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ORIGINAL ARTICLE

Revealing *Coix lacryma-jobi* var. *lacryma-jobi* (Job's tears) in Han Dynasty burials with evidence from phytolith identification

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Abstract

Coix lacryma-jobi L. (Job's tears, adlay, yiyi 薏苡in Chinese) is a tropical member of the Poaceae family which is widely grown in southeast Asia for its grain, as medicine and for beads. However, archaeobotanical evidence of *Coix* from macrofossils or phytoliths remains limited, and the varieties used in ancient China have yet to be identified through research. In this study, the remains of involucral bracts of *Coix* from two Han Dynasty tombs (2004CSX Tomb M110 and RNSM Tomb M1, dated to around 2,100 cal BP) in Xi'an, Shaanxi Province, China, were examined. Macrobotanical analysis suggested they were *C. lacryma-jobi*, and phytolith analysis further confirmed their identification as *C. lacryma-jobi* var. *lacryma-jobi*. This is the first report to successfully identify ancient remains of this plant to variety level from phytoliths. The findings provide new insight into the cultural significance of *Coix* in Han Dynasty funerary customs and demonstrate the potential of phytolith analysis for the identification of taxa from archaeological contexts to variety.

Keywords Coix lacryma-jobi · Macroremain · Phytolith morphology · Funerary practices · Han Dynasty

Introduction

Coix lacryma-jobi L. (Job's tears or adlay, yiyi 薏苡in Chinese), is a widely distributed member of the Poaceae which grows in South and East Asia. Its spikelets are enclosed in a hard bead-like structure, the involucre or pseudocarp, a hardened bract which is formed from metamorphosed leaf sheaths, with the stamen of the inflorescence protruding from the top (Jain and Banerjee 1974; Chen and Phillips 2006) (Fig. 1). There are four known varieties, three of which have hard and thick involucres (*C. lacryma-jobi* var. *lacryma-jobi*, *C. lacryma-jobi* var. *stenocarpa* and *C. lacryma-jobi* var. *puellarum*) and one with a softer and thinner one (*C. lacryma-jobi* var. *ma-yuen*) (Jain and Banerjee 1974; Chen and Phillips 2006).

Job's tears is a multifunctional plant valued for its nutritional, decorative and medicinal uses (Jain and Banerjee 1974; Mehra et al. 1975; Arora 1977; Li et al. 2020; Biswas and Das 2022). Its name comes from an ancient story in the traditions of several religions about Job, a prophet who had a difficult life. Its use for food is shown by *Coix* starch remains which have frequently been recovered from pottery, grinding stones and dental calculus in China, suggesting that it was a common traditional food crop and an important ingredient for making alcoholic drinks in ancient China (Liu

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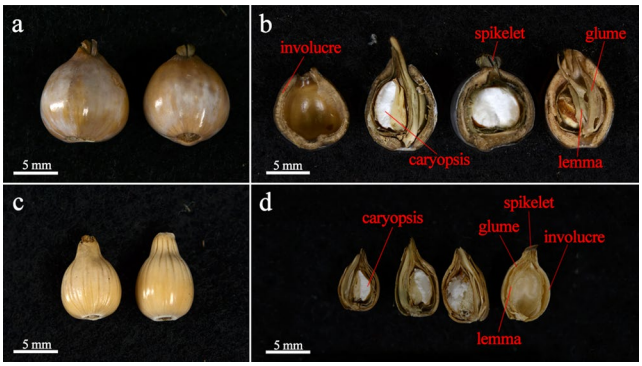

Fig. 1 The two varieties of *Coix lacryma-jobi* discussed in this study; **a** var. *lacryma-jobi*, tear-shaped; **b** dissected; **c** var. *ma-yuen*, tear-shaped; **d** dissected

