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The effect of geographical margins on cereal grain size variation: Case study for highlands of Kyrgyzstan

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A R T I C L E I N F O

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A B S T R A C T

Archaeobotanical research in prehistoric Central Asia and beyond has repeatedly reported highly compact wheat and barley varieties found along piedmont sites of the Inner Asian Mountain Corridor (IAMC). The morphotypical variation of wheat caryopses across Eurasia generated the Liu et al. (2016) publication pointing out a decrease in grain size relative to eastward dispersal into China; the decrease in wheat caryopses was explained as human selection of smaller grain sizes for better culinary properties.

In this study we discuss the possible effect of geographical margin, mountains in particular, on grain morphotypes. By understanding the patterns and reasoning of crop morphotypical variation in mountain zones we can better understand their subsequent dispersal patterns into lower altitudes. Here we present both wheat and barley grain measurements from four Bronze Age sites in Kyrgyzstan, located in the central Tian Shan mountains of average elevation 2000 masl. The data reveals that sites located in mountain valleys at higher elevations display a higher variability in crop dimensions. By analysing grain size variation within and between the sites in Kyrgyzstan and comparing our dataset with published metadata by Liu et al. (2016), we argue that variation in grain size was driven by environmental factors, while compact grain forms in particular could have formed in geographical margins such as mountains.

1. Introduction

When crop species moved beyond their original ecological boundaries they endured novel environmental and seasonal conditions, and annual temperature patterns (Lister, et al., 2009). Post-domestication genetic and often morphotypical changes were crucial for crop survival in varied latitudes and altitudes (Fuller and Lucas, 2017; Liu, et al., 2017). In other words, changes in climatic conditions as crops dispersed from their areas of domestication drove alterations in a variety of their genes so that they could grow and survive in new environments. These genetic adaptations to new environments included resistance to certain diseases, drought, adaptation to ultraviolet (UV) intensity, changes in vernalization requirements and flowering times (Dawson, et al., 2015). For example, as barley moved into northern latitudes or cooler climates, the genes Ppd-H1 responsible for photoperiod time had to be silenced to permit growth during the long days of polar summers, or in high altitude environments with high variability between day and night temperature (Jones, et al., 2012). Once crops such as wheat and barley moved from southwest Asia where they were domesticated to different environments, they usually were under pressure to become spring-sown rather than autumn-sown in order to adjust better to the change of seasonality and temperature patterns (Lister et al. 2009). It has been suggested that the gene controlling plant's response to day length (photoperiod response gene Ppd−H1) was a contributory factor for delays in the agricultural spread to diverse latitudes and altitudes (Jones, et al., 2012). In barley the photoperiod plays a major and interactive role with vernalization in determining flowering time, therefore vernalization genes are normally also non-responsive in relation to climate-related stress (Dawson, et al., 2015) often making such barley varieties spring-sown rather autumn-sown.

The earliest evidence of southwest Asian crops in the mountain range that separated China from Central Asia dates back only to the Bronze Age (the middle of the 3rd millennium cal BC) for wheat (Doumani, et al., 2015) and the early 2nd millennium cal BC for barley

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(Motuzaite Matuzeviciute, et al., 2015). Subsequently, with some delay (at the beginning of 2nd millennium cal BC), wheat and barley were dispersed across western regions of China (Liu, et al., 2017, 2016; Stevens, et al., 2016). It has also been argued that one of the key factors for the delay in arrival of southwest Asian crops into China was the interposition of marginal environments such as the Tibetan plateau (d'Alpoim Guedes, et al., 2014) and the Central Asian mountain ranges (Spengler, et al., 2014a); in order to cross them crops had to undergo major genetic transformations, mainly to become spring-sown (Liu, et al., 2017).

It is important to point out, however, that once transported to different latitudes and altitudes crops were forced to endure not only genetic modifications but also transformations in morphotypes that fit their new environments (Fuller and Lucas, 2017; Fuller, et al., 2010). Based on large meta analysis of cereal grain measurements it has been demonstrated that crop species became smaller in the northern latitudes of Europe where they were less well-adapted to environments outside the Mediterranean climate (Fuller, et al., 2017).

In another meta study of grain size measurements by Liu et al. (2016), it is demonstrated that the first wheat grains which reached China in prehistory were much smaller than their counterparts in India and West Asia. This pattern of small wheat grain distributions in CE China in particular, has been explained as due to human action through selection by culinary choice defined by better flour quality from smaller grain sizes (Liu, et al., 2016). In archaeobotanical studies conducted west of China in the Inner Asian Mountain Corridor (IAMC) and south of China on the Tibetan plateau, small round compact grain varieties of both wheat and barley are repeatedly reported (d'Alpoim Guedes et al., 2015; Motuzaite Matuzeviciute, et al., 2015; Spengler, et al., 2016, 2014b; Miller, 1999) one of the smallest being in the high altitude sites in Nepal (Asouti & Fuller, 2009). However, where and why these patterns of small, lax, spherical grains seen in both wheat and barley species has developed remains unclear.

In this paper we present grain size measurements of wheat and barley from four Bronze Age sites in Kyrgyzstan, from the central Tian Shan Mountains. This region constitutes a part of the IAMC, which acted as an early network corridor in prehistory (Frachetti, 2012). In this research we aim to demonstrate the importance of geographical margins, highland mountain valleys in particular, not only for understanding rates of crop dispersal due to genetic changes that crops had to endure in new environments, but also to better understand their influence in the development of special crop morphotypes. This research on morphotypical variations in crops can help to explain crop size and shape pattern in regions adjacent to such marginal zones.

2. Archaeological and environmental settings

It is not clear when agriculture arrived in the present territory of Kyrgyzstan, as archaeobotanical research in this country is in a primary stage (Motuzaite Matuzeviciute, et al., 2015). Previous research found the remains of wheat and barley grains and chaff at the Aigyrzhal-2 site within a burial ground context, located in central Kyrgyzstan along the Naryn River valley. At the Aigyrzhal-2 site a ritual pit of ash filling contained some pottery shards, horse vertebrate, sheep limb bones as well as cereal grains of wheat and barley, dated to ca. 1800 cal BC (Motuzaite Matuzeviciute, et al., 2015). These crops require laborious land preparation and attendance, suggesting at least a semi-sedentary nature of Bronze Age populations inhabiting the highlands of the Tian Shan.

Human bones from the Aigyrzhal-2 site were selected for stable isotope analysis were radiocarbon-dated to ca. 2500 cal BC (unpublished data). Unfortunately, the sediments around these particular human inhumations that contained ash deposits around them potentially with charred cereal remains, were not sampled for archaeobotanical analysis. However, archaeobotanical research from human burial contexts in the neighbouring regions of southeast Kazakhstan has shown that from around the middle of the 3rd millennium cal BC humans inhabiting mountain environmental niches were already practicing agro-pastoralism, which involved both crop cultivation and animal herding (Doumani, et al., 2015; Spengler, et al., 2014c; Frachetti, et al., 2010). Therefore, future archaeobotanical studies in Kyrgyzstan may push the current date for the earliest crops further into antiquity.

In general we possess very limited knowledge on the Bronze Age period in Kyrgyzstan, due to the lack of research on settlement sites and the fact that Bronze Age settlements are located in very geologically active landscapes in deep mountain valleys, and therefore they might remain undocumented by the specialists. Currently, most information about the Bronze Age societies in Kyrgyzstan has been obtained from burial excavations (Soltobaev and Moskalev, 2014; Tabaldiev, 2011) and from rock art sites (Akmatov, 2008). Nevertheless, some discoveries witness to the complex economical networks in the highlands of the Tian Shan. The Shamshinskii hoard, discovered in the Kochkor region of Kyrgyzstan, contained around 27 bronze items which included sickles, mirrors, jewelry, axes, hammers and work tools (Kozhomberdiev and Kuzmina, 1980).

3. Study sites

The samples used for this study were obtained from four sites: Aigyrzhal-2, Uch-Kurbu, Chap and Mol Bulak-1 (Fig. 1).

The *Aigyrzhal-2* site is located two kilometers west of the city of Naryn in central Kyrgyzstan, at 2005 masl. The climate in the Naryn valley is very cold; mean January and July temperatures are – 16.8 and 17.1 °C respectively, the annual mean temperature is 2.7 °C and the annual mean precipitation is 285.5 mm (World Climate 2014). The current inhabitants of the Naryn River valley practice agriculture by growing summer wheat, barley, oats and broomcorn millet. The archaeological site is situated on a small oval-shaped loess hill in the middle a canyon, on the southern bank of the Naryn River, and contains human burials from the Early Bronze Age (2500 cal BC) onwards. The cereal grains used in this study were obtained from a Bronze Age pit that was previously radiocarbon-dated to 1800–1500 cal BC (Fig. 2) (Motuzaite Matuzeviciute, et al., 2015). At the start of excavations it was thought that the pit was a Bronze Age human burial, as the stone circle and the stone cairn found on the top was a typical setting for burials of this period. However, further investigations showed it to be a pit containing a single stratum, filled during one episode of use (Motuzaite Matuzeviciute, et al., 2015).

The *Uch-Kurbu* site is located in the foothills 2.5 km from Issyk-Kul Lake at 1750 masl. The climate in Issik Kul is moderate, where temperatures in wintertime can drop to −7 °C while in the summer it normally does not exceed 25 °C, and the average annual rainfall is 390 mm (Climate.data.org, 2017). The current inhabitants of the region live in permanent settlements in the valley and practice agriculture and horticulture while sending usually the youngest son to higher mountain valleys to take care of sheep (goats stay in the winter villages) and horses during the spring, summer and autumn months.

The site consists of mainly Bronze Age human burials located on the edge of a mountain slope that was previously excavated by the archaeologist K. Tabaldyev (Tabaldiev, 2011). The samples for archaeobotanical investigation were taken during small-scale research in 2015 and 2016 from the lenses of ash, cremation cysts and pits, all located within the necropolis. The samples from the burial contexts revealed a large range of crop species (see Motuzaite Matuzeviciute et al. forthcoming). Four radiocarbon dates were conducted from cereal grains from the same contexts as grain measurements data presented in this study, that include: ritual pit nr 1 3236 ± 24 BP, 1607–1439 cal BC [Beta-449,283]; cremation cist: 3339 ± 22 BP, 1689–1534 cal BC [TKA-18647]; Layer 2: 2979 ± 22 BP, 1266–1122 cal BC, [TKA-18646]; Layer 3, 2988 ± 21 BP, 1279–1127 [TKA-18644]; Layer 9: 3257 ± 23 BP, 1613–1460 cal BC [TKA-18645] (Fig. 2).

The *Chap* site is located in the mountains of the Koch-Kor river