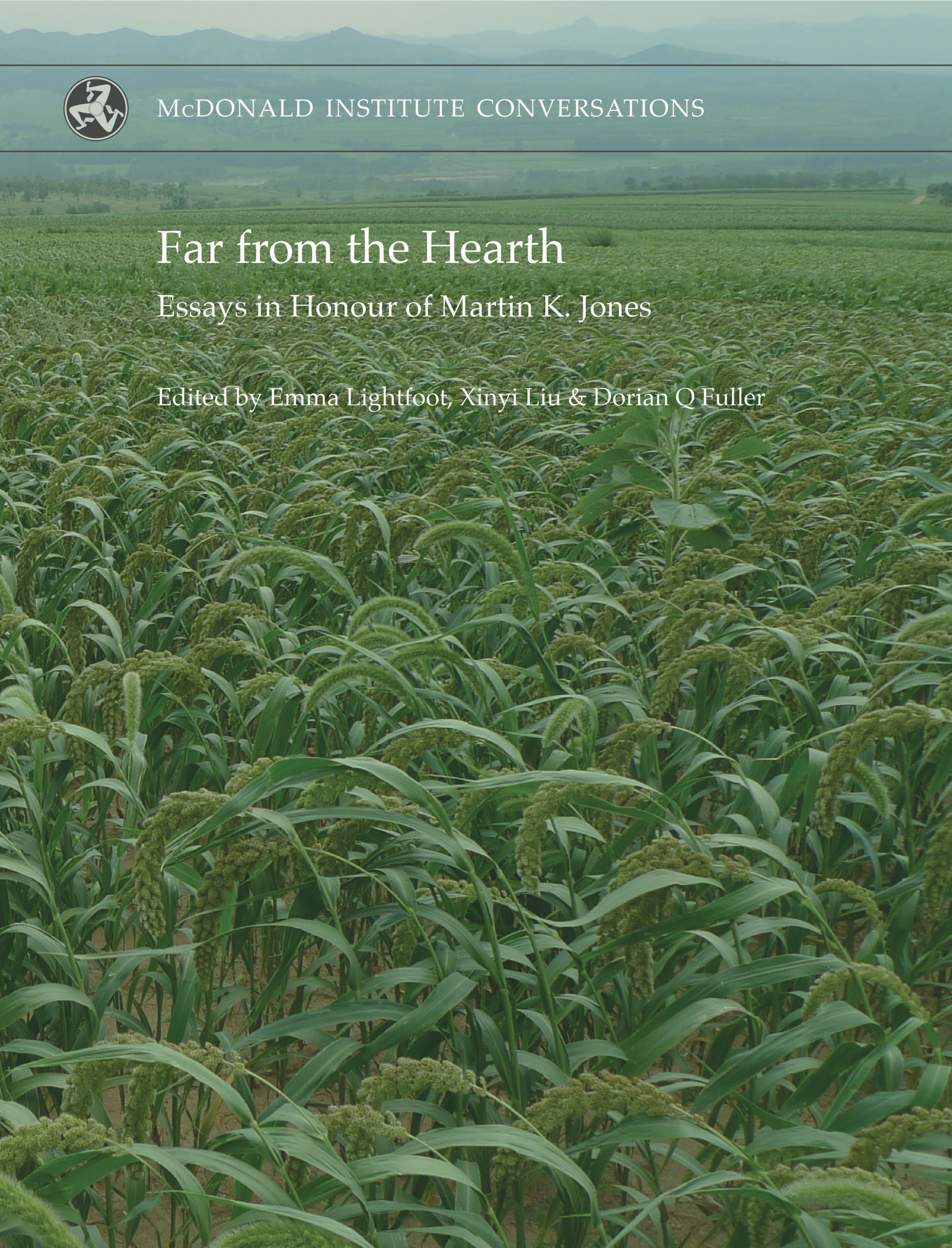
McDONALD INSTITUTE CONVERSATIONS

# Far from the Hearth

## Essays in Honour of Martin K. Jones

Edited by Emma Lightfoot, Xinyi Liu & Dorian Q Fuller



Far from the Hearth

*(Above) Martin Jones at West Stow, 1972 (with thanks to Ian Alister, Lucy Walker, Leonie Walker, and West Stow Environmental Archaeology Group); (Below) Martin Jones in a millet field, Inner Mongolia, 2010. (Photograph: X. Liu.)*

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Cover image: *Foxtail millet field near Xinglonggou, Chifeng, China, photographed by Xinyi Liu, September 2014.*

Edited for the Institute by James Barrett (*Series Editor*) and Anne Chippindale.

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## Figures

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# Acknowledgements

The initial idea of editing this volume grew out of a conversation between Xinyi Liu and Graeme Barker at St John's College, Cambridge in June 2016. The editors subsequently discussed the provisional layout of the volume. By April of the following year, our list of agreed contributors was complete. Abstracts followed, and the chapters themselves soon after. First of all, the editors would like to pay tribute to our 36 authors, whose excellent work and timely contributions made it all possible.

For the last two-and-a-half years, the volume has been known as 'Fantastic Beasts' in order to keep it a secret from Martin. As we enter the final stage, we wish to extend our thanks to all who have ensured Martin remains blissfully unaware, including Lucy Walker, and we offer her our sincere thanks. We are extremely grateful to Harriet Hunt, Diane Lister, Cynthia Larbey and Tamsin O'Connell, who are kindly organizing the gatherings to mark Martin's retirement and the publication of this volume.