et al. 2019, 2024; Liao et al. 2022b, 2025; Liu 2023). The grains (caryopses) are also mentioned in numerous Chinese ancient texts, used for both food and medicines (Yue et al. 2008; Luo et al. 2018). As decoration, the hard *Coix* involucres are commonly used to make ornaments and prayer beads by the aboriginal tribes of southeast Asia as well as in Buddhist and Catholic countries (Simmonds 1857; Jain and Banerjee 1974; Mehra et al. 1975). A previous study at the Sampula cemetery of the ancient Khotan Civilization (ca. 2,000 cal BP) in Xinjiang, China (Fig. 2) found three bead necklaces made of involucres of *C. lacryma-jobi* var. *lacryma-jobi*, which were considered to have had a connection with the Buddhist religion (Jiang et al. 2008). Although there is no direct archaeological evidence for ornaments in ancient China so far, a written record in the Ming Dynasty pharmacopeia *Ben Cao Gang Mu* (本草纲目, compiled in 1552–1578 CE) states: "Job's tears have two types: one with thin husks, suitable for porridge and alcoholic drinks; the other with hard husks, used to make beads". This confirms that the harder variety was indeed used for ornamental purposes in ancient China. The earliest medicinal reference for *Coix* can be traced back to the Han Dynasty pharmacopeia *Shennong Bencao Jing* (神农本草经), written around 2,000 years ago.

Despite its importance in the past, it is difficult to find phytoliths and macroremains of *Coix* in archaeological contexts and to differentiate between its varieties. Starch grains of *Coix* were identified from 33 archaeological sites in China, while phytoliths were identified from only five sites and seeds from six (Liu et al. 2019). These few remains from a small number of sites may be due to limitations in

