Archaeological evidence for buckwheat cultivation and use is limited. At present, the earliest evidence for Tartary buckwheat come from Chu-gong/Qugong 曲贡, Tibet, ca. 1400-1000 BCE (Gao et al. 2021). Archaeological seeds of common buckwheat have been reported from Xingyi 兴义 in central Yunnan, ca. 1800-1000 BCE (Ma et al. 2024) and Haimenkou, in northwestern Yunnan, ca. 1400-700 BCE (Xue et al. 2022). Seeds of buckwheat have also been reported from Zongzan 宗咱, dated by cultural association to the second-first millennia BCE (Li 2016) **[tab. 12]** and from Donghuishan 东灰山 (1600-1450 BCE; Wei 2019; Wei et al. 2020). For both species the earliest known macro-botanical remains are reported from Southwest China dating to the late second millennium BCE, which would support an origin of the crop from this region. However, a recent review of all instances of buckwheat remains, including macro-botanical remains, pollen and starch grains recovered from archaeological sites in China has highlighted that the majority of the reported remains come from both northern and southern China alike (Krzyzanska et al. 2021; Hunt, Shang, Jones 2017). This gives rise to seemingly contradicting theories regarding the domestication of the crop, with some scholars suggesting that the centre of domestication should be individuated in northern China around the fourth millennium BCE, based on pollen remains (Krzyzanska et al. 2021; Hunt, Shang, Jones 2017).

A few problems persist with this theory: the lack of unambiguous taxonomic identification, most finds are in fact reported as *Fagopyrum* sp., and the lack of possibility of direct dating of either pollen or starch grains, which doesn't allow confirmation of their antiquity. At present is not clear whether the pollen finds refer to human activity or natural depositional processes from nearby wild populations, since most of the finds reported come from off-sites locations (Hunt, Shang, Jones 2017).[55] A recent study on buckwheat pollen highlighted the difficulty of securely identifying pollen grains to species and distinguishing between wild and domesticated plants (Yao et al. 2022). The same study further highlighted an increase in pollen grains from sediments in Southwest China from the Holocene onward, suggesting that, in line with phylogenetic reconstruction and macro-botanical evidence, this region is a likely candidate for the domestication of this crop. The general lack of

---

[53] Ohnishi 2004; Ohnishi, Yasui 1998; Chauhan et al. 2010.

[54] Ohnishi, Yasui 1998; Ohnishi, Konishi 2001; Ohnishi, Tomiyoshi 2005; Konishi, Yasui, Ohnishi 2005; Konishi, Ohnishi 2007.

[55] Of note, similar conflicting evidence has been reported from Europe. Here, directly dated macro-botanical remains indicate an introduction of the crop in the Middle Ages (e.g., Rösch 1998; Brown et al. 2017), but pollen-based reconstruction suggested an introduction already in the Neolithic time (e.g., Janik 2002; Jones et al. 2011; Alenius, Mökkönen, Lahelma 2012; de Klerk, Couwenberg, Joosten 2015).

archaeological buckwheat remains from early periods across East Asia could also imply depositional processes that negatively impact the preservation and recovery of buckwheat, or simply that a more intensive use of the plant developed much later compared to other species. Based on charred macro-botanical remains, such as those from Qugong and Haimenkou, buckwheat was exploited from at least the late second millennium BCE in broader Southwest China,[56] but the lack of systematic morphological and morphometrical studies on ancient buckwheat grains, but most importantly, the general lack of ancient buckwheat remains makes it challenging to reconstruct the timing and region of early human use of this plant.