With respect to the volume's production, we would like to thank the McDonald Institute for Archaeology Research for financial support. The McDonald Monograph Series Editor James Barrett oversaw and encouraged all aspects of this project, and we offer him sincere thanks. We would also like to acknowledge the support of Cyprian Broodbank, not least for allowing us to host the workshop at the institute, but also for his encouragement throughout all phases of the volume's implementation. Particular thanks must go to several key individuals: Anne Chippindale, Ben Plumridge, Emma Jarman, Simon Stoddart and Samantha Leggett. Finally, we are also grateful to the anonymous reviewers who recommended changes that have greatly enhanced the final version of this volume.

*Xinyi Liu, Emma Lightfoot and Dorian Fuller*
*August 2018*

# *Foreword*

The 28-year term of Martin Jones as the first George Pitt-Rivers Professor of Archaeological Science witnessed, and in part created, a transformation in the fields of environmental and biomolecular archaeology. In this volume, Martin's colleagues and students explore the intellectual rewards of this transformation, in terms of methodological developments in archaeobotany, the efflorescence of biomolecular archaeology, the integration of biological and social perspectives, and the exploration of archaeobotanical themes on a global scale. These advances are worldwide, and Martin's contributions can be traced through citation trails, the scholarly diaspora of the Pitt-Rivers Laboratory and (not least) the foundations laid by the Ancient Biomolecules Initiative of the Natural Environment Research Council (1989–1993), which he chaired and helped create. As outlined in Chapter 6, Martin's subsequent role in the bioarchaeology programme of the Wellcome Trust (1996–2006) further consolidated what is now a central and increasingly rewarding component of archaeological inquiry. Subsequently, he has engaged with the European Research Council, as Principal Investigator of the Food Globalisation in Prehistory project and a Panel Chair for the Advanced Grant programme. As both practitioner and indefatigable campaigner, he has promoted the field in immeasurable ways, at critical junctures in the past and in on-going capacities as a research leader.

The accolades for Martin's achievements are many, most recently Fellowship of the British Academy. Yet it is as a congenial, supportive—and demanding—force within the Pitt-Rivers Laboratory that the foundations of his intellectual influence were laid. Here, each Friday morning, the archaeological science community would draw sticks to decide who would deliver an impromptu research report or explore a topical theme. Martin is among the most laid-back colleagues I have worked with, yet simultaneously the most incisive in his constructive criticism. As a provider of internal peer-review he was fearless without being unkind. The themed Pitt-Rivers Christmas parties were equally impactful—on one occasion Alice Cooper appeared, looking ever so slightly like our professor of archaeological science.

Martin's roles as a research leader extended to several stints as head of the Department of Archaeology, chairing the Faculty of Archaeology and Anthropology and serving as a long-term member of the Managing Committee of the McDonald Institute for Archaeological Research. Having started his professional career as an excavation-unit archaeobotanist in Oxford, he was a long-standing proponent of the highly successful Cambridge Archaeological Unit. In the wider collegiate community, he is a Fellow (and was Vice-Master) of Darwin College and was the staff treasurer of the Student Labour Club. In all roles he fought valiantly and often successfully for the interests of his constituency. His capacity to fight for deeply held priorities while recognizing the value of diverse perspectives was of utmost importance. His nostalgic enthusiasm for the debate with archaeological science that was engendered by the post-processual critique is one signal of an underlying appreciation of plurality. His active support for the recent merger of the Divisions of Archaeology and Biological Anthropology, within our new Department of Archaeology, is another. As a scientist (Martin's first degree, at Cambridge, was in Natural Sciences) he values the peer-reviewed journal article above all scholarly outputs, yet has authored as many highly regarded books as a scholar in the humanities. His *Feast: Why humans share food* has been translated into several languages and won Food Book of the Year from the Guild of Food Writers. He views academia and society as a continuum, campaigning for archaeobotanical contributions to global food security (e.g. by promoting millet as a drought-resistant crop) and working with world players such as Unilever to encourage archaeologically informed decisions regarding food products.

That Martin's achievements and influence merit celebration is clear. That his colleagues and students wish to honour him is equally so. Yet does the McDonald Conversations series publish *Festschriften*? This is a semantic question. As series editor I am delighted to introduce a collection of important papers regarding the past, present and future of archaeobotany, representing its methodological diversity and maturity. That this collection concurrently pays respect to a treasured colleague is a very pleasant serendipity.

*Dr James H. Barrett*

# *Part IV*
# Between Fertile Crescents

# Chapter 13

# From a Fertile Idea to a Fertile Arc: The Origins of Broomcorn Millet 15 Years On

Xinyi Liu, Giedre Motuzaite Matuzeviciute & Harriet V. Hunt

'I've always thought the best thing to do with festschrifts was to air something too speculative to get in a refereed journal, so that one worked well.'

(Martin K. Jones)

## Introduction

In 2004, in a chapter contributed to Colin Renfrew's festschrift, which Martin Jones edited, he drew attention to the relationship between research projects and research questions: 'Research projects typically proceed by posing a question, and working in a systemic manner towards finding its answer. Collectively, however, the whole constellation of research projects within a discipline depends upon a converse process. Some scholars begin with a tentative answer, drawn from a wealth of experience, insight and guesswork, and pressing questions, which go on to drive research' (Jones 2004, 127). In the past decades, Martin Jones has played that role in asking new questions that offered opportunities to generate diverse research projects and to steer the direction of future archaeological enquires. This is particularly the case for the broomcorn millet (*Panicum miliaceum*) question (Jones 2004): whether it was domesticated once in North China, or multiple times across Eurasia.

