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Origin and spread of wheat in China

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ABSTRACT

Wheat was added as a new crop to the existing millet and rice based agricultural systems of China. Here we present 35 radiocarbon ages from wheat seeds collected from 18 sites between western (Xinjiang Province) and eastern (Henan Province) China. The earliest wheat ages cluster around 2100–1800 BCE in northern China's Hexi corridor of Gansu Province, where millet was already a well-established crop. Wheat first appears in Xinjiang and Henan about 300–400 years later, and perhaps a little earlier than this in Xinjiang, and we hypothesize that the likely route of wheat into China was via Russia through Gansu.

1. Introduction

Rice, millet and wheat are the dominant crops in China. Millet and rice based agriculture originated in the Yellow and Yangtze valleys, respectively, in the early Holocene (Zhao, 1998; Jiang and Liu, 2006; Lu et al., 2009). Wild wheat strains were first used in the Fertile Crescent of southwest Asia in the Lateglacial (Belfer-Cohen and Goring-Morris, 2011) and domesticated wheat was widespread in that region by 8500 BCE (Before Common Era) (e.g. Bellwood, 2005), by which time use of wild starch foods had seemingly ceased there.

Common millet (*Panicum miliaceum*) occurs in China as a crop plant prior to 5000 BCE (Crawford, 2009; Lu et al., 2009), and in western Asia and Europe much later than this with either or both crop or weed status (Hunt et al., 2008). Some wheat remains from China date to as early as 2600–1600 BCE (Li et al., 2007; Flad et al., 2010) and this has led to speculation that the introduction of wheat and the broadening of agriculture may have been coincident with the introduction of metallurgy and domestication of several animals (Lee et al., 2007; Dodson et al., 2009). Indeed the broadening of agriculture may have been a major factor in the rise and development of the early phase of Chinese Civilisation. The early dates also confirm the age that an exchange of ideas and possibly people between West and East Asia occurred and currently this is at least 2000 years before the Silk Road trade routes were established. There is a growing body of research which establishes farming settlements in Iran, Afghanistan, and several former Soviet republics to the west of China (e.g. Francfort, 1989; P'yankova, 1994; Mallory, 1997; Mallory and Mair, 2000), and these were flourishing in the second millennium BCE but it is not clear how important wheat was as a crop.

Here we report on 35 AMS radiocarbon ages made directly on individual wheat grains from 18 sites across northern China between Xinjiang and Henan Provinces (Fig. 1). The sites were associated with archaeological settings with abundant pottery, bone, microliths, charcoal and sometimes bronze and slag showing they were living places of established communities. Zhou et al. (2012) provide evidence that the early sites were abandoned when agriculture caused land degradation and loss of productivity to support farming communities. While the focus of this paper is on the wheat grains, note is made of the associated archaeological settings.

2. Methods

Recent work using flotation techniques to collect botanical remains has greatly expanded knowledge on agricultural origins of millet and the rise of cropping areas in China (Zhao, 2011). Here we

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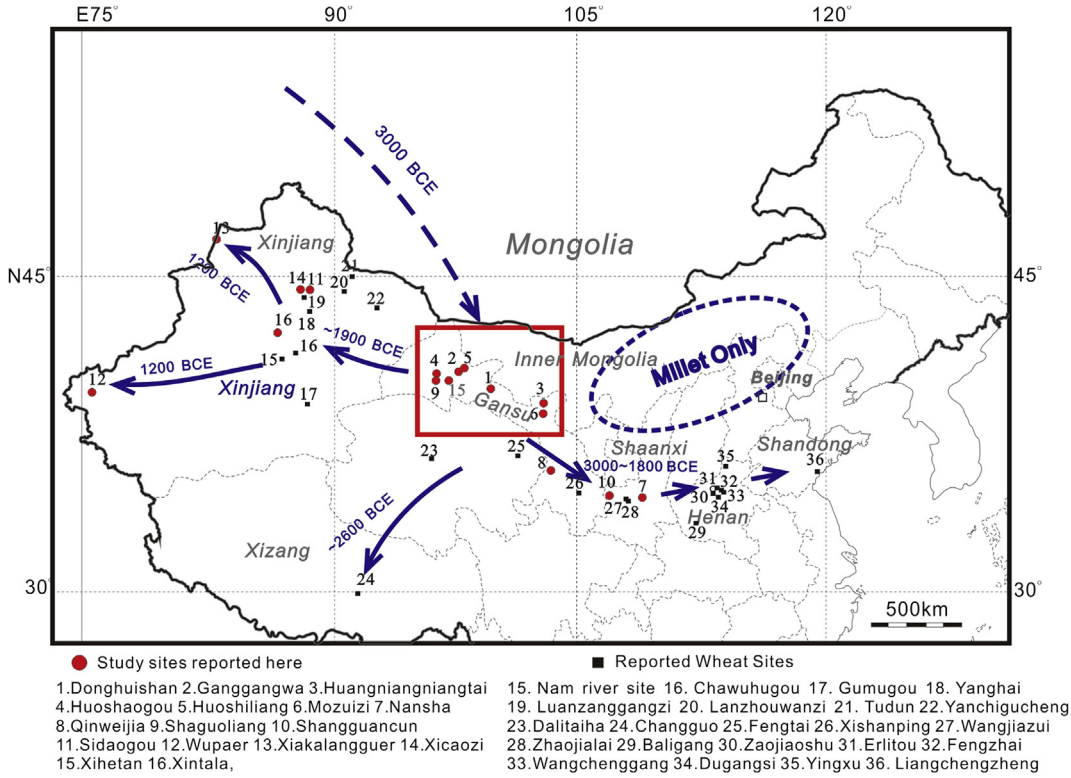