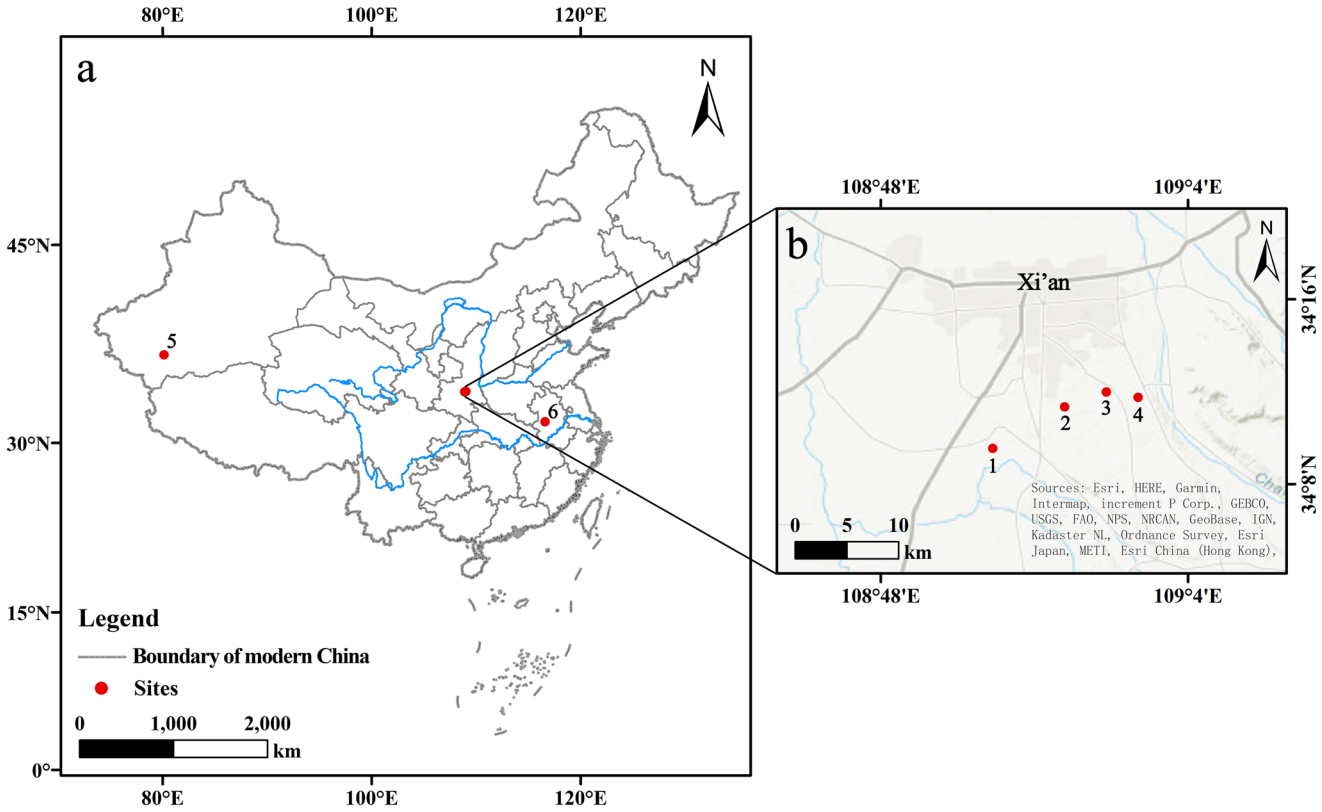

Fig. 2 Locations of the six sites discussed in this study; **a** 5, Sampula cemetery in Xinjiang, ca. 2,000 cal BP; 6, Shuangdun No.1 Tomb in Lu'an, Western Han Dynasty, 202 BCE–8 CE; **b** enlarged map showing the detailed location of the other four sites in Xi'an. 1, 2004CSX Tomb M110, Han Dynasty, 202 BCE–220 CE; 2, RNSM Tomb M1, Eastern Han Dynasty, 25–220 CE; 3, Yanhu Tomb M16, Eastern Han Dynasty, 25–220 CE; 4, Sanzhao Tomb M4, Western Han Dynasty, 202 BCE–8 CE

identification and preservation caused by processing and taphonomic factors. For instance, dehusking can easily break the grains into small fragments, complicating preservation and identification (Liu et al. 2019). New identification methods have been developed by studying phytoliths in the leaf and glume tissues, as well as starch grains in the seeds (Duncan et al. 2019; Liu et al. 2014, 2019). These have improved the identification of *Coix* at the species level but lack precision in distinguishing between varieties.

Recent research on phytoliths in bracts has shown clear morphological differences in modern common Panicoideae plants and in particular distinguishing various different phytolith types in the involucres of some *C. lacryma-jobi* varieties (Ge et al. 2020). The cultivated *C. lacryma-jobi* var. *ma-yuen* has BILOBATE and ELONGATE DENDRITIC/DENTATE phytoliths on the involucre surface; the wild type *C. lacryma-jobi* has BLOCKY AMOEBOID phytoliths, which are tightly packed and form a more rigid phytolith layer. While this provides a morphological basis for differentiation to the level of variety, no study has yet used this method to identify varieties of *Coix* from archaeological remains.

This is a study into the identification to variety of remains of *Coix* from two Han Dynasty tombs excavated in the city of Xi'an, China (Fig. 2). To provide a clear reference framework for identifying ancient remains of *Coix*, we also re-examined the phytolith morphology and the length and thickness of the involucres from two modern varieties, *C. lacryma-jobi* var. *lacryma-jobi* and var. *ma-yuen*, following the work of Ge et al. (2020). Rather than proposing a new identification system, the aim was to verify the published characteristics and use them as reference material for comparison with ancient samples, to contribute to the understanding of plant use and cultural practices in Han Dynasty funerary contexts.

Archaeological background

2004CSX Tomb M110

Located in the south of Xi'an, the capital city of the province of Shaanxi, Tomb M110 (34°9′33.18″N, 108°53′50.29″E) was discovered in 2004 during construction at the Shaanxi Normal University Art Museum (Fig. 2). Excavated by the Shaanxi Provincial Institute of Archaeology, the tomb consisted of an entrance passage, a covered corridor and one burial chamber. The burial chamber was built of brick with a vaulted roof, measuring 3.74 m long, 1.56 m wide and 1.62 m high. Inside it, the coffin and human skeleton had decayed away; 14 pottery vessels, coins and a bronze mirror were found (Fig. 3a). Approximately 100 seeds with white involucres were scattered on the floor near the lower limbs of the skeleton (Fig. 3b). The overall structure of the burial and the characteristics of the artefacts date Tomb M110 to the Han Dynasty (202 BCE–220 CE).

RNSM Tomb M1

Located in the northern part of the village of Sanyaocun, about 300 m southeast of the Xi'an television tower, the tomb M1 was discovered in 2001 during construction of the Xi'an ring road (34°11′20.6″N, 108°57′35.1″E) (Fig. 2).