The millet question first arose in the 1970s when Jones was surveying British crops between 500 BC and AD 500 (Jones 1981). A noteworthy feature was that the British record lacked a crop, broomcorn millet, that recurred on the neighbouring countries of the European mainland. At that period, the absence from Britain was the exceptional feature, rather than its presence in Europe. In the next few decades the presence of millet in much earlier European records emerged, provoking the key question that Jones spelled out in the seminal 2004 paper: 'Any western domestication of broomcorn millet would presumably have been very early, and comparable in age certainly with the date from the eastern Fertile Crescent [*c*. 6000–5000 BC], and possibly the western Fertile Crescent [*c*. 10000–8000 BC]. It may indeed be that the two regions begin to join up' (Jones 2004, 132). By 'eastern fertile crescent', he meant the Early Neolithic sites in the Yellow River region. It became clear later that a series of foothill locations along the eastern edge of the Loess Plateau played a key role in early millet cultivation, forming 'China's Fertile Arc' (Liu *et al*. 2009; Ren *et al*. 2016).

## The context in 2004

Early discussions on East–West interconnections in prehistoric Eurasia focused primarily on the inter-continental exchange of material cultures. By 2004, much had been debated about the dispersal of metallurgical technologies, the horse and horse management, among other material traditions, from the West to East Asia (Levine 1999; Mei 2003; Mei & Shell 1998; Olsen 2003). It was suggested that the cultural separation of East and West began to break down around the middle of the second millennium BC (Sherratt 2006). Before this date, societies in the eastern and western parts of Eurasia were largely mutually isolated. Meanwhile, scholarly attention was drawn to a number of published early western records of two crops principally associated with China, broomcorn millet and foxtail millet (*Setaria italica*). Their significance was that at the apparent time period (pre-5000 BC) of these European millet records, no material culture context explained the dispersal of eastern crops. This elevated minor cereals, which had hitherto been rather overlooked, to a conspicuous position in relation to questions of origins and spread within Old World prehistory, and provide a unique example (possibly the oldest) of how eastern agriculture had an influence on the western system from an early stage.

At that time, the archaeobotanical patterning of minor crops with apparently widely dispersed early records in East and West came against a background of archaeogenetic debate on single *versus* multiple origins of domesticated plants and animals. The driving question in archaeogenetic research in the late 1990s

