

Ancient Chinese Literature Reveals Pathways of Eggplant Domestication

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- **Background and Aims** Changes in key traits occurring during the processes of plant domestication have long been subjects of debate. Only in the case of genetic analysis or with extensive plant remains can specific sets of changes be documented. Historical details of the plant domestication processes are rare and other evidence of morphological change can be difficult to obtain, especially for those vegetables that lack a substantial body of archaeological data. Botanical records chronicled in the ancient literature of established ancient civilizations, such as that of China, are invaluable resources for the study and understanding of the process of plant domestication. Here, the considerable body of ancient Chinese literature is used to explore the domestication process that has occurred with the eggplant (*Solanum melongena*), an important vegetable in Old World.
- **Methods** Information about eggplant domestication in the ancient Chinese literature was retrieved using a variety of methods. The information obtained was then sorted by taxon, examined and taxonomic identifications verified.
- **Key Results** It was found that the earliest record of the eggplant documented in ancient Chinese literature was in a work from 59 bc. As far as is known, this is the earliest reliable and accurately dated record of eggplant in cultivation. The analysis reveals that the process of domestication of the eggplant in China involved three principal aspects of fruit quality: size, shape and taste. These traits were actively and gradually selected; fruit size changed from small to large, taste changed from not palatable to what was termed at the time sweetish, and that over time, a wider variety of fruit shapes was cultivated.
- **Conclusions** The results indicate that, in addition to data gleaned from archaeology and genetics, evidence as to changes in key traits occurring during the process of plant domestication and selective forces responsible for these changes can be traced through the ancient literature in some civilizations.

Key words: *Solanum melongena*, ancient Chinese literature, domestication process, domestication traits, selective forces.

INTRODUCTION

Changes in key traits occurring during the process of plant domestication are mostly inferred by reference to wild relatives or to primitive land races, especially for those crops outside western Eurasia, and therefore are subject to continuous debate (Ladizinsky, 1998; Diamond, 2002). Only in the case of genetic analysis (e.g. Doebley *et al.*, 1997) or with extensive plant remains (e.g. Zohary and Hopf, 2000) can specific sets of changes be documented. Historical details of the plant domestication processes are rare and other evidence of morphological change can be difficult to obtain, especially for those vegetables that lack a substantial body of archaeological data.

With potato (*Solanum tuberosum*) and tomato (*Solanum lycopersicum* = *Lycopersicon esculentum*), eggplant or aubergine (*Solanum melongena*) is one of the three most important cultivated crops in the Solanaceae (FAO, 2007). The origin and domestication of eggplant, however, is still a challenging question. Hypotheses about the origins and evolution of eggplants have in the past been based on inference (Lester and Hasan, 1991; Choudhury, 1995) owing to the lack of archaeological evidence for origins and early domestication. Lester and Hasan (1991) suggested that the eggplant was derived from the subtropical species *S. incanum*, native to north Africa and the Middle East. They suggested that the wild progenitor developed as a

garden weed, and through human selection in south-east Asia, progressively more advanced cultivars were selected. They divided *S. melongena* into a series of morphological types or gene pools, identified as A (putative wild progenitors) to G (advanced cultivars), and suggested eastwards movement of cultivated forms, with subsequent movement westwards complicating patterns of character change (Lester and Hasan, 1991). AFLP (Mace *et al.*, 1999) and DNA sequence (T. Weese and L. Bohs, University of Utah, USA, pers. comm.) data sets support the broad relationships between *S. incanum* and its African relatives and the eggplants, but the data sets used were relatively small and did not include Chinese samples. None of the *S. incanum* s.s. group as currently understood is present in China or adjacent south-east Asia; Lester and Hasan (1991) hypothesized that the true wild progenitor of the eggplant was an undiscovered species in the savanna ecosystems of the region. No Asian prickly solanums have been included in any phylogenetic analyses of relationships in *Solanum*, making this a priority for understanding not only evolution in *Solanum* in general, but the origin of the eggplant in particular.

Several candidate areas for eggplant domestication have been proposed: India and south-east China (Doganlar *et al.*, 2002a), China, India and Thailand (Doganlar *et al.*, 2002b), Burma to Indo-China (Daunay *et al.*, 2001) and south-east Asia (Lester and Hasan, 1991). Evidence for each of these is based on presence of weedy forms (putative

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progenitors for many authors) and literature references. The authors' field work in recent years has revealed the presence of wild, weedy forms of eggplants in southern China, supporting a south-east Asian origin, but the possibility of multiple domestication events has not yet been investigated.