Fig. 3 2004CSX Tomb M110; **a** interior chamber of the tomb; **b** enlarged view of the involucre remains. Photos by Daiyun Liu

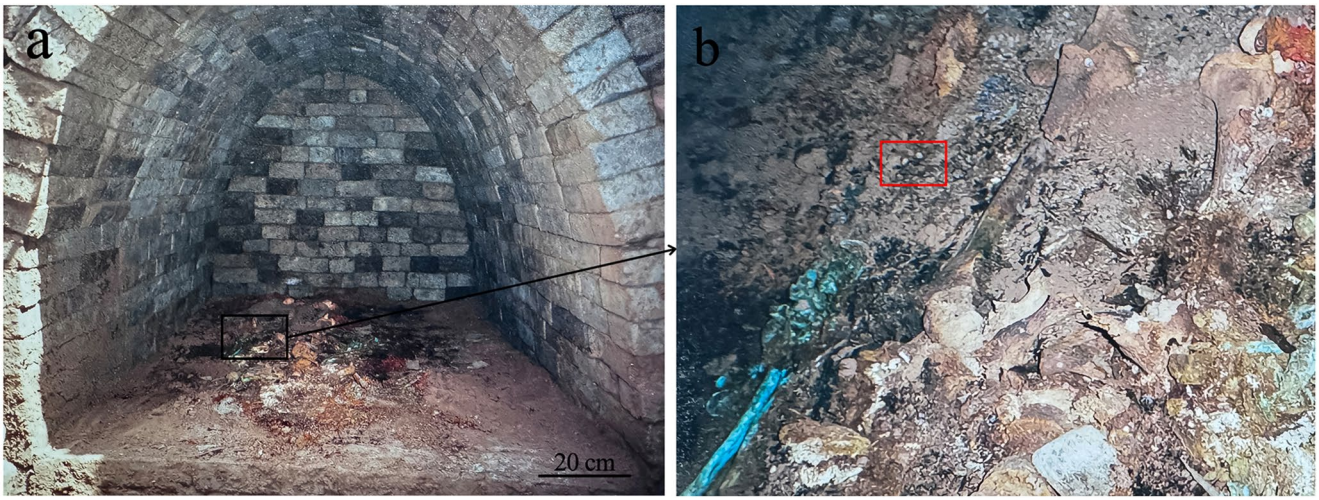

Fig. 4 RNSM Tomb M1; **a** northern chamber inside of the tomb; **b** enlarged view of the involucre remains (red square). Photos by Daiyun Liu

Excavated by the Shaanxi Provincial Institute of Archaeology, this brick tomb had an entrance passage, a covered corridor and four burial chambers. A total of 69 artefacts were found there, including pottery, bronze artefacts, iron tools, jade, lead objects and glassware. The eastern chamber was 2.98 m wide and 2.8 m long, and contained buried pottery but no human skeleton. The western chamber was 1.84 m wide and 2.7 m long and contained two human skeletons, identified as one male and one female. The southern chamber was 1.2 m wide and 1.2 m long and contained a wooden cart and two wooden horses, but no skeleton. The northern chamber (Fig. 4a) was 1.48 m wide and 2.7 m long, and contained a male skeleton with three well-preserved remains of *Coix* involucres near the hand (Fig. 4b). The overall structure of the burial and the characteristics of the finds, especially bronze mirrors and coins, date Tomb M1 to the Eastern Han Dynasty (25–220 CE).

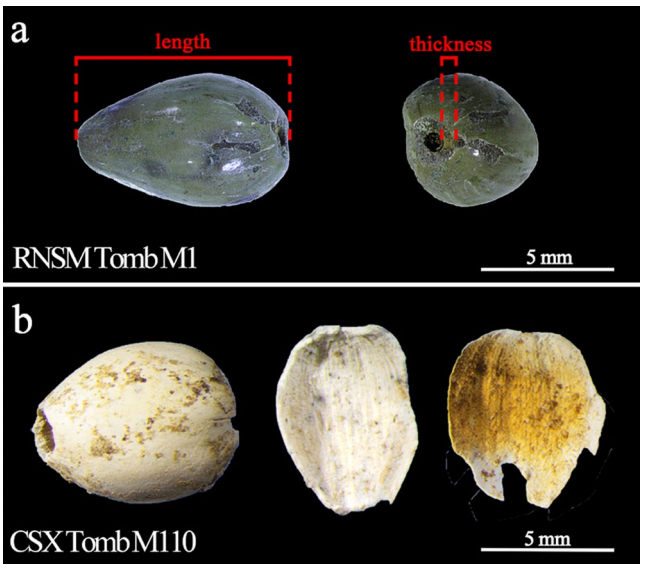

Fig. 5 Morphological and anatomical characters of the whole involucres; **a** from tomb M1; **b** M110

Materials and methods

For modern reference material, specimens of *Coix lacryma-jobi* var. *lacryma-jobi* (Fig. 1a) and *C. lacryma-jobi* var. *mayuen* (Fig. 1b) were obtained from local produce markets in the provinces of Anhui and Fujian. The ancient involucral remains from the two tombs were collected directly on site by the excavation teams and sent to the laboratory for analysis.

Macrobotanical identification of the ancient specimens was done by Professor Hongen Jiang, a specialist, by morphological comparison with reference collections at the Peking Herbarium, Institute of Botany, Chinese Academy of Sciences.

The morphological characteristics of the ancient specimens were first studied under a Nikon SMZ800N stereomicroscope at the Institute of Archaeological Science, Fudan University. Then both ancient and modern specimens were processed with wet oxidation methods to extract the phytoliths from their involucres at the Bio-Archaeology Laboratory in the Department of Archaeological Sciences, Leiden University, The Netherlands. The lengths and thicknesses of both modern and ancient specimens were measured, following the method illustrated in Fig. 5.

Absolute radiocarbon dating of an involucre specimen from Tomb M110 was done at Peking University. The slight differences between untreated and pre-treated seeds did not affect the results of the isotope values (Reed and Wallace 2024), so we did not pre-treat the samples. The date was calibrated using the IntCal 20 calibration curve (Reimer et al. 2020) and OxCal v. 4.4.2 (http://c14.arch.ox.ac.uk/oxcal).

Extraction of the phytoliths by wet oxidation preparation followed the procedure of Lu et al. (2009), with minor modifications. The involucre samples were treated with 20 ml of 65% nitric acid (HNO_3) in a beaker which was then gradually heated on a hot plate to oxidize the organic matter. After the samples had dried, an additional 20 ml of 65% HNO_3 was added, and they were kept at room temperature for 2 to 5 days until they became transparent. The samples were then heated again until they became dry, then 20 ml of 10% hydrochloric acid (HCl) was added and they were left at room temperature for 12 h to remove carbonate impurities. They were then transferred to a 50 ml centrifuge tube and 45 ml of purified water was added. The mixture was centrifuged twice at 2,000 rpm for 10 min to wash away the chemical residues. Then the samples were gently transferred with tweezers to microscope slides. A small amount of anhydrous ethanol was added with a pipette and burnt to evenly disperse and dry the sample. Finally, a small amount of neutral balsam was added to the slide and a cover slip was placed on top. All these steps were done within a fume hood. The slides were examined using a Zeiss Axioscope microscope at 200×, 400× and 630× magnifications. Phytolith morphology nomenclature follows ICPN 2.0 rules (International Committee for Phytolith Taxonomy 2019).

Results

Radiocarbon dating

The involucre from 2004CSX Tomb M110 was radiocarbon dated to 2,185 ± 40 BP, with a calibrated 2σ range (95.4%) of 2,328–2,095 cal BP (91.4%) and 2,089–2,057 cal BP (4.0%), corresponding to the early Western Han Dynasty.

Identification of modern phytoliths

In modern *Coix lacryma-jobi* var. *ma-yuen*, the phytolith layer of the involucre is composed of alternating arrangements of short and long cells (Fig. 6a–e). Two types of short cell phytoliths were found, Bilobate, with concave ends on the outer periclinal surface in planar view, and Cross, with three or four roughly equal lobes. The long cell phytoliths were Elongate dendritic/dentate, elongated with a rectilinear outline and the margins of the long side were dendritic or dentate.

In the involucres of modern *C. lacryma-jobi* var. *lacryma-jobi*, a single type of phytolith was observed (Fig. 6f–h). These Blocky amoeboid phytoliths were irregularly blocky and arranged close together, with protrusions along the edges and granules on some surfaces.

These observations are consistent with the characteristics of the different varieties of *Coix lacryma-jobi* (Ge et al. 2020), further supporting the reliability of their findings.