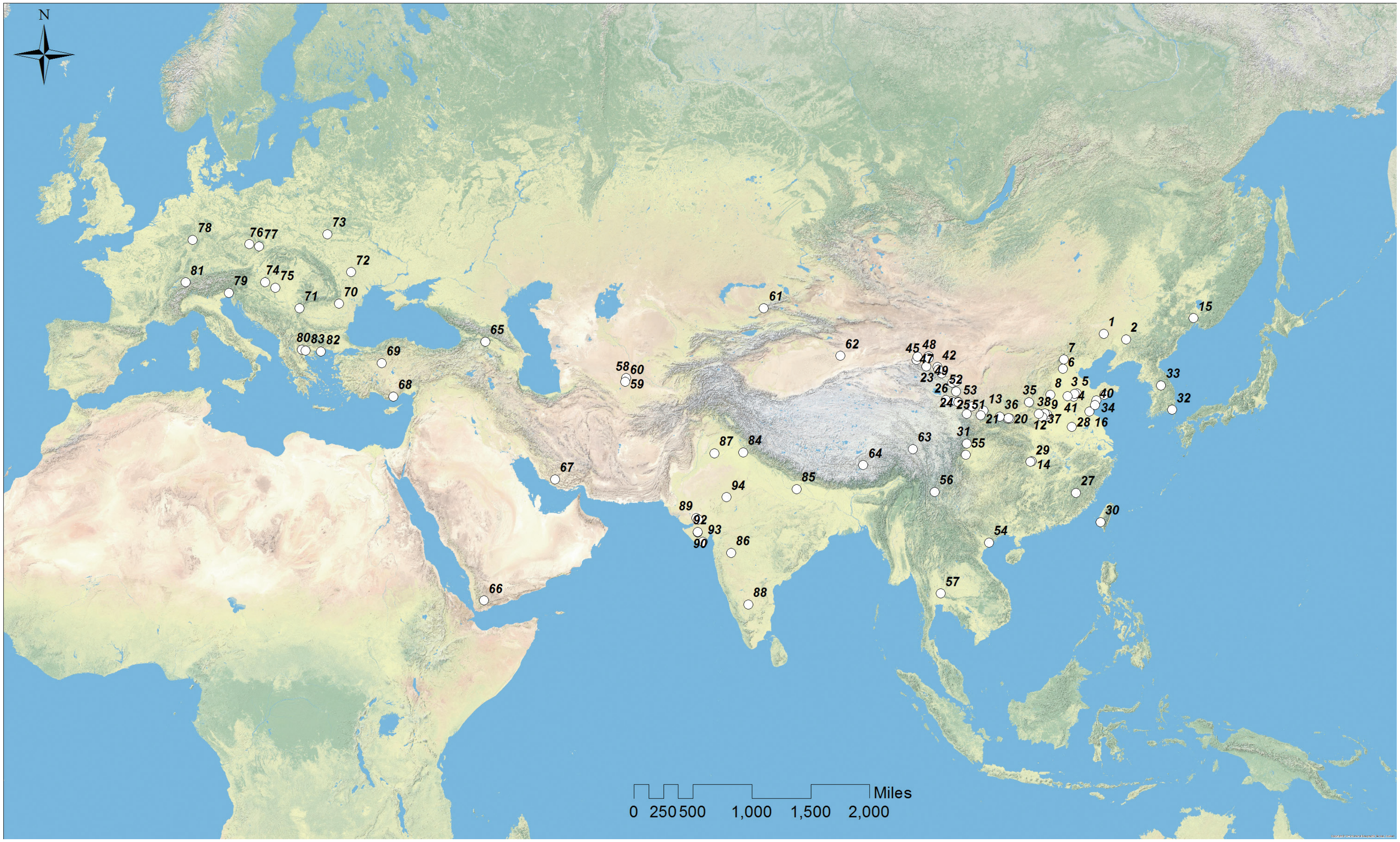


**Figure 13.1.** *Locations of key millet sites across Eurasia. (Map generated by ArcMap v. 10.2.) (1) Xinglonggou; (2) Xinle; (3) Zhangmatun; (4) Yuezhuang; (5) Xihe; (6) Nanzhuangtou; (7) Donghulin; (8) Cishan 9) Peiligang; (10) Shawoli; (11) Wuluoxipo; (12) Zhuzhai; (13) Dadiwan; (14) Baligang; (15) Krounovka 1; (16) Dongpan; (17) Beiqian; (18) Yuhuazhai; (19) Xinjie; (20) Yangguanzhai; (21) Xishanping; (22) Buziping; (23) Gaomuxudi; (24) Hurere; (25) Luowalinchang; (26) Gayixiangjing; (27) Nanshan; (28) Yuchisi; (29) Chengtoushan; (30) Nanke; (31) Yingpanshan; (32) Tongsamdong; (33) Gahyeon-ri and Seongjeori; (34) Zhaojiazhuang; (35) Taosi; (36) Zhouyuan; (37) Wangchenggang; (38) Erlitou; (39) Daxinzhuang; (40) Liangchengzhen; (41) Jiaochangpu; (42) Xihetan; (43) Huoshiliang; (44) Ganggangwa; (45) Huoshaogou; (46) Donghuishan; (47) Xichengyi; (48) Shaguoliang; (49) Mozuizi; (50) Huangniangniangtai; (51) Mogou; (52) Jinchankou; (53) Lajia; (54) Guangtaoyuan; (55) Baodun; (56) Haimenkou (early phase); (57) Non Pa Wai; (58) Gonur Tepe; (59) Ojakly; (60) 1211/1219; (61) Begash (Ia); (62) Xiaohe; (63) Karuo; (64) Changguogou; (65) Kwemo-Kartli sites; (66) Jubabat al-Juruf; (67) Haftavan; (68) Kilise; (69) Gordion; (70) Mãgura-Buduiasca; (71) Liubcova; (72) Sacarovca; (73) Ratniv-2; (74) Zánka; (75) Fajsz 18; (76) Bylany; (77) Mohelnice; (78) Bruchenbrucken-Friedberg; (79) Sammardenchia; (80) Mandalo; (81) Mintraching; (82) Skala Sotiros; (83) Kastanas; (84) Sanghol; (85) Lahuradewa; (86) Daimabad; (87) Harappa; (88) Pirak; (89) Surkoada; (90) Rojdi; (91) Kanmer; (92) Oriyo-Timbo; (93) Babar Kot; (94) Ojiyana.*

and early 2000s was whether domesticated plants and animals had evolved in and dispersed from those discrete centres of agricultural origin inferred from archaeology, or whether domestication was a much more geographically diffuse process. The principal toolkit, phylogeographic analysis of domesticated animal breeds and crop-plant landraces, together with their wild ancestral species where these were known and still extant, necessarily produced bifurcating evolutionary trees from which the monophyly (indicating a single origin) and/or rates of evolutionary change of the domesticate, in relation to geography, could be inferred. By 2004, all the major domesticates had been subjected to phylogeographic analysis, and an intriguingly broad picture had emerged of multiple, geographically widespread domestications of livestock species, in contrast to single, localized domestications of each of the principal crops (Larson *et al*. 2005; MacHugh & Bradley 2001; Matsuoka *et al*. 2002; Salamini *et al*. 2002).

In the years following Jones' 2004 paper, the gathering of novel archaeobotanical evidence intensified across the Eurasian continent. In the same year that Jones raised the millet question, a major recovery of millet grains from the Neolithic site of Xinglonggou in China was published (Zhao 2004). This study marked the advent of systematic archaeobotanical research in China, with more than 1200 flotation samples taken at the site. In contrast to solitary finds in Europe, over 1400 charred millet grains were recovered at Xinglonggou (predominantly broomcorn, but also some foxtail millet) dated back to 6000 BC. Xinglonggou is only one example of the many archaeobotanical investigations in East, South and Central Asia in the past 15 years or so, which vastly increased the database of millet sites (Ren *et al*. 2016; Zhao 2011). Stable isotopic studies have complemented archaeobotany in directly evidencing the role of millet in the human and animal diet, with more than 50 publications featuring isotopic results in China alone during the past decade (Lightfoot *et al*. 2013). Archeogenetic research on the processes that shaped patterns of intraspecific genetic diversity in *P. miliaceum* is inherently bound up with the wider evolutionary context (Hunt *et al*. 2014). In this chapter we will review recent advances in our understanding of broomcorn millet origins and spread, focusing on three areas: genetic work on the origins and spread of broomcorn millet; the earliest archaeological evidence of cultivation and consumption of the crop in China; and new advances in Central Asia and Europe. By doing so, we will revisit the questions of where broomcorn millet was first cultivated and consumed, and its spread across Eurasia (see Figure 13.1 for locations of key millet sites across Eurasia).