2.4.2.2 Barnyard Millet – *Echinochloa* sp.

Echinochloa (*bai* 稗) is an herbaceous millet-type plant within the Poaceae family. Globally, there exists at least 50 *Echinochloa* species, some annual and some perennial, usually summer growing and regarded as the toughest invasive weedy plants in the world. *Echinochloa* plants are able to survive and adapt extremely well to a wide range of different ecological conditions, from fully submerged (e.g., *E. crus-galli* var. *oryzoides* syn. *E. oryzoides* and *E. oryzicola*, obligate weeds of rice and rice mimics) to dry settings (Michael 2001). In Eurasia two species have sometimes been cultivated for either food or fodder: *E. frumentacea* (Indian sawa/mawa millet, also called Indian barnyard millet) and *E. esculenta* (syn. *E. utilis*, Japanese barnyard millet).[57] *E. frumentacea* is thought to be derived from *E. colona*,[58] and scholars generally agree that it was domesticated in South Asia, more specifically in the Indian peninsula. Today, cultivation of *E. frumentacea* can still be found in India, Pakistan and Nepal, as well as northwestern Yunnan among the Drung people (Gros 2014; Yabuno 1962; Fischer 1934). Ethnobotanical reports from these regions state this species is most often grown inter-cropped in mixed fields with other millet-type crops, including foxtail millet and finger millet (*Eleusine coracana*; De Wet et al. 1983). *E. crus-galli* is considered the wild progenitor of *E. esculenta* (Yabuno 1962; 1987; Yamaguchi et al. 2005). *E. crus-galli* is extremely tolerant and well-adapted to harsh and varying conditions and has been reported to survive up to 40 days in flooded conditions (Maun, Barrett 1986). This ability to thrive in submerged environments makes it amongst the most common infesting weeds of irrigated rice fields in East Asia. *E. esculenta* has been grown as an alternative to rice in high elevation areas of East Asia (above 2,000 m asl; Yabuno 1987). Today, cultivations of *E. esculenta* can still be found in the Korean peninsula, in Japan, in northern and southwestern China, especially in the province of Yunnan; however, the recent development of frost-tolerant rice is slowly contributing to the decrease of barnyard millet popularity in the region.[59]

---

[56] Gao et al. 2021; Xue et al. 2022; Weisskopf, Fuller 2014c; Boivin, Fuller, Crowther 2012.

[57] *Echinochloa* has a complex taxonomic history and a high degree of morphological similarities across species, causing persistence of scholarly debates regarding taxonomic identification and nomenclature of different species (e.g., Hoste, Verloove 2022). Throughout this book I refer to the potentially cultivated *Echinochloa* species in Asia as indicated in Hoste, Verloove 2022.

[58] Yabuno 1962; Yabuno 1966; Yamaguchi et al. 2005; Hoste, Verloove 2022.

[59] See Ye et al. 2009; Su et al. 2010; Pereira da Cruz et al. 2013; Ma Y. et al. 2015; Li et al. 2022.

Barnyard millet has a short growing season, reaching maturity in less than two months, and moderate water requirements, surviving with as little as 350-420 mm of annual precipitation **[tab. 7]**. *E. esculenta* is better adapted to colder temperatures than *E. frumentacea*. Given *Echinochloa*'s ability to grow in a variety of environments including in harsh conditions, there has been recent scholarly interest in the plant as a potential crop for the future (Sood et al. 2015).

Table 7 Main growing requirement of cultivated *Echinochloa* species. Sources: Muldoon, Peraaon, Wheeler 1982; Padulosi et al. 2009; Rojas-Sandoval, Acevedo-Rodríguez 2018

Growing requirements	***E. frumentacea*; *E. esculenta***
Water requirements	350-720 mm (optimal range 650-720 mm)
Minimum temperature to germinate	20°C
Optimal temperature for flowering	27-36°C
Frost tolerance	Some
Days to maturity	40-60
Yield/ Hectare	400-600 kg/ha (modern)

Ancient seeds of *Echinochloa* are sometimes reported from early archeological sites in East and South Asia, most often from Japan, China, and India. Archaeobotanical finds of *Echinochloa* are most often categorised as weed; however, in cases of retrieval of high quantities, scholars have suggested possible human exploitation or even cultivation. In India, archaeologically preserved seeds of *Echinochloa* have been reported from early Harappan sites in the northwest of the country, dating to the third millennium BCE (Murphy, Fuller 2016, 346; 2017). Additional finds have been reported from first millennium BCE South India and 100 BCE Sri Lanka (Cooke, Fuller, Rajan 2005; Cooke, Fuller 2015; Murphy et al. 2018). In Japan, scholars have suggested that barnyard millet has been cultivated since at least 4,000 years ago, and archaeological seeds have been reported from southwest Hokkaido. A morphometric study on these seeds revealed a 15% increase in their size by the second millennium BCE, which could possibly indicate a domestication process, or intensive human cultivation of this species.[60] Within China, reports of ancient *Echinochloa* are scarce. Macro-botanical remains mostly come from the southwestern region, including Yunnan (see § 4.3.1). Barnyard grass phytoliths and starches have been found on stone tools from ca. 7000 BCE Shangshan, in the lower Yangzi (Yang et al. 2015b); however, this could relate to general wild resources exploitation. At present, the scarcity of archaeological remains and the lack of morphological and morphometrical studies on ancient *Echinochloa* seeds hinders the possibility of clarifying the ancient history of cultivation of this plant.