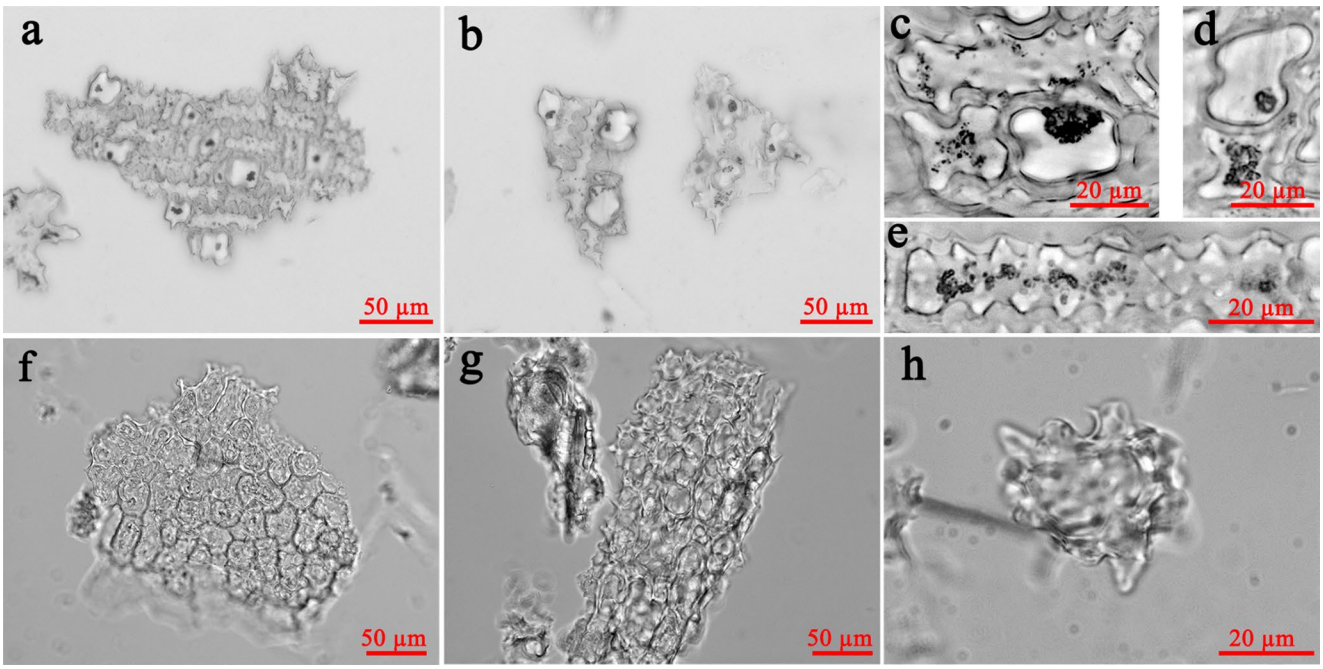

Fig. 6 Phytoliths in involucres of modern *Coix lacryma-jobi*; **a–e** phytoliths in *C. lacryma-jobi* var. *ma-yuen*, consisting of short cells (Bilobate or Cross) and long cells (Elongate dendritic/dentate); **f–h** phytoliths in *C. lacryma-jobi* var. *lacryma-jobi*, consisting of more closely packed Blocky amoeboid