**Genetic data and the origins of broomcorn millet**

From a genetic perspective, research on the processes that shaped patterns of intraspecific genetic diversity in *P. miliaceum* is inherently bound up with the wider evolutionary context. Furthest back in evolutionary time, this means the evolution of its genome composition, which was followed in the relatively recent past by the differentiation, imposed by human selection, from a wild ancestral taxon to the phenotypically domesticated form. These issues have been partly clarified since 2004. Patterns of sequence diversity in our exploratory studies of genetic markers were strongly suggestive that broomcorn millet is an allotetraploid or amphidiploid, that is, its genome of 36 chromosomes comprises two distinct sets of 18 chromosomes combined from two wild species in a polyploidization event. This is comparable to the genomes of the better-understood tetraploid wheats, emmer (*Triticum turgidum* subsp. *dicoccum*) and durum (*T. turgidum* subsp. *durum*). This led to a collaborative cytogenetics project with Pat Heslop-Harrison in Leicester, in which DNA sequence and genomic *in situ* hybridization analyses of *P. miliaceum* and available wild *Panicum* species confirmed the allotetraploid nature of *P. miliaceum* and indicated that one of the two wild genome donors was the diploid *P. capillare*, or a genetically very similar species. The other genome in *P. miliaceum* appears to have some identity with one of the two genomes in a wild allotetraploid species, *P. repens* (Hunt *et al*. 2014). These findings themselves pose new biogeographical conundrums, as *P. capillare* is thought to be a New World native.

We can speculate that, as in the tetraploid wheats, allopolyploidization preceded domestication and thus that the direct wild ancestor of *P. miliaceum* is also allotetraploid. Little progress has been made to date on evaluating the weedy-type forms of *P. miliaceum* (*P. miliaceum* subsp. *ruderale*) that have been reported from a wide geographical range from central Europe to northeastern China. Miller and colleagues (2016) suggest that we have 'simply written off the range of this wild progenitor as somewhere in the vast terra incognita of Central Eurasia'. The difficulties here have proved twofold. First, in contrast to the large-grained cereals, such as Triticeae, existing herbarium or germplasm collections of *P. miliaceum* subsp. *ruderale* are very few in number, lacking in clearly stated morphological criteria for their identification, and lacking provenance or passport data. *De novo* field collections with adequate coverage of the Eurasian range are a challenging proposition within the timespan of any research project. Second, the genetic and genomic resources available for *P. miliaceum* have made study of its intraspecific diversity unusually challenging.

**Figure 13.2.** *Harriet Hunt visiting the Vavilov Herbarium, St Petersburg in 2011, collecting millet accessions. (Photograph: courtesy of Harriet Hunt.)*

Miller and colleagues (2016) incorrectly state that the genome of broomcorn millet has been sequenced; although a number of other Panicoid cereals and wild relatives have been the subject of genome sequencing projects in the last decade, including foxtail millet (*Setaria italica*), green foxtail (*S. viridis*) and switchgrass (*Panicum virgatum*), the large polyploid genome and low global economic importance of *P. miliaceum* (in contrast to the bioenergy crop *P. virgatum*), have left it lagging in the priority list for genome sequencing. In consequence, in relative terms, the paucity of known genetic sequence for broomcorn millet (Saha *et al*. 2016) is even more strongly true than it was in 2004. From the markers that are available, intraspecific genetic diversity in *P. miliaceum* appears to be unusually low, and is in stark contrast to the high morphological diversity (Hunt *et al*. 2011; 2013). This presumably results from the fact that polyploidization and domestication have both imposed genetic bottlenecks, narrowing the gene pool.

Nonetheless, the geographic picture that emerged from microsatellite markers (the state-of-the-art technique for most plant-population genetic studies prior to the 2010s) is strongly illuminating regarding the patterning of broomcorn millet diversity. Initial studies showed that domesticated *P. miliaceum* is divided into two major gene-pools with distinct eastern and western distributions, which both subdivide further into a total of six or seven clades whose distribution shows clear geographical structuring (Hunt *et al*. 2011; 2013; see Figure 13.2, for Harriet Hunt visiting the Vavilov Institute). A number of considerations from the genetic diversity statistics, let alone evidence from other proxies, were more suggestive of a single centre of domestication of broomcorn millet in China (Hunt *et al*. 2011; 2013). This is supported by an updated analysis of genetic data that included many additional Chinese samples, based on a simple model of population expansion. Further, these analyses suggest that the centre of origin may lie in western China, at the western end of the Loess Plateau (Hunt *et al*. 2018).