2.4.2.3 Fat Hen/Lambsquarter – *Chenopodium album*

Chenopodium (*li* 藜) is a genus in the Amaranthaceae family (Chenopodioideae subfamily) of about 150-250 annual and perennial species, of which only *C. quinoa, C. pallidicaule*, *C. berlanderi* subsp. *nuttalliae*, and *C. album* have

---

[60] Crawford 2011b; Takase 2010; Crawford 2006; 1983.

economic value today (e.g., Risi, Galwey 1984). These are cultivated as leafy vegetable or grain crop (Joshi 1991). Among these, only *C. album* is native to most of Eurasia and northern Africa (the others being native to the American continent).[61] Today, *Chenopodium album* is cultivated in regions of East and South Asia but is otherwise considered a rather invasive dryland weed. Thanks to its high level of drought tolerance, it adapts well to harsh environmental conditions, surviving in arid and semi-arid regions. It is also known to survive at very high altitudes **[tab. 8]**, although it does not have frost-tolerance (Williams 1963).

Table 8 Main growing requirement of *Chenopodium album*. Sources: Williams 1963; Partrap 1985a

Growing requirements	***Chenopodium album***
Water requirements	400-1200 mm
Minimum temperature to germinate	10-15°C
Optimal temperature for flowering	15-20°C
Frost tolerance	None
Days to maturity	120
Yield/ Hectare	50 mil. seeds/ha
Photoperiod sensitivity	Yes

Ethnobotanical surveys in the late 1970s documented winter cultivations of *C. album* in small communities living in remote and isolated villages in the southern Himalayan region at altitudes as high as 3,650 m asl.[62] In northeastern India, *Chenopodium* seeds are used to make bread, gruel, and fermented beverages (Nesbitt 2005, 59). The Lu-k'ai tribe in highland Taiwan is known to collect and consume C. *album* both as greens and grain (Fogg 1983). In China, recent ethnobotanical surveys investigating modern wild plant exploitation have documented widespread collection of *C. album* for greens among Tibetan villages in southern Gansu, western Sichuan and southern Tibet, and among the Drung people in northwest Yunnan.[63] While Tibetan and Drung people participating in the study live in remote mountain villages and the collection of *C. album* may be motivated by the need of supplementing the diet with fresh vegetables, *C. album* has also been recorded as collected by ethnic Han farmers of maize, wheat and potatoes residing in mountain villages in southwestern Shaanxi. These farmers encourage the natural growth of the plant around their homestead by not applying herbicide on them (Kang et al. 2013). This suggests a widespread knowledge of the potential nutritional value of the plant and use in Chinese cuisine.

There are currently no known domestication studies focusing on *Chenopodium album* from archaeological material in Eurasia.[64] *C. quinoa*,

---

[61] Gremillion 2014 provides a review of the American chenops, including a botanical overview of the plant, a review of the archaeological evidence with discussion on domestication and current uses of the species in the American continent.

[62] Partap, Kapoor 1985a; 1985b; 1987; Partap, Joshi, Galwey 1998; Singh, Thomas 1978; Partap 1999.

[63] Malaisse et al. 2012; Boesi 2014; Kang Y.X. et al. 2014; Kang J. et al. 2016; Cheng Z. et al. 2022.

[64] The available studies discussing the evolution of the Eurasian *Chenopodium* species focus on the cytological and phylogenetic aspects of the species, for a summary see Ohri 2015.

which is considered an American relative to *C. album*, has been investigated more in depth and it is assumed that *C. album* would develop similar domestication traits; these include a more compact inflorescence, loss of natural seed shattering, a progressive thinning, lightning and smoothing of the seed coat and an increase in seed size (Gremillion 2014; Bruno 2006; see also Smith 1992 for studies on *Chenopodium berlanderi* in northeastern Americas).