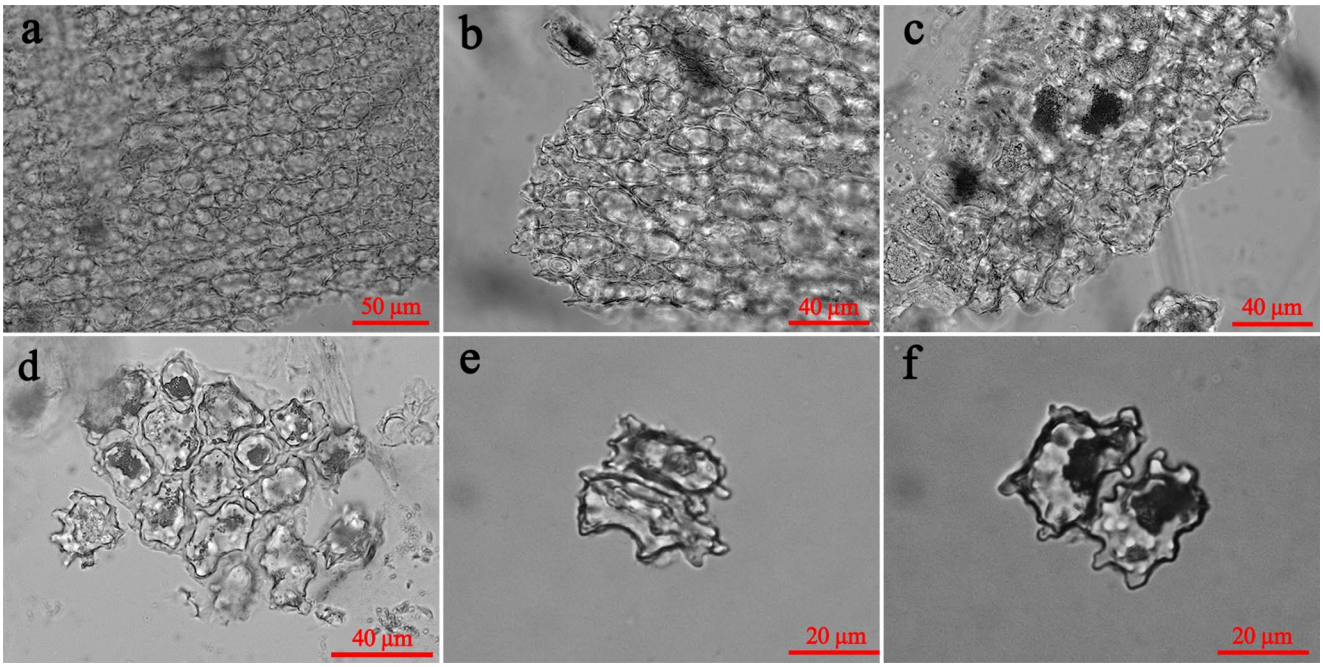

Fig. 7 Phytoliths from involucres of ancient *Coix lacryma-jobi*; **a**, **b**, **d** and **e**, from the remains in 2004CSX tomb M110; **c** and **f**, from the remains in RNSM tomb M1; **a**, **b**, **c**, and **d** show the tightly packed BLOCKY AMOEBOID phytoliths; **e** and **f** are single BLOCKY AMOEBOID ones

Observation and measurement of ancient and modern involucres

The *Coix* remains from RNSM Tomb M1 had complete involucre structures. They were teardrop-shaped, glossy and featured dark stripes, with no signs of charring. The involucres were 7.5 to 8.0 mm long (n = 3) and 0.4 to 0.7 mm thick (Fig. 5a). Among the four known varieties of *C. lacryma-jobi*, var. *lacryma-jobi* and var. *ma-yuen* involucres are teardrop-shaped (Fig. 1), while those of var. *stenocarpa* are more elongated, and var. *puellarum* are flatter and rounder (Jiang et al. 2008). Therefore, the morphological characteristics of the archaeological remains are consistent with var. *lacryma-jobi* and var. *ma-yuen*. One distinguishing feature between these two is the thickness of their involucres. Based on our measurements on modern specimens, the former ranges from 0.33 to 1.8 mm (n = 42) and the latter from 0.13 to 0.5 mm (n = 50). Considering this, our involucre remains are more likely to belong to var. *lacryma-jobi*.

Most of the ancient specimens from Tomb M110 were fragmented, making it difficult to determine the species from their appearance. Some relatively well-preserved specimens were teardrop-shaped and showed no signs of charring. The involucres were 7.1 to 8.0 mm long (n = 22) and about 0.26 mm thick, with vertical stripes on the inner side (Fig. 5b). These morphological features suggest they may belong to var. *lacryma-jobi* or var. *ma-yuen*.

Identification of ancient phytoliths

As shown in Fig. 7, the surfaces of the involucres from tombs M1 and M110 revealed a layer of closely packed, irregularly shaped BLOCKY AMOEBOID phytoliths, which corresponds to the phytolith morphology of modern *C. lacryma-jobi* var. *lacryma-jobi* involucres. (Fig. 6d–f). In contrast, the phytoliths in involucres of modern var. *ma-yuen* are more loosely arranged ELONGATE DENDRITIC/DENTATE, BILOBATE and CROSS types (Fig. 6a–c). This comparison with the phytolith types of modern specimens provides further evidence that the ancient involucres are *C. lacryma-jobi* var. *lacryma-jobi*.