With the growth of functional genetics and genomics since 2004, the role of selection alongside demography in shaping patterns of crop variation has also come to prominence. Broomcorn millet has apparently undergone selection for starch quality, specifically for a high frequency of varieties with waxy or glutinous starch in those areas of East Asia (central-eastern China, Korea and Japan) where this trait is valued in the cuisine (Fuller & Rowlands 2009). The evolution of waxy grain starch in the polyploid genome of *P. miliaceum* was non-trivial, requiring mutations at two parallel loci followed by their combination in a single plant (Hunt *et al*. 2010; 2013). As part of the 'constellation of research projects' on broomcorn millet, the distribution of the waxy-starch genotypes poses new questions on culinary choice and its cultural boundaries (Hunt *et al*. 2013).

### Earliest evidence for cultivation and consumption of broomcorn millet in China—an updated picture

Since 2004, archaeological investigations on Pleistocene and early Holocene sites have transformed knowledge about hunter-gatherers in north China. A few Pleistocene sites in Shanxi province have provided residue and tool use-wear evidence for pre-agricultural plant processing, including grinding implements and the use of Panicoid grasses (Liu & Chen 2012; Liu *et al*. 2013). Macrofossil remains reported from one of these (Shizitan: 10,700–9600 BC) suggest the existence of Paniceae grains (Bestel *et al*. 2014). None of these data provide direct evidence for millet cultivation, but they nevertheless indicate the use of post-harvest processing techniques that would incorporate grains in the diet.

Evidence from phytoliths and starch granules places the first use of broomcorn and foxtail millet in the early Holocene. In the case of foxtail millet, the

**Figure 13.3.** *Martin Jones at a broomcorn millet field near Lanzhou, Gansu Province, western China, September 2007. (Photograph: Xinyi Liu.)*

**Figure 13.4.** *Visiting millet sites in Gansu Province, western China, September 2007: from left to right, Xinyi Liu, Giedre Motuzaite Matuzeviciute, Dustin White and Martin Jones. (Photograph: courtesy of Giedre Motuzaite Matuzeviciute.)*

oldest claim—inferred from starch granules—is from Nanzhuangtou (*c*. 9500 BC), followed by Donghulin (*c*. 7500 BC ) (Yang *et al*. 2012a); and in the case of broomcorn millet, the earliest claim related to phytoliths is from Cishan (*c*. 8000 BC: Lu *et al*. 2009; Yang *et al*. 2012b). However, there are considerable disagreements among scholars regarding both the lack of species-specificity from starch grains and phytoliths (Liu *et al*. 2013) and the radiocarbon dates from Cishan (Zhao 2011).

Compared with microfossil evidence, macrofossil identification in the early Holocene is less controversial. The earliest charred grains of broomcorn and/or foxtail millet in archaeological contexts date to the turn of the seventh/sixth millennia BC. Seven localities report charred broomcorn and foxtail millet grains prior to 5000 cal. BC (Liu *et al*. 2009; Ren *et al*. 2016; see Figures 13.3 & 13.4, for fieldtrips to China).

Considering domestication as a plant evolutionary process, data on the loss of seed dispersal, a key domestication trait, are lacking for broomcorn millet. This is partly because the millet rachis is delicate and does not normally survive the charring process, in contrast to rice, wheat and barley. In some seed crops an increase in grain size evolved alongside the non-shattering trait (e.g. Fuller *et al*. 2014), a proxy for domestication that has potential to be used for broomcorn and foxtail millets. It has been noticed that broomcorn and foxtail millet grains show a gradual increase in size and change in shape over the Neolithic period. This has led some scholars to speculate that the broomcorn millet from Early Neolithic sites such as Xinglonggou had undergone some selection for caryopsis size and shape (e.g. Zhao 2004), with grains from later sites showing a more pronounced morphological change. However, multiple factors, such as sowing depth and culinary choices, may also influence the grain shapes of seed crops; grain size alone cannot be used as the sole indicator of the domestication process (Harlan *et al*. 1973; Liu *et al*. 2016a).

Turning to the consumption of millet, there has been a rapid increase in the past decade of palaeodietary studies using stable isotopes across Eurasia, particularly in China (see Lightfoot *et al*. 2013, for a review of the isotopic evidence). This isotopic research shows that human consumption of millet at a significant scale is surprisingly old in north China, but variable both among sites and among individual consumers. Human skeletal remains have been analysed isotopically from five northern sites pre-dating 5000 BC. Isotope values from one site are consistent with no millet consumption (Jiahu) and two are consistent with a mix of $C_3$ and $C_4$ consumption (Guowan and Xiaojingshan: Hu *et al*. 2006; 2008). The remaining two—Xinglonggou and Xinglongwa—have carbon isotope values indicating millet consumption on a significant scale (Liu *et al*. 2012). Therefore, the Xiliao River region (where the Xinglongwa culture is situated) provides evidence for both the oldest directly dated millet grain as well as the oldest millet consumers. After 5000 BC, almost all northern populations are consistent with $C_4$ diets and they also produced enough millet to provision their animals, particularly pigs (Barton *et al*. 2009; Chen *et al*. 2012; Guo *et al*. 2011; Pechenkina *et al*. 2005).