Archaeological seeds of *C. album* are widely reported in archaeobotanical studies in China at sites dating as early as the seventh to the fifth millennia BCE onward,[65] and in India at sites dating to the Harappan Rojdi period (2500-1700 BCE; Weber 1989). In Europe *Chenopodium* grains have been reported from numerous prehistoric sites dating to between the sixth to fifth millennia BCE (Bakels 1979) and in a ceramic vessel found inside a house at the pre-Roman site of Gordin Hede in Denmark (Helbæk 1954). Ingested *Chenopodium* seeds were also recovered in the stomach of several 'peat bog bodies', such as the Tollund Man and the Grabaulle Man (ca. 400 BCE-400 CE; Helbæk 1959; 1960; 1961). The retrieval of seeds inside stomachs is a strong indication that the plant was consumed as food and that *Chenopodium* might have contributed to a greater extent to past diets that we assume today. However, the lack of morphological and morphometrical studies on ancient remains greatly limits our understanding of this plant in the past. Archaeobotanical reports rarely include morphometric or morphological data on archaeological *Chenopodium* grains, and the species is interpreted as possibly consumed only when retrieved in extremely high quantity or unambiguous food/ingested contexts such as those mentioned above from Europe.

2.4.3 Selected Fruits

2.4.3.1 Peach and Apricot – *Prunus persica* and *Prunus armeniaca*

Peach (*Prunus persica*, syn. *Amygdalus persica*, *tao* 桃) and apricot (*Prunus armeniaca,* syn. *Armeniaca vulgaris*, *xing* 杏)[66] are two Chinese native species within the Rosaceae family, Prunoideae subfamily, Prunus clade. Members of this clade (which count more than 400 species) include important economic fruits such as plums (*Prunus domestica* ssp.), Japanese plums (*P. salicina*), cherry plums (*P. cerasifera*), sloes (*P. spinosa*) and cherries (*P. cerasus*). Their evolutionary history is still somewhat poorly understood due to their high level of hydridisation, close morphological similarities, and wide range of phenotypic diversity, resulting in several, sometimes contradicting, taxonomic systems.[67] Archaeologically, the high degree of

---

[65] Yang et al. 2009; Gao 2021; Xue et al. 2022; Song et al. 2021.

[66] In the Flora of China (FoC) peach and apricot are referred to by the old nomenclature *Amygdalus persica* and *Armeniaca vulgaris*; this is sometimes still used in many Chinese publications. The Flora has been completely digitised and can be consulted at `http://www.efloras.org/flora_page.aspx?flora_id=2`.

[67] For a summary of recent proposed taxonomic systems see Shi et al. 2013, fig. 1; for classifications proposed on the combination of archaeological and modern materials, with a focus on Europe, see Körber-Grohne 1996; for a review on recent archaeological finds of peach, plums, and apricot and their routes of dispersal across Eurasia, see Dal Martello et al. 2023a.

morphological similarity among *Prunus* stones creates some ambiguity in species-level identification. As a result, in the archaeobotanical literature, many *Prunus* remains, especially when fragmented, are often identified only to the genus level (Dal Martello et al. 2023a). This may also result in misidentification of wild with domesticated species, further complicating the issue of tracing these fruits domestication trajectories.[68] Peaches and apricots are perennial, deciduous fruit trees that are now widely distributed in temperate regions across the world. When sown from seeds, they start producing fruits usually after three to five years of growth, with flowering and fruiting seasons in March-April and August-September, respectively (Bassi, Monet 2003). Some scholars have suggested that the management of fruit trees arose later than the cultivation of herbaceous perennials (such as cereals and legumes), due to the intrinsic, multi-year perspective required to obtain fruits. It has been inferred that such perspective only developed with urbanism and the establishment of land ownership and reliable exchange networks.[69] Establishing a domestication pathway for peach and apricot has been challenging, since the wild ancestors are yet unknown, possibly extinct (Lu, Bartholomew 2003; Yazbek, Oh 2013). An increase of the fleshy part of the fruit and sugar content differentiates domestic from wild species; however, this is almost impossible to trace archaeologically, since only the stones preserve. Fuller has recently suggested that an elongation of the fruit stone might be indicative of the domestication process (Fuller 2018); however, further studies are needed to confirm this.

Peach was thought to originate in Persia,[70] but recent phylogenetic analysis and archaeological evidence both point to a Chinese origin. The oldest stone peach fossils have been found in a pre-hominid context in Yunnan, dating to ca. 2.6 million years ago. These Pliocene stones were close in morphology and size to modern stones. This would indicate that the initial selection of this fruit was possibly driven by primates, which acted on stone size, and later human selection acted on varietal differentiation and fruit size (Su et al. 2015). Some wild peach varieties are documented in north China, and early Chinese texts have referred to this region as the centre of origin for this fruit (Keng 1973). At present early archaeological remains have been reported from South China only, especially from sites in the lower Yangzi basin. The oldest securely dated fossilised peach stones from archaeological sites come from storage pits at Kuahuqiao and Tianluoshan, dating to ca. 6000-5500 BCE, with some later examples from the Liangzhu Culture sites of Bianjiashan 卞家山, Maoshan, and Qianshanyang 钱山漾, dating to ca. 3300-2300 BCE. Morphometrical analyses on these revealed that Liangzhu Culture peach stones show a substantial increase in overall stone size compared to the Kuahuqiao and Tianluoshan remains (Zheng, Crawford, Chen 2014). This is in line with phylogenetic reconstructions indicating a division from a wild species in China around four thousand years ago (Cao et al. 2014). Outside of the lower Yangzi Basin, peach finds have been reported from Chengtoushan and Nanjiaokou 南交口 dating