Fig. 1. Map showing location of places for collection of seed and charcoal for this study. The arrows map the hypothesis of the spread of wheat as outlined in this paper.

used dry sieving of about 500 g of sediment from pits adjacent to the archaeological settings. The seeds of wheat and other cereals were identified and transported to the Australian Nuclear Science and Technology Organisation (ANSTO) for AMS radiocarbon dating. Seeds other than wheat included millets and sometimes rice, and all wheat grains were identified as *Triticum aestivum* (bread wheat) as seems to be the case with all other wheat seeds identified from the Holocene in China.

Seeds for radiocarbon dating were washed in acid/alkali solutions and rinsed to neutral pH. They were then graphitised and stable carbon isotopes were measured on an Isotope Ratio Mass Spectrometer (GV Instruments *IsoPrime*) and radiocarbon was measured on the STAR and ANTARES accelerators at ANSTO. The results were converted to calibrated calendar ages by the Calib program (v6.0) with the IntCal09 calibration curve (Stuiver and Reimer, 1993; Reimer et al., 2009).

3. Results

The ages of the wheat grains are shown with 2σ age ranges in Table 1 and Fig. 1. The Table lists associated cultures based largely on associated pottery in the locations published in the Xinjiang Cultural Gazetteers Editorial Committee (2007) and by the State Administration of Cultural heritage (2003; 2011). Most of these sites have not been examined in detail by archaeologists, and the cultures by and large are currently described by location (or even undescribed in one case). Wheat seeds in Xinjiang Province in western China had ages in the range from 2006 to 427 BCE. Seeds from Gansu/Qinghai provinces had ages between 2135 and 1633 BCE while wheat from Shaanxi sites ranged between 1883 and 1030 BCE. The most easterly sites examined in Henan had wheat seed ages between 1663 BCE and 1251 CE. Fig. 2 shows the relative abundance of seeds identified from selected sites, and these are based on identifications from 100 to 300 seeds. These data demonstrate that millet dominates in sites Huoshiliang, Ganggangwa, Huangniangniangtai and Mozuizi and wheat (*Triticum*) dominates in sites Donghuishan, Shaguoliang and Huoshaogou.

4. Discussion

Flad et al. (2010) reported wheat seed ages between 1687 and 1126 BCE from Gansu to Henan, while Li et al. (2007) described a charcoal date associated with wheat at about 2650 BCE from Xishanping in Shaanxi. Lee et al. (2007) noted that wheat became a significant crop in the Yiluo valley in Henan between 1600 and 1300 BCE, with a wheat age of 1410–1126 BCE. The earliest dates on wheat seeds reported by Flad et al. (2010), and the here-reported earliest dates for sites in Xinjiang, Shaanxi and Henan, fall in the first half of the second millennium BCE. Wheat seeds from Gansu – at Huoshiliang, Donghuishan and Muozuizi sites – are significantly older than this, but are not as old as the charcoal date associated with wheat reported by Li et al. (2007) from Xishanping.

From the seed abundance diagram (Fig. 2) it is clear that wheat is a minor component, with less than a few percent of the counts compared to over 95% for millets at the oldest sites (Huoshiliang and Ganggangwa), wheat is absent at sites such as Xihetan and Mozuizi which are completely dominated by millet, but wheat is abundant to co-dominant in some sites with ages of about 1800 BCE or younger (e.g. Donghuishan, Shaguoliang and Huangniangniangtai). This suggests that wheat was introduced into regions where millet was already well-established as the dominant crop, and it gradually expanded in importance.

These data confirm that the earliest dates for wheat in China (older than 2000 BCE) appear to be relatively widespread with the oldest ages in Gansu in the Huoshiliang and Gangangwa area. These are ancient agro-pastoral sites that were surrounded by woodland species, and were apparently abandoned when the surrounding woody fuel reserves were spent (Li et al., 2011; Zhou et al., 2012).

Table 1
Radiocarbon ages of cereal seeds from north and northwest China. The calibrated age ranges are given as BCE or CE (before common era or common era). The archaeological setting is based some earlier survey work (bracketed numbers refer to references below).

Site	Archaeological setting reference	Lab no.	$\delta^{13}C$	Radiocarbon age	Cal age (2σ range)
Wupaer	Wupaer culture[a]	OZL443	−23.4 ± 0.4	2497 ± 36	788–418 BCE
Wupaer	Wupaer culture[a]	OZK661	−23.0 ± 0.1	2540 ± 50	808–427 BCE
Wupaer	Wupaer culture[a]	OZK660	−23.1 ± 0.1	2595 ± 50	892–542 BCE
Wupaer	Wupaer culture[a]	OZL442	−24.5 ± 0.1	2856 ± 40	1189–910 BCE
Wupaer	Wupaer culture[a]	OZL441	−23.3 ± 0.1	3155 ± 39	1508–1318 BCE
Xintala	Xintala culture[a]	OZM451	−25.3	3435 ± 35	1879–1641 BCE
Xintala	Xintala culture[a]	OZK663	−23.7 ± 0.1	3430 ± 50	1883–1622 BCE
Xintala	Xintala culture[a]	OZK662	−23.3 ± 0.1	3435 ± 50	1884–1626 BCE
Xintala	Xintala culture[a]	OZL437	−22.4 ± 0.1	3515 ± 50	2006–1694 BCE
Xicaozi	Undescribed	OZM674	−22.8 ± 0.3	2975 ± 45	1375–1051 BCE
Sidaogou	Sidaogou[a]	OZK664	−22.5 ± 0.1	3030 ± 50	1411–1129 BCE
Sidaogou	Sidaogou[a]	OZK665	−23.4 ± 0.1	3080 ± 60	1493–1132 BCE
Donghuishan	Siba culture[b]	OZK655	−24.2 ± 0.1	3425 ± 40	1878–1627 BCE
Donghuishan	Siba culture[b]	OZK654	−23.7 ± 01	3405 ± 50	1879–1538 BCE
Donghuishan	Siba culture[b]	OZK656	−23.6 ± 01	3410 ± 50	1881–1541 BCE
Donghuishan	Siba culture[b]	OZK653	−24.8 ± 0.1	3260 ± 45	1635–1433 BCE
Ganggangwa	Siba culture[b]	OZK658	−23.2 ± 0.1	3558 ± 47	2026–1759 BCE
Huoshiliang	Siba culture[b]	OZK603	−24.3 ± 0.1	3636 ± 44	2135–1895 BCE
Mozuizi	Majiayao culture/Machang type[b]	OZK667	−23.9 ± 0.1	2115 ± 50	356–0 BCE
Shaguoliang	Siba culture[b]	OZK669	−24.4 ± 0.1	3390 ± 50	1874–1531 BCE
Shaguoliang	Siba culture[b]	OZK668	−23.3 ± 0.1	3450 ± 60	1920–1618 BCE
Huangniangniangtai	Qijia culture[b]	OZK416	−25.0	529 ± 102	1274–1632 CE
Huangniangniangtai	Qijia culture[b]	OZK418	−23.7	3570 ± 60	2043–1746 BCE
Dadiwan	Majiayao culture[b]	OZK645	−22.1 ± 0.1	1080 ± 45	832–1030 CE
Huoshaogou	Qijia culture[b]	OZK670	−22.7 ± 0.1	1640 ± 60	255–548 CE
Huoshaogou	Qijia culture[b]	OZK671	−21.1 ± 0.1	2495 ± 45	787–417 BCE
Huo shao gou	Qijia culture[b]	OZK672	−23.7 ± 0.1	3430 ± 50	1883–1622 BCE
Qiaocun	Qijia culture[b]	OZK675	−22.2 ± 0.1	885 ± 45	1031–1251 CE
Shangguancun	Shang dynasty[c]	OZL434	−23.7 ± 0.1	1320 ± 39	649–773 CE
Koujia	Song dynasty[c]	OZM466	−26.8	1480 ± 30	541–642 CE
Donggao	Zhou dynasty[c]	OZM464	−23.1 ± 0.1	960 ± 35	1017–1159 CE
Donggao	Zhou dynasty[c]	OZM463	−27.0	2850 ± 35	1122–919 BCE
Nansa	Shang dynasty[c]	OZM459	−24.8	3260 ± 35	1618–1450 BC
Nansa	Shang dynasty[c]	OZM460	−26.9	3275 ± 30	1626–1461 BC
Nansa	Shang dynasty[c]	OZM458	−22.9 ± 0.1	3300 ± 30	1663–1501 BC

[a] Xinjiang Cultural Gazetteers Editorial Committee (2007).
[b] State Administration of Cultural Heritage (2011).
[c] State Administration of Cultural Heritage (2003).

There is not a great difference in the oldest ages measured either west or east of Gansu, although a single date from Xinjiang (Xintala 2006–1694 BCE) is slightly younger than the oldest from Gansu, and significantly younger than the age of wheat identified at Xishanping. We hypothesize that wheat based agriculture arrived in established millet growing regions of Gansu in east Asia via Russia or Mongolia before 3000 BCE, and its use as a crop expanded regionally and then east and west of there over 300–400 years (Fig. 2). However, more work is needed, most particularly in Xinjiang to confirm the one early age, and to check if our hypothesis of earliest wheat in China from Gansu is a robust one.

A shift in agricultural practice from millet to wheat and millet in northern China at about 2000 BCE may have been driven by climate change and necessity. Yang et al. (2010) and Yang et al. (2011) have

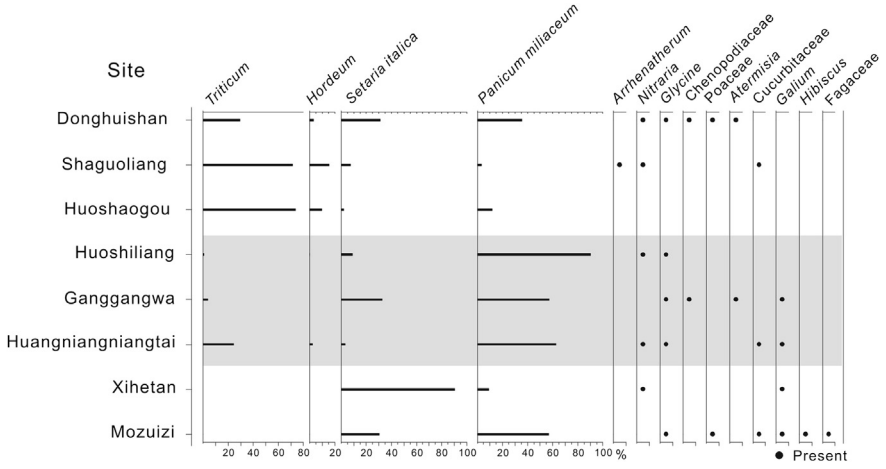

Fig. 2. Relative abundance of seeds identified in selected sites. These are based on minimum counts of 100 seeds.

recently studied and reviewed the climate and hydrological history of the Gansu and Qinghai regions, and concluded that a drying trend occurred across these regions from about 4000 years ago and persisted for at least the next 3500 years. The greatest expansion of lakes in the Badain Jaran Desert were in the Qijia Cultural period (2400–1900 BCE). This may well have favoured those groups who chose wheat as a crop to add to millet, especially those carrying out cropping away from the main rivers.