There are, however, some marked gaps in our understanding regarding millet uptake through food chains. For example, conventional isotopic analysis of bulk collagen alone stops short of answering questions such as to what extent did Neolithic humans consume millet directly, and what proportion of their diets consisted of meat or dairy from animals fed on millet? When dietary reconstruction is based on bulk collagen isotopic determinations, informative variation at the molecular level is masked. Carbon isotope analyses of individual amino acids show that collagen amino acid carbon isotope ($\delta^{13}C$) values can differ by up to 27‰ (Hare *et al*. 1991; Tuross *et al*. 1988). Future research to analyse single amino acids will be plausible and timely. Furthermore, the assumption that the $C_4$ signal detected in human skeletal remains reflects human and animal consumption of major $C_4$ crops/millets should be further tested (see Chapter 14, this volume, for further discussion).

The early millet sites in north China are concentrated along a chain of low mountains broadly running northeast–southwest, extending along a 2500 km boundary between the Loess Plateau and eastern China floodplains, a pattern echoing the 'hilly flanks of the Fertile Crescent' in southwest Asia (Liu *et al*. 2009; Ren *et al*. 2016). This early association of millet sites with foothill locations is also helpful to understand the geography of the later dispersal of millet cultivation. In Central Asia, the earliest archaeological sites with millet remains are restricted to a narrow foothill zone between 800 and 2000 m a.s.l., where summer precipitation is relatively high (Miller *et al*. 2016).

**Chronology of broomcorn millet in Europe**

Very early records of broomcorn millet in Europe have puzzled scholars since macrobotanical remains of millet were found in strata dated to as early as the seventh millennium BC (reviewed in Hunt *et al*. 2008). Some twenty sites dated to pre-5000 BC in Europe and the Caucasus were reported, mostly containing a few remains of broomcorn millet (Hunt *et al*. 2008; Jones 2004). Direct radiocarbon dates obtained on some of those broomcorn millet grains (10 sites in total), reported from pre-5000 BC sites in Europe, resulted in a very different age than the archaeological chronology. The earliest directly dated broomcorn millet grain was placed at only *c*. 1600 cal BC (Motuzaite Matuzeviciute *et al*. 2013). The AMS dates of the early millet records in Europe have indicated that at least some, and possibly all, of these 'early' records are doubtful and could well be intrusions of recent-age seeds into Neolithic layers. There is also a series of early indirect dates from grain impressions in Neolithic pottery from east Europe (Hunt *et al*. 2008). These are dependent upon the reliability of identification of casts from impressions, largely conducted and published prior to the possibilities of electron microscopy.

The beginning of millet cultivation in Europe more likely began sometime during the Middle Bronze Age (*c*. 1500 BC). Along with the earliest directly dated grain, it is during this period that many sites across Europe report broomcorn millet seeds in large quantities, providing clear evidence of its cultivation (Kneisel *et al*. 2015). In some places in Europe millet remains can be found in ubiquities of up to 65 per cent of samples (e.g. Rosch 1998; Szeverényi *et al*. 2015). The dietary changes associated with $C_4$ plant consumption can also be seen in Europe only starting from the Middle Bronze Age (e.g. Varalli *et al*. 2016). Lightfoot and colleagues (2013) noted that during the

Bronze Age, $C_4$ consumers outside China are often individuals within communities where the majority of people are $C_3$ eaters. In a different study by Lightfoot and colleagues (2015), only individuals buried in simple pits seemed to consume millet in prehistoric Croatia, while Ananyevskaya *et al*. (2017) have noted the opposite in Central Kazakhstan, where individuals with elevated $\delta^{13}C$ values belong to exceptionally rich male burials. Therefore, millet status as a food seems to be culture driven and differ across the region, at least in the pioneering stage of its dispersal.

It has been suggested that millet in the Mid–Late Bronze Age contributed to the 'third food revolution' in Europe, associated with changes in crop-production strategies and increased diversity of cultivated crops (Kneisel *et al*. 2015). At the northern limit of its distribution in Europe, in Latvia and Lithuania millet became one of the dominant crops at the end of the Bronze Age (800–600 BC; Grikpėdis & Motuzaite Matuzeviciute 2017; Pollmann 2014). Its cultivation coincided with population increase and the formation of fortified hillfort sites in this region. Furthermore, the increase in ubiquity of millet records in Europe coincides with the evidence of highly increased human mobility during the Bronze Age.

**Globalization of millet crops**

The accumulated data for China and Europe now suggest that broomcorn millet was cultivated at least 4000 years earlier in the east than in the west, overturning the maps of Jones (2004) and Hunt *et al*. (2008). The route of the implied east–west spread of millet has therefore been debated (see Figure 13.1 for locations of key millet sites across Eurasia). Jones (2004) proposed the steppe pathway, following the northern grassland route from China to Europe. The steppe has been often proposed as a 'highway' across Eurasia that allowed innovations to advance rapidly, given the lack of geographical obstacles (e.g. Middleton 2015). Despite the sporadic nature of archaeobotanical investigations in northern Eurasian steppe, macrobotanical evidence of millet is absent from the region before the mid second millennium BC. Recent stable isotope studies show that $C_4$ human consumers appeared in Minusinsk Basin during the Late Bronze Age, *c*. 1400 BC (Svyatko *et al*. 2013). In this period, $C_4$ consumers also appeared in southern and central Kazakhstan, but not northern Kazakhstan (Ananyevskaya *et al*. 2017; Lightfoot *et al*. 2014; Motuzaite Matuzeviciute *et al*. 2015). Millet may still have moved westward along the steppe pathway at a later period, as indicated by macrobotanical evidence from Early Iron Age Scythian graves in Siberia and Charasmian Steppe in Central Asia (Brite *et al*. 2017; Hunt *et al*. 2018; Spengler *et al*. 2016), but the focus of research on the first wave of westward expansion has now shifted south, to Central Asia.