Evidence for an Indian domestication has been drawn from examination of the Sanskrit literature. Khan (1979) cited common names for the eggplant from various works, with the oldest dated between the 3rd century BC and the 3rd century AD. His citation of the oldest Sanskrit work from 300 BC, however, was based on a secondary source (Monier-Williams, 1899), and the time range he estimated cannot be substantiated, due to the many revisions of the work in question over the centuries (S. Y. Ye, Peking University, China, pers. comm.). It is essential that the primary sources of exact dates be re-examined in order to explore this further. These Sanskrit names have been regarded as evidence that the eggplant was first cultivated in India, although no more detailed and continuous evidence about the domestication process can be gleaned from the Indian ancient literature. In contrast, in depth examination of the ancient Chinese literature has revealed a rich set of references to many cultivated plants (Li, 1969; Keng, 1974; Walters, 1989), including the eggplant. The Chinese literature is especially characterized by its antiquity, continuity and coherence (Needham, 1986). Much written evidence about the eggplant can be found in this vast reservoir. It is a treasure trove of information about plant domestication (Brestschneider, 1871; Li, 1969) and has previously usually only been referenced from secondary sources. The purpose of the present study is to use primary sources to document as many of these historical data as possible and, by piecing them together, to draw a relatively authentic picture of the process of the domestication and evolution of the eggplant in China.

MATERIALS AND METHODS

Details of the ancient Chinese literature

The size and scope of the ancient Chinese literature has been a major obstacle to using it to study both uses of plants and the domestication process. This literature is huge and complex and includes books about botany, agricultural practice, Chinese herbals, historical documents and relics, local chronicles, literary works, dictionaries and *Leishu*. *Leishu* are a class of works combining to some extent the characteristics of encyclopaedias and concordances, embracing the whole field of literature, methodically arranged according to subjects, each heading giving extracts from former works on the subject in question, e.g. *Gujin Tushu Jicheng (Imperial Encyclopaedia)* cited in this paper. The complete extent of this botanical literature is still unclear even now. In an early *magnum opus* on ancient Chinese botanical literature (Brestschneider, 1882), for example, 1148 books were included; nevertheless this treatment and description was relatively superficial and contained mistakes. The general condition and complexity of the ancient Chinese botanical literature were discussed to some extent in another Western compendium (Needham, 1986), but today, work is being

actively undertaken by Chinese botanists in this field. Therefore, retrieving all the information in the huge ancient Chinese literature is a great challenge to its use in research. In the previous studies on eggplant (or aubergine, *Solanum melongena* L.) involved in ancient Chinese literature (Institute of Vegetables and Flowers of the Chinese Academy of Agricultural Sciences, 2001; Daunay and Janick, 2007), very few works were considered. The most often cited works are *Qimin Yaoshu* and *Nanfang Caomu Zhuang*. Some papers (e.g. Daunay and Janick, 2007) cite the *Qimin Yaoshu* as two works using alternative spellings; this illustrates the importance of consultation of the primary Chinese literature.

Information retrieval methods

Here, we attempted to retrieve the information about eggplant domestication from the ancient Chinese literature in a variety of ways, and we are relatively certain that all important records were retrieved and analysed. Three methods were adopted.

- (1) Retrieval of information from important books on botanical subjects that have been important and significant in the development of Chinese ancient botany and therefore partly studied by the scholars. Most of these have been compiled and reprinted in modern times.
- (2) Consultation of a wide variety of *Leishu* and *Congshu* (encyclopaedias and collected books), such as *Gujin Tushu Jicheng (Imperial Encyclopaedia)* and *Siku Quanshu (Complete Library of the Four Treasuries)*, where many ancient books that have been lost through historical time have been partly preserved; these are not easily accessible at present.
- (3) Consultation of electronic databases of non-botanical ancient Chinese literature, for example, the database for the poetry of the Tang Dynasty (<http://chinese.pku.edu.cn/tangPoem/>). These databases are important for special studies on plant domestication, although most databases only present partial information and re-analysis of the primary records is necessary.

Data analysis

Those records that repeated early statements or descriptions and those not closely related to the questions of changes during domestication that are being addressed are excluded from the present analysis. In total, 189 records from 76 books were included in the final analysis. Information obtained was sorted by taxon, examined and taxonomic identifications verified. The data presented here are the most significant to trajectories of character changes during domestication of the eggplant.

RESULTS

The earliest record and early dispersal in ancient China

The earliest written record of the eggplant documented in Chinese ancient literature is the statement of Wang Bao in

his work *Tong Yue* in 59 BC (Wang, 59 BC). He states: ‘In the second month of the year, the Spring Equinox . . . separate and transplant seedlings of eggplant and scallion’. About the same time, Yang Xiong in his famous *A Rhapsody on Metropolitan of Shu* (Yang, 1st century BC to 1st century AD) mentioned: ‘The eggplant is included as one of the vegetable crops’. Both of these records referred to the eggplant that was then planted on the Chengdu Plain of south-west China (Fig. 1). These records, although rather brief, revealed that the eggplant was already being specifically cultivated in gardens as a crop, not a wild form collected from the surrounding habitat. They also indicate that the domestication of the eggplant took place not later than 59 BC in China. As far as is known, this is the earliest record of eggplant, the time of which is precisely determined.

