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Usewear and residue analyses of experimental harvesting stone tools for archaeological research

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ABSTRACT

Chinese millets (*Setaria italica* and *Panicum miliaceum*), first domesticated in north China, were among the most important East Asian crops in the past. Previous studies have mainly focused on the morphological changes of millet grains for evidence of domesticity, but very few attempts have been made to understand the pre-domestication cultivation processes that predated morphological domestication and were likely involved with using certain harvesting methods. In order to develop methods for detecting evidence of this early stage of domestication we conducted a series of experiments cutting various wild and domesticated plants with stone tools, and analyzed the usewear traces and starch and phytolith residues on these tools. To evaluate the origins of the tool residues, we also extracted microbotanical contents from the stems and leaves of related plants with a focus on starch, and observed *in-situ* starches in leaves. The results show that stone tools with varying hardness and surface roughness used for harvesting cereals show diverse forms of polish and striations on their edges, and the confirmation of relatively large non-transient starch grains existing in stems/leaves provides a new opportunity for functional analysis of archaeological tools. This study proposes a multi-proxy approach to examine cutting tools for the evidence of cereal harvesting, particularly millets.

1. Introduction

Among the many research topics relating to the origins of agriculture, the domestication of cereals has been an enduring subject in archaeology. It has been widely accepted that cereal domestication was a very long process, including a stage of pre-domestication cultivation that predates morphological domestication and a continuous selection for the non-shattering trait on rachises until such a characteristic became dominant in the species (Purugganan and Fuller, 2010; Willcox, 2012). Selection for non-shattering seeds may have been achieved by using sickles in harvesting, as this technique would cause the grain to be gathered from the rare mutant plants with a semisolid rachis which hold the grain even at maturity (Hillman and Davies, 1999). Two lines of evidence have often been used in studies on the origins of domestication based on the data from West Asia: (1) morphological change of rachises in cereals, such as wheat and barley, from shattering to non-shattering forms (Purugganan and Fuller, 2010; Willcox, 2012); and (2) the presence of "sickle gloss" on cutting tools as an indicator of cereal harvesting (Anderson, 1999; Unger-Hamilton, 1989, 1999).

In East Asia, foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum miliaceum*), first domesticated in north China, were among the most important crops in the past. Foxtail millet was domesticated from green foxtail (*Setaria viridis*), but the wild progenitor of broomcorn millet is uncertain (Crawford, 2006). It is currently unclear, however, when and how predomestication cultivation of millets happened. No study has been done to examine millet rachises, because millet seeds are very small, and fragile rachises rarely survive in the archaeological contexts. Instead, archaeobotanists use grain morphology to determine millet domesticity, as domesticated millets are larger in size and more spherical in shape than the wild species (Walsh et al., 2016; Zhao, 2004). The earliest evidence for millet domestication, indicated by a few *Setaria* sp. grains showing morphology in between green foxtail and foxtail millet (small in size but rather spherical in shape), has been found at Donghulin near Beijing (*ca.* 10,000 cal BP) (Zhao, 2014). Millet grains with clear morphologically domesticated traits (larger and more spherical) have been recovered in the Yellow and Liao River regions, dating to the eighth millennium cal BP (Crawford et al., 2016; Lee et al., 2007; Liu, 2006; Zhao, 2011). However, these traits are indicative of a later stage in the domestication process (Purugganan and Fuller, 2010). If the initial cultivation of wild millet grasses for selection

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Fig. 1. Experimental harvesting and examples of tools used.
1: Cutting dry cattails with sickle; 2: cutting dry brome grass near roots with knife; 3: cutting half-green green foxtail near heads with sickle; 4: cutting green cattail with flake; 5: cutting dry foxtail millet near head with knife; 6: sharpening the edge of sandstone knife on a whetstone; 7: slate sickle (LY-XSK4) for cutting half-green green foxtail; 8,9: sandstone knife (KF-XKN2) for cutting green reeds (A: upper side, B: lower side; 8 showing PVS on the tool edge); 10: chert flake (KF-XFK2) for cutting green green foxtail; 11: quartz flake (LY-XFK1) for cutting green green foxtail; 12: chert flake (SM-XFK1) for cutting dry foxtail millet, showing large fractures on edge (lower right) due to breaking stems by pulling, lower side.

of non-shattering rachises occurred long before the seed's morphological change, we are unable to detect this early stage by examining charred grains. Thus, alternative approaches need to be developed. We argue that associated evidence of cultivation, such as plant-related usewear traces and microbotanical remains on Paleolithic cutting tools, can help overcome the deficiency with the absence of rachises in the archaeological record.

Many researchers have demonstrated that experimental replication techniques integrated with usewear and residue analyses form a powerful approach to the understanding of tool functions. Usewear helps determine whether or not the artifacts were used, how they were used, and what general types of materials (grasses, wood, bones, *etc.*) were worked on. Additional information from botanical residue analysis provides more details on the plant taxa that were in contact with the tools (*e.g.*, Fullagar, 2006a; Fullagar and Wallis, 2008; Högberg et al., 2009; Kealhofer and Fullagar, 1999; Kononenko, 2011). This multi-proxy approach, however, has not been effectively applied to the research of the origins of plant domestication in China. Here, very few studies have been conducted to understand how cutting tools may have interacted with plant foods, by examining either usewear traces (Cui, 2010; Lu, 1999; Wang, 2008) or microbotanical remains (Guan et al., 2014). A small number of studies have focused on usewear and/or residues on Neolithic cutting tools (ground stone sickles and knives) to understand the harvesting of domesticates (Cunnar, 2013; Jin et al., 2011; Kamijo, 2008; Ma et al., 2014; Yang et al., 2014). No study has systematically integrated the three analytical methods (experiments, usewear analysis, and residue analysis) on cutting tools to investigate the transitional process from wild to domesticated cereals. To fill this gap, we conducted a series of experiments in which we cut various plants with stone tools, and analyzed the usewear traces and microbotanical residues on the tools. For comparison, we also extracted starches from the stems and leaves of related plants, and observed *in-situ* starches in leaves. The existence of non-transient starches in stems/leaves was confirmed, opening a new avenue to the functional study of plant-related archaeological tools. This study provides a comparative database for future archaeological research on this subject, and proposes a multi-proxy approach to study cutting tools for the evidence of cereal harvesting, which was a crucial dynamic in the origins of millet domestication in China.