Archaeobotanical research has now been conducted at multiple sites across Central Asia, embracing a wide variety of geographical zones including grasslands, mountain piedmont, high mountain valleys and riverbeds. The earliest evidence of broomcorn millet comes from Begash, located on the piedmont of the Tian Shan mountains in southeastern Kazakhstan. Direct radiocarbon dates from broomcorn millet placed its arrival in this region at the end of the third millennium BC (Frachetti *et al*. 2010). There is evidence for the expansion of broomcorn millet westwards from Begash along the northern slopes of the Inner Asian mountains during the first half of the second millennium BC, with records at sites in Afghanistan, Turkmenistan and Uzbekistan (Rouse & Cerasetti 2014; Spengler 2015; Spengler *et al*. 2014; 2016).

In South Asia, both broomcorn and foxtail millet are common in late Harappan sites in the early second millennium BC, although the precise dates are open to radiocarbon scrutiny (Pokharia *et al*. 2014; Weber 1998). Broomcorn millet is also reported in Yemen dated to the mid second millennium BC and there is evidence for its spread into Sudan in the same period (Boivin & Fuller 2009; Fuller *et al*. 2011). In Southeast Asia, foxtail millet is reported from Thailand at around *c*. 2000 BC (Weber *et al*. 2010).

The 2004 title 'Between fertile crescents' was not intended to suggest that broomcorn and foxtail millet themselves might link the eastern (north China) and western (southwest Asia) Fertile Crescents. Archaeobotanical data at the time (Nesbitt & Summers 1988) indicated that these crops were late arrivals among the crops grown in southwest Asia. Subsequent work has supported this chronology and clarified its geography and seasonality. In the second millennium BC, Asian millets are found in central Turkey and northwest Iran; they become more widespread across Anatolia, Iran, Iraq and northern Syria during the first millennium BC (Hunt *et al.* 2008; Lightfoot *et al.* 2013; Miller *et al.* 2016).

In 2004 the pattern was enigmatic; the western records of eastern millet are older than any material cultural evidence. This archaeobotanical patterning of minor crops with apparently widely dispersed early records in East Asia and Europe stimulated archaeobotanical, isotopic and genetic research across the continent. Archaeobotanical research since 2004 has secured and extended the evidence base for broomcorn millet in multiple regions of north China prior to 5000 BC. In contrast, re-evaluation of the solitary early *Panicum* records from Europe and the Caucasus has shown that their chronology was incorrect, and therefore fails to substantiate the presence of millet in the west at this early date. The isotopic and genetic evidence are also consistent with a single early focus of millet agriculture in China. The documentation of broomcorn millet in eastern Kazakhstan from the late third millennium BC marks the first step on a Bronze Age pathway westward that followed the Inner Asian Mountains towards the Caucasus and Europe, although many details of this pathway remain to be explored. By the second millennium BC, archaeobotanical evidence of broomcorn millet are reasonably established in Afghanistan, Turkmenistan and Turkey in Central Asia; Greece, Romania and Hungry in Europe; India and Pakistan in South Asia; and Yemen and Sudan in North Africa. From isotope studies, there is evidence for $C_4$ consumption in at least 12 sites outside China. An emerging theme of the early millet agricultural sites is their location in the soft foothill spurs, shifting the focus away from the river-valley bottoms. This growing emphasis upon foothill locations, and the exploitation of slope runoff as opposed to valley-bottom water, also resonates with the locations of important new millet sites in Central Asia.

## Conclusion

It was not so long ago that the idea of a single centre of the origin of civilization was a popular and widespread narrative. One consequence of recent discoveries in East Asian agricultural origins has been to undermine this notion. Studies into Asian millets have a significant agenda in this process. In terms of the spatial, the western and southern expansions of broomcorn and foxtail millet provide a unique example (and possibly the oldest) of how East Asian agriculture had an influence on the global system from a very early stage. This can encourage us to reflect on assumptions we have held in a western context, which include the assumptions about what agriculture actually is. Turning to the temporal, the gradual temporal change in millet consumption, as well as the slow dispersal of its cultivation, can be considered by contrasting the perpetual needs of the poor with the more ephemeral cultural choices of the powerful. The former may endure for centuries and millennia, whereas the latter, as the word 'choice' indicates, are to some extent biographically situated and more open to constant reconfiguration (Liu & Jones 2014). The dates available so far indicate a process spanning millennia. While this does not in itself exclude a cultural choice trigger, it would require a separate and more lengthy driver to sustain it over these much longer periods.

Over 10 years, the Asian millets have moved from a poorly understood peripheral resource to a well-charted core feature of Old World prehistoric agriculture and its globalization. This greatly changed status has not only transformed our understanding of the past, but also our appreciation of the present, and its invaluable crop resources, whose diversity is continuously in danger. The research into the past of Asian millets has dramatically changed the profile of the Asian millet heartlands today. In 2012, the United Nations Food and Agriculture Organisation (FAO) designated the Aohan district of Inner Mongolia (the region in which Xinglonggou is situated) a Globally Important Agricultural Heritage System. This designation, explicitly acknowledging the role of archaeology in establishing its importance, has already impacted visibly upon the lives of Asian millet farmers.

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