---

68 See, for example, Wu et al. 2025 for a critical discussion on peach species.

69 Fuller, Stevens 2019; Janick 2005; Zohary, Hopf, Weiss 2012; Gross, Olsen 2010.

70 A Persian origin is suggested also in the scientific name, derived from Greek *malon persikon* and Latin *malum persicum*, translated in ‘Persian apple’. This is how the fruit was referred to by ancient Greek and Roman writers (Dal Martello et al. 2023a), a classification later adopted by nineteenth century botanists (e.g., Faust, Timon 1995).

to around 4200-3700 BCE which may indicate peach dispersed with rice (Jacques, Stevens 2024). Although some reports of peach presence in Korea date to as early as the fourth millennium BCE, a revaluation of the current evidence suggests caution since the chronology of those finds is unclear (Dal Martello et al. 2023a, 22).

Apricot's origin was placed by ancient Greco-Roman writers in the Caucasus, possibly the Fergana region in modern Uzbekistan.[71] Wild apricot populations today have been documented from eastern China to the Tianshan Mountains, and while some scholars still argue for a separate centre of domestication/diversification of apricots in the Fergana region (giving rise to European lineages; see Bourguiba et al. 2020; Decroocq et al. 2016), recent studies have instead suggested that it originated in China (Jacques, Stevens 2024; Fuller, Stevens 2019; Zheng, Crawford, Chen 2014). Here, archaeological remains currently predate those from Central Asia (Dal Martello et al. 2023a). Early apricot finds include those from Kuahuqiao, Jiahu, Jiajiagou West and Tachiyingzi in Liaoning Province (Shelach-Lavi et al. 2019), all dating to the fourth millennium BCE. A recent study summarising archaeological, archaeobotanical and linguistic data thus proposed a single domestication centre in China around 4000 BCE, after which the fruit dispersed westwards with millets and rice, and subsequently separated and went feral in Central Asia around 1000 BCE, and from there later dispersed to Europe (which would explain the more recent genetic split of European apricot lineages; see Jacques, Stevens 2024).

2.4.4 Agriculture Beyond Cereals: a Note on the Hypothesised Tropical Tuber-Based Agriculture in Southern China

Beyond the centre for millet domestication in North China, and the centre for rice domestication in the middle-lower Yangzi region (§ 2.3.1) **[fig. 6]**, some scholars have proposed an additional centre of agricultural origin in the Pearl River Valley of southern China, spanning Guangxi and Guangdong provinces, based on evidence suggesting the possible cultivation of vegetatively propagated plants (Zhao 2006; 2011).[72] Here, recent archaeobotanical investigations at cave and shell midden sites dating between ca. 8000-3000 BCE have retrieved remains of lotus roots (*Nelumbo nucifera*), taro (*Colocasia esculenta*), yam (*Dioscorea* spp.), sago-type palms (Aracaceae, *Caryota* sp.), and banana (*Musa* sp.), among other plants.[73] These have been identified based on phytoliths or starches, and based on this evidence some scholars have suggested that plants such as palms, roots, rhizomes, corms, and tubers may have been cultivated in this region before the introduction of cereal agriculture (ca. pre 2800 BCE). This view, however, is not widely accepted as the retrieval of such remains is not

---

[71] See for example Dioscorides *De Materia Medica*, where apricot is named *mailon/armeniacon* (Osbaldestone, Wood 2000), and Pliny the Elder *Naturalis Historia* and Columella *De Re Rustica,* where apricot is referred to as *pomum armeniacum/armeniaca arbor* (Rackham 1938-63; Harrison 1941-55). Similarly to peach, the Latin classification adopted in the nineteenth century reflected the view of a Caucasian origin (Dal Martello et al. 2023a).

[72] This theory has originally developed on previous hypothesis proposed by Li 1970.

[73] Zhongguo et al. 2003; Wan 2013; Yang et al. 2013; 2017; Zhang Y.K. et al. 2020; 2021; 2024; Zhang 2022a; Wang W. et al. 2024.

direct evidence that these were cultivated, but rather of their presence in the landscape. The collection of such resources in the wild is widely undertaken in tropical and subtropical regions around the world, and at present there are no morphological or genetic studies trying to understand whether remains from the above sites represent collection in the wild or cultivation. Debates about the extent of exploitation of these resources persist (Denham, Zhang, Barron 2018). These studies, however, clearly demonstrate groups of foraging communities inhabiting this region before the spread of cereal-based agriculture to the area and lay the basis for understanding the relationship between incoming farmers and pre-existing local populations in future studies.[74]

2.5 Non-Native Crops

2.5.1 Barley – *Hordeum vulgare* and Wheat – *Triticum aestivum*

Barley (*Hordeum vulgare*) and wheat (*Triticum* ssp.) are two cereals that originate in Southwest Asia and were introduced and successfully adopted into Chinese agriculture. Of the two, wheat is today extremely prevalent worldwide, ranking among the top three cultivated cereals in the world (after maize and rice; FAOSTAT 2024). Today there exists two seasonal (a winter and a spring) varieties of these crops; growing requirements differentiate based on seasonal variety rather than species, and water requirements are unchanged across species and varieties **[tab. 9]**. Winter varieties are sturdier, cold tolerant and need vernalisation (undergoing a period of frost when buried underground) in order to later germinate. Given this requirement, winter varieties take a much longer period between sowing and harvest compared to the spring varieties. Both crops have been domesticated as winter cereals, since this was the rainy season in their domestication homeland. The timing and place of evolution of spring varieties is still not fully understood. Early Chinese textual sources dating to the first millennium BCE describe different sowing times depending on the regions of China where the plants were cultivated. This led some scholars to suggest seasonal varieties had developed by at least the first millennium BCE, most likely in conjunction with the introduction of the species to the Tibetan Plateau, where the harsh winter conditions would not have allowed their cultivation (Liu et al. 2017; see Ch. 5).

---

[74] Studies focused on hunter-gatherers' specific subsistence and the transition to agriculture in South China include Zhang, Hung 2012; Deng et al. 2020; Wang, Jiang 2022.

Table 9 Comparing main growing requirements for winter and spring varieties of wheat (*T. aestivum*) and barley (*H. vulgare*). Sources: FAO 2024; Klepper et al. 1998

Growing requirements	Winter variety	Spring variety
Water requirements	450-650 mm	
Sowing	September-October	March-April
Minimum temperature to germinate	–7°C	4°C
Optimal temperature to flower	10-12°C	15-20°C (min. 12°C)
Days to maturity	180-250	100-130
Harvest	April-May	June-July
Yield/ Hectare	6-9t/ha (modern)	
Photoperiod sensitivity (changes in day lengths)	High	Low
Vernalisation required	Yes	No
Tolerance to frost	High (–20°C)	None

In the 1980s, after finds of wild barley populations in Tibet, some scholars suggested the plant was (also) domesticated on the Tibetan Plateau (e.g., Xu 1982; Ma et al. 1987). Recent genetic studies have demonstrated that genetic similarity between modern cultivated and wild barley on the Plateau derives from gene flow that occurred after the introduction of the domesticated plant from Southwest Asia to the Plateau, instead of a local domestication (e.g., Yang et al. 2008), but some scholars suggest this instead indicates a polyphyletic origin of the cultivated crop (Dai et al. 2012; 2014; Ren et al. 2013). The broader consensus is that barley was domesticated in Southwest Asia from *Hordeum vulgare* ssp. *spontaneum*.[75] At present, earliest conclusive evidence for domesticated barley has been reported from ninth millennium BCE with an increase in remains from the eighth millennium BCE onward (see Arranz-Otaegui, Roe 2023 for a recent review of the accumulated evidence). Domesticated barley differentiates from its wild progenitor by having a brittle (non-shattering) rachis, reduced seed dormancy, vernalisation, photoperiod sensitivity, and a general increase in seed size.

Several wheat species have been domesticated; these include einkorn (*Triticum monococcum*) and emmer (*T. turgidum* subsp. *dicoccum*, sometimes still referred to as *T. dicoccum* in the archaeobotanical literature), which chronologically are the first to be domesticated around the eighth/seventh millennium BCE in southwest Asia (Zohary, Hopf, Weiss 2012). Durum wheat (*T. turgidum* subsp. *durum*, sometimes referred to as macaroni wheat) evolved in Southwest Asia from emmer (Feldman, Kislev 2007). Bread wheat (*T. aestivum*) evolved from the hybridisation of durum wheat with the wild goatgrass *Aegilops tauschii* (Dvorak et al. 2012), although the exact region where it underwent this evolution is still unclear. Remains have been reported from modern day Turkey and Syria dating to around 6600-5800 BCE (Willcox 1996; Nesbitt, Caligari, Brandham 2001; Nesbitt 2002), and shortly after from southern Central Asia. Both durum and bread wheat are free-threshing (or naked) wheat species, meaning that they evolved a softer glume which detaches from the ripe grain with much more ease than in the hulled/threshing species and varieties, such as einkorn and

---

[75] Relevant literature is too numerous to fully cite here, readers are referred to Harlan, Zohary 1966; Zohary 1999; Allaby 2015; Arranz-Otaegui et al. 2016; Wang Y.L. et al. 2019; Arranz-Otaegui, Roe 2023.

emmer. Naked varieties are considered more desirable as they require less processing after harvest, thus reducing considerably work; however, by not having the protective barrier offered by the glumes, they are more prone to pests and diseases. According to present evidence only free-threshing wheat has ever been reported from early archaeological sites in China. Similarly to barley, with domestication wheat evolves a non-shattering rachis, reduced seed dormancy, and a general increase in seed size; for free-threshing varieties there is also a softening of the glumes, which considerably reduces grain processing times after harvest, but have the disadvantage of being more susceptible to pests. Barley also evolved naked varieties, which may have initially emerged in Southwest Asia by the Late Pre-Pottery Neolithic period (ca. 7000-6000 BCE; Fuller, Weisskopf 2020; Komatsuda et al. 2007). A recent study suggested that naked barley in Tibet may have evolved independently from that in Southwest Asia (Tang et al. 2025).

2.5.2 The Question of The Routes and Timing of Dispersal of Wheat and Barley to China

In China, reports of wheat and barley grains have been documented from archaeological sites in China dating to at least the third millennium BCE (e.g., Stevens et al. 2016; Deng et al. 2020; Zhou et al. 2020). How the two species dispersed to China has been a central topic in Chinese archaeological research for decades. Several routes have been proposed, including a northern route through the Inner Asian Mountain Corridor into Xinjiang, from where it possibly reached Central China either through the Hexi corridor or via Mongolia through Northeast China (e.g., Long et al. 2018), and a southern route along the southern Himalayan Mountains (e.g., Lister et al. 2018). Others have suggested the species might have dispersed individually via separate routes, based on the apparent absence of barley where early finds of wheat are documented **[figs 9-10]**.[76] According to proponents of the northern route, both species were transported by Central Asian pastoralists, which were using wheat and barley to supplement their diets (Betts 2019). In 2020, seeds of naked barley and free-threshing wheat were reported from Tongtian 通天 Cave, in the Altai Mountains of modern Xinjiang, and have been directly dated to ca. 3200 BCE and 3000 BCE, respectively (Zhou et al. 2020). At present, these are the earliest occurrence of both species in China **[figs 9-10]**.

---

[76] For the northern route see Kuzmina 2008; Frachetti et al. 2010; Dodson et al. 2013; Betts, Jia, Dodson 2014; Stevens et al. 2016; Long et al. 2018; Dong et al. 2017; Betts 2019; Zhou et al. 2020. For the southern route see Vishnu-Mittre 1972; Knörzer 2000; Liu et al. 2017; 2019; Lister et al. 2018. For separate routes see Flad et al. 2010; Liu et al. 2017; Deng et al. 2020.