Discussion

By studying both the macroscopic anatomy of the whole involucres and their phytoliths, the remains of *Coix* involucres from the two tombs were identified as *C. lacryma-jobi* var. *lacryma-jobi*. This identification allows for a more detailed discussion of the possible uses of this plant and its significance in funerary contexts.

Although the archaeological record in China indicates the consumption of *Coix* grain, as noted in the introduction, the lack of identification of the variety makes it difficult to determine the specific uses of the different varieties in the past. Ethnographic records and traditional customs show that both ancient and modern Chinese prefer the softer

variety of *Coix* for food due to its higher starch content and better taste, while the variety with hard involucres is mainly used for making beads. Based on this, we speculate that the *Coix* grain recorded in ancient texts as food and medicine was probably var. *ma-yuen*. Interestingly, one written record from the Song Dynasty (960–1279 CE) described the use of beads made from *Coix* to treat hernias. However, the description was vague, leaving uncertainty about the specific variety used. Given that var. *lacryma-jobi*, rather than var. *ma-yuen* was used for beads, the possibility that the harder variety was also sometimes used as food in ancient China cannot be completely ruled out.

In the two tombs analysed in this study, the *Coix* grains were placed close to the body, indicating a degree of significance for the deceased. One common funerary custom during the Han Dynasty was burying edible plants in pottery granaries to provide food for the dead (Liao et al. 2022a). However, there is no strong evidence to suggest that the grains in this study were meant as food, as they were neither in pots nor charred. Similarly, no definitive evidence, such as strings for threading beads or having been placed around the neck or wrists, was found to support their use as ornaments.

It is noteworthy that *Coix* macroremains have also been found in three other Han Dynasty tombs (Fig. 2): the Sanzhao Tomb M4 (late Western Han) and Yanhu Tomb M16 (middle Eastern Han) in Xi'an (Zhao 2010), as well as the Shuangdun Tomb No.1 (middle Western Han) in Lu'an (Zhao and Wang 2016). In these finds, the *Coix* grain was stored in a pottery granary in Sanzhao Tomb M4, while in the others it was scattered on the tomb floor and inside the coffin for unknown reasons. Unfortunately none of these remains have been identified to variety. Based on the on-site excavation of Tomb M110, the excavators suggested that these grains had probably been placed on the coffin and had then fallen onto the tomb floor as the coffin decayed. If this interpretation is correct, this practice may reflect an overlooked aspect of Han Dynasty funerary customs. According to legend, Yu (the third king in ancient Chinese mythology) was conceived after his mother ate *Coix* grain, illustrating its special significance in ancient China. According to the evidence presented here, we propose that selecting *Coix* grains as burial items and placing them on coffins or near human remains during the Han Dynasty, without the intention of consumption, may represent a funerary ritual with symbolic significance, similar to the use of colour pigments and plants placed on coffins, among human remains as grave goods, or on tomb floors, in other ancient cultures (Leroi-Gourhan 1975; Wu et al. 2017; Bueno-Ramírez et al. 2019; Zhang and He 2019; Marinova 2023).

Conclusions

In this study, macrobotanical analysis has suggested that the remains of *Coix* involucres excavated from two Han Dynasty tombs were *C. lacryma-jobi*, and phytolith analysis has enabled further identification as *C. lacryma-jobi* var. *lacryma-jobi*. This is the first report of the identification of ancient *Coix* remains to variety level by using phytolith evidence. Our findings suggest that the placing of *Coix* grains in Han Dynasty tombs, potentially showing their cultural and symbolic significance, is an aspect of Han funerary customs that was previously overlooked. However, key questions remain to be answered, such as the origins of this practice, its prevalence, what were its specific symbolic meanings, and whether the uses of different ancient *Coix* varieties can be clearly distinguished.

Overall, *Coix* is an overlooked but significant plant in ancient China. The stable physical and chemical properties of phytoliths provide a methodological advantage for identifying *Coix* in diverse archaeological contexts, especially where macroremains are poorly preserved. Establishing a reference database for finds of ancient varieties of *Coix* and their archaeological contexts in different regions and time periods will be the focus of our future research.

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Declarations

Conflict of interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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