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References

Belfer-Cohen, A., Goring-Morris, A.N., 2011. Becoming farmers: the inside story. Current Anthropology 52 (S4), S209–S220.
Bellwood, P., 2005. First Farmers: the Origins of Agricultural Societies. Blackwell Publishing, Oxford.
Crawford, G., 2009. Agricultural origins in north China pushed back to the Pleistocene–Holocene boundary. Proceedings of the National Academy of Science USA 106, 7271–7272.
Dodson, J., Li, X., Ming, J., Zhao, K., Zhou, X., Levchenko, V., 2009. Early Bronze in two archaeological sites in Gansu, NW China. Quaternary Research 72, 309–314.
Flad, R., Li, S., Wu, X., Zhao, Z., 2010. Early wheat in China: results from new studies at Donghuishan in the Hexi Corridor. The Holocene 20, 955–965.
Francfort, H.-P., 1989. Fouilles de Shortughai. Recherches sur L'Asiae Centrale Protohistorique. Boccard, Paris.
Hunt, H.V., Vander Linden, M., Liu, X., Motuzaeciciute, G., Colledge, S., Jones, M.K., 2008. Millets across Eurasia: chronology and context of early records of the genera *Panicum* and *Setaria* from archaeological sites in the Old World. Vegetation History and Achaeobotany 17 (Suppl. 1), S5–S18.
Jiang, L., Liu, L., 2006. New evidence for the origins of sedentism and rice domestication in the Lower Yangtze River, China. Antiquity 80, 355–361.
Lee, G.A., Crawford, G.W., Liu, L., Xingcan, C., 2007. Plants and people from the early Neolithic to Shang periods in North China. Proceedings of the National Academy of Science USA 104, 1087–1092.
Li, X., Dodson, J., Zhou, X., Zhang, H., Masutomoto, R., 2007. Early cultivated wheat and the broadening of agriculture in Neolithic China. The Holocene 17, 555–560.
Li, X., Sun, N., Dodson, J., Ji, M., Zhao, K., Zhou, X., 2011. The impact of early smelting on the environment of Huoshiliang in Hexi Corridor, NW China, as recorded by fossil charcoal and chemical elements. Palaeogeography, Palaeoclimatology, Palaeoecology 305, 329–336.
Lu, H., Zhang, J., Liu, K.B., Wu, N., Li, Y., Zhou, K., Ye, M., Zhang, T., Zhang, H., Yang, X., Shen, L., Xu, D., Li, Q., 2009. Earliest domestication of common millet (*Panicum miliaceum*) in East Asia extended to 10,000 years ago. Proceedings of the National Academy of Science USA 106, 7367–7372.
Mallory, J.P., 1997. Afanasevo culture. In: Encyclopedia of Indo-European Culture. Fitzroy Dearborn Publishers, London and Chicago.
Mallory, J.P., Mair, V.H., 2000. The Tarim Mummies: Ancient China and the Mystery of the Earliest Peoples from the West. Thames & Hudson Press, London.
P'yankova, L., 1994. Central Asia in the Bronze Age: sedentary and nomadic cultures. Antiquity 68, 355–372.
Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Burr, G.S., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., McCormac, F.G., Manning, S.W., Reimer, R.W., Richards, D.A., Southon, J.R., Talamo, S., Turney, C.S.M., van der Plicht, J., Weyhenmeyer, C.E., 2009. INTCAL09 and Marine 09 radiocarbon age calibration curves, 0–50,000 years cal BP. Radiocarbon 51, 1111–1150.
State Administration of Cultural Heritage, 2003. Chinese Cultural Heritage Atlas: Shaanxi Province (Fascicule). Xi'an Atlas Press, Xi'an (in Chinese).
State Administration of Cultural Heritage, 2011. Atlas of Chinese Cultural Relics: Gansu Province (Fascicule). Surveying and Mapping Press, Beijing (in Chinese).
Stuiver, M., Reimer, P.J., 1993. Extended ^{14}C database and revised CALIB radiocarbon calibration program. Radiocarbon 35, 215–230.
Xinjiang Cultural Gazetteers Editorial Committee, 2007. Provincial Gazetteers of Xinjiang: Cultural Heritage Gazetteers. Xinjiang People's Publishing House, Urumqi (in Chinese).
Yang, X., Scuderi, L.A., 2010. Hydrological and climatic changes in deserts of China since the late Pleistocene. Quaternary Research 73, 1–9.
Yang, X., Scuderi, L., Paillou, P., Liu, Z., Li, H., Ren, X., 2011. Quaternary environmental changes in the drylands of China – a critical review. Quaternary Science Reviews 30, 3219–3233.
Zhao, Z., 1998. The middle Yangtze region in China is one place where rice was domesticated: phytolith evidence from the Diaotonghuan cave, northern Jiangxi. Antiquity 72, 885–897.
Zhao, Z., 2011. New archaeobotanic data for the study of the origins of agriculture in China. Current Anthropology 52 (S4), S295–S306.
Zhou, X., Li, X., Dodson, J., Zhao, K., Atahan, P., Sun, N., Yang, Q., 2012. Land degradation during the Bronze Age in Hexi corridor (Gansu, China). Quaternary International 256, 42–48.