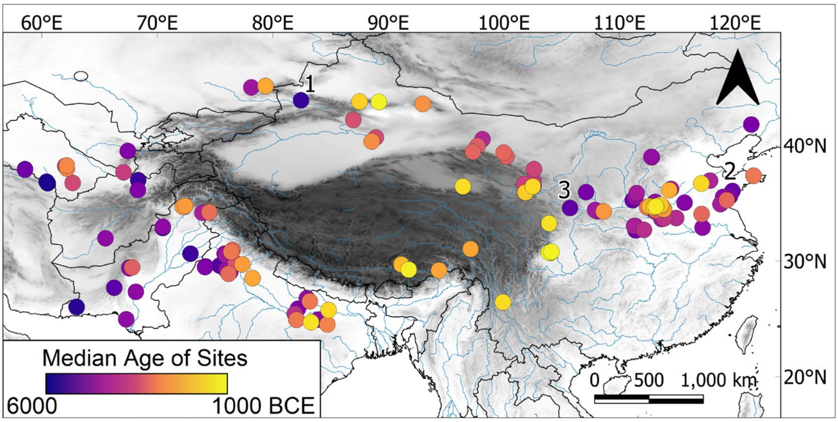

Figure 9 Sites with evidence of wheat before the second millennium BCE, plotted chronologically based on median age of occupation (see Appendix 2). Sites mentioned in text: 1. Tongtian cave; 2. Zhaojiazhuang; 3. Xishanping. Made by the Author with QGIS 3.28.5-Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

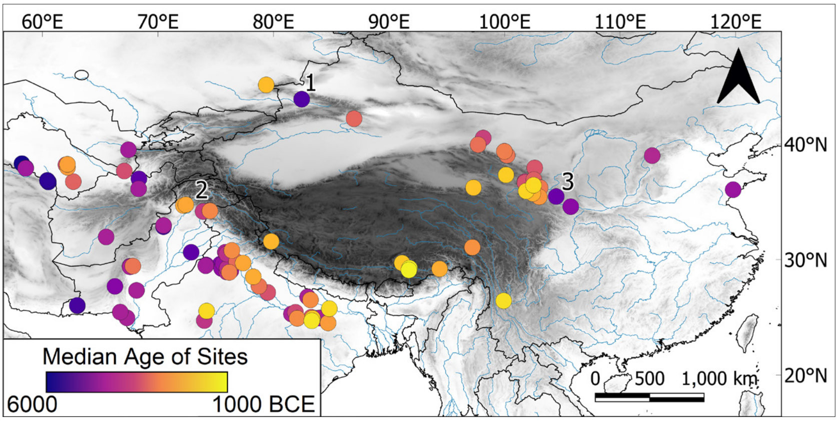

Figure 10 Sites with evidence of barley before the second millennium BCE, plotted chronologically based on median age of occupation (see Appendix 2). Sites mentioned in text: 1. Tongtian cave; 2. Kanispur; 3. Xishanping (AMS dating on rice grains). Made by the Author with QGIS 3.28.5-Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

Proponents of the southern and/or of separate routes for wheat and barley put forth their hypotheses on the basis of modern barley landraces genetic studies, and the direct dating of barley grains from Kanispur, in Kashmir (c. 2400-2200 BCE),[77] which, however, is still later than the recently reported grains from Tongtian cave. Although some earlier finds suggested the introduction of wheat into Central China dated to the fourth millennium BCE or possibly earlier, recent direct radiocarbon dating of these grains revealed they were intrusive from later phases (Deng et al. 2020). This raises doubts on building chronology of dispersal based on dating by cultural association rather than the direct dating of grains. At present the earliest attested evidence for wheat in the Central Plains date to no earlier than the late third millennium BCE, but even so seed numbers are low. A slight increase is seen only after ca. 1000 BCE, although the crop remained of minor importance until after the Han Dynasty (ca. early first millennium CE, see Deng et al. 2020). Within eastern China, the earliest directly dated wheat grain come from Zhaojiazhuang 赵家庄 and Dinggong in Shandong around 2200-1980 BCE, with some earlier grains dated by association to ca. 2400 BCE, which could indicate trade and exchange with agro-pastoral groups in the north (Jin et al. 2011a; Long et al. 2018). Figures 9 and 10 illustrates finds of wheat and barley across Central, South and East Asia from before the end of the second millennium BCE, with indication of the earliest directly dated evidence for the species in China.[78] It is worth noting that there still exist very large geographical gaps and, as evident from the recent report from Tongtian cave, new finds continuously refine and change these theories, thus only future research will be able to determine precise routes of dispersal of these crops to China. After their introduction to China, wheat seems to take a more prominent role than barley in the ancient agricultural practices of the Central Plains. Barley becomes predominant on the Tibetan Plateau, where other crops have much more difficulty growing (see Ch. 5).

---

[77] Pokharia et al. 2018; Liu et al. 2017; Lister et al. 2018 fig. 10 site 2; Zeng et al. 2015.

[78] Sites are mapped chronologically using the median date of the accepted chronology for each site, note that not all wheat and barley remains have been directly dated, and most of the sites have been dated by association or radiocarbon dating on other material. See Appendix 2.