Eggplant cultivation in southern China and northern Vietnam is documented in *Nanfang Caomu Zhuang* (*Nan-fang ts’ao-mu chuang*) (Ji, 304; Fig. 1). Thereafter, from the 4th to the 6th century (Jin Dynasty and Northern and Southern Dynasties), written records of the eggplant referred mostly to the crop cultivated in the lower Yangtze River regions (Shen, 5th and 6th centuries; Li, 659; Sima, 1084) (Fig. 1), and by the early 6th century, eggplant was widely grown in the middle and lower

Yellow River regions (Jia, 6th century; Fig. 1). By the Song Dynasty in the early 11th century, eggplant cultivation had spread all over China, and the crop had differentiated into a number of different cultivars (Su, 1069).

Changes in key traits during the process of domestication

The process of domestication of the eggplant in China involved three principal aspects of fruit quality: size, shape and taste.

Size. The *Qimin Yaoshu* of the early 6th century AD (Jia, 6th century) first described the size of eggplant fruit as ‘as large as *Danwan*’. At that time a *Danwan* was a mud or an iron pellet used in a slingshot and the term was often used to describe very small or tiny objects. By the 12th and 13th centuries (South Song Dynasty), the fruit was described as ‘as large as *Zhan*’ (Wu, 12th and 13th centuries), a teacup of the time of about 10 cm diameter. In AD 1069 (North Song Dynasty) a drawing (Fig. 2A) of the eggplant appeared in *Tu Jing Bencao* (Su, 1069); this is, as far as is known the first drawing of the eggplant; the plant has no prickles on the stems or leaves, and the fruits are round and apparently much larger than a pellet. No more than 200 hundred years later, a coloured drawing of the eggplant appeared in

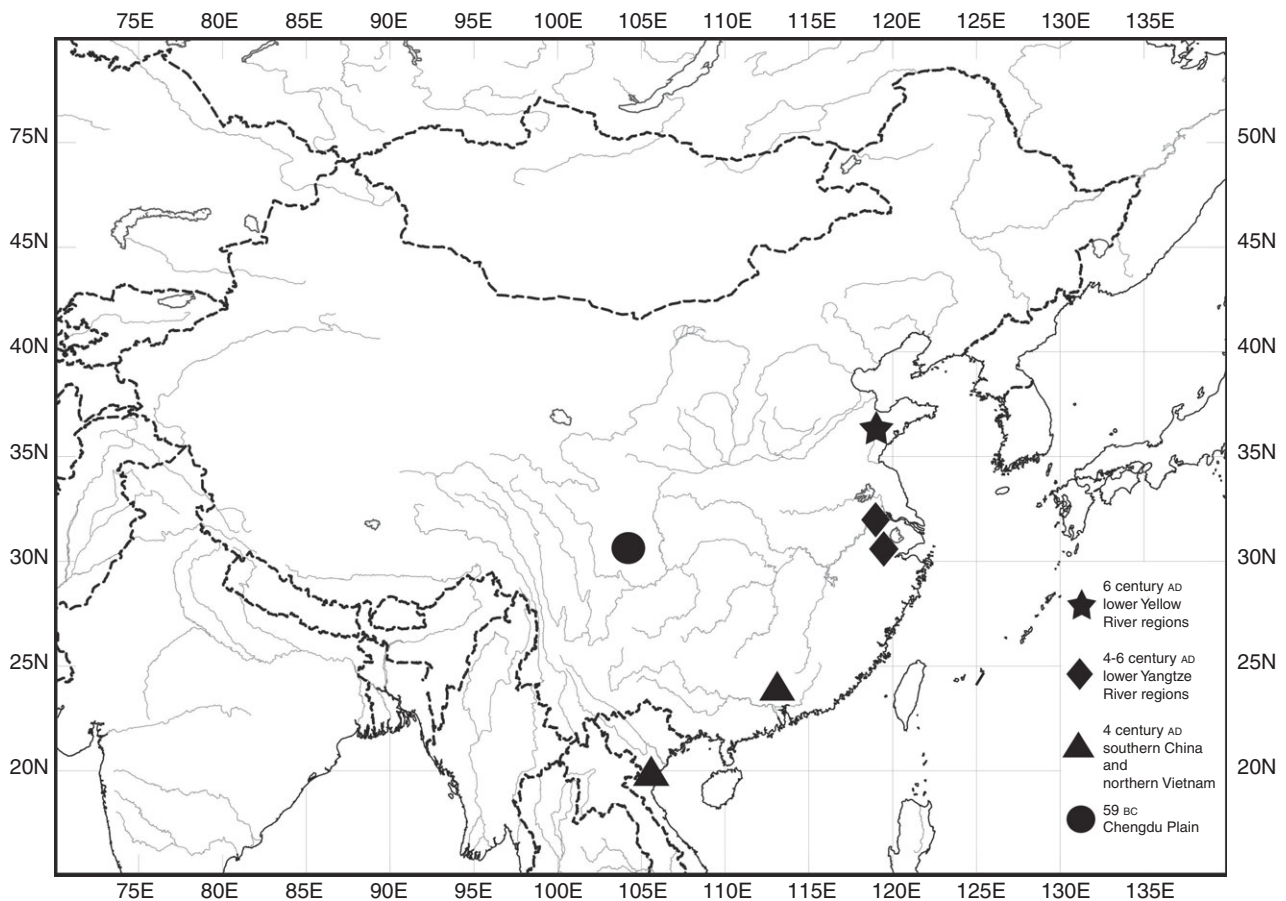


FIG. 1. Distribution map of eggplant references in the early Chinese literature, before the crop's spread across the entire region by the 6th century. Black symbols indicate documented sites recorded in ancient Chinese literature.



FIG. 2. Drawings of eggplant from selected works of the ancient Chinese literature: (A) *Tu Jing Bencao* in AD 1069 (North Song Dynasty); (B) *Bencao Gangmu* in AD 1590 (Ming Dynasty); (C) *Sancai Tu Hui* in AD 1609 (Ming Dynasty); (D) *Zhiwu Ming Shi Tu Kao* in AD 1848 (Qing Dynasty). Reproduced by permission of the Chinese Academy of Sciences.

Lüchanyan Bencao (Fig. 3) (Wang, 1220), a book produced in 1220 (South Song Dynasty) based on plants from Zhejiang Province, eastern China. This painting shows that the fruit were purple in colour and the ratio of fruit to the flowers and leaves indicates that the size of the fruit of the eggplant of that time was much larger than a pellet. In the 16th century (Ming Dynasty), Li (1590) described the fruit of the eggplant as ‘as round as Chinese trichosanthes’ (*Trichosanthes kirilowii* Maxim., Cucurbitaceae, with fruits approx. 7–10 cm in diameter) in the *Bencao Gangmu*. During the Qing Dynasty (17th to 19th centuries) numerous cultivars were



FIG. 3. Coloured drawing of eggplant from *Lüchanyan Bencao* in AD 1220 (South Song Dynasty). Reproduced by permission of the Chinese Academy of Sciences.

recorded in local chronicles. In the *Chronicles of Jiangxian* (Shanxi Province) (Chen, 1726), for example, a kind of eggplant is described with a fruit ‘as large as Yu, and the weight of the largest one could be up to two jin and ten liang’. Yu is a kind of wide-mouthed receptacle for holding tea or water, and according to the weight system used during the Qing Dynasty, two jin and ten liang equals 1549 grams. This is a very large eggplant fruit even by modern standards. All of these reports indicate that ancient Chinese farmers were continuously selecting eggplants with larger fruits.

Shape. Eggplants recorded in early Chinese literature were mostly round-shaped (Jia, 6th century; Su, 1069; Wu, 12th and 13th centuries; Wang, 1220). The first recorded long fruit of the eggplant appeared in the 14th century (Yuan Dynasty) work entitled *Wang Zhen Nongshu*: ‘a cultivated ‘Shui Qie (水茄)’ with long fruit and a slightly sweet taste, could quench one’s thirst.’ (Wang, 14th century). The *Bencao Gangmu* (Li, 1590) of the Ming Dynasty recorded eggplants with fruits ‘as long as four to five cun (寸; approx. 12.8–14 cm in the length system of the Ming Dynasty)’ (Fig. 2B). In the 17th century (Qing Dynasty) a number of cultivars with long rod-shaped fruit named ‘Chansi Qie (缠丝茄)’ were recorded (Chen, 1726). The name refers to the length of the fruit; ‘Qie (茄)’ is the part of the name indicating an eggplant variety, while ‘Chansi (缠丝)’ described the long, thin fruit. Today there are still long fruit eggplant cultivars like ‘Chansi Qie’ grown in East China; ‘Ningbo Teng Qie’, for example, has a length of 30–40 cm with a diameter of only 1.7–2.0 cm (Institute of Vegetables and Flowers of the Chinese Academy of Agricultural Sciences, 2001). At about the same time, an egg-shaped eggplant was drawn in *Sancai Tu Hui* (Wang and Wang, 1609; Fig. 2C). By the late Qing Dynasty numerous cultivars with different shapes were recorded in the many local chronicles published at that time (Chen, 1726). These varieties were in large part similar to those grown today by Chinese farmers, and comprised round types, egg-shaped types and long, thin types. The most common

TABLE 1. Changes during the domestication of the eggplant recorded in ancient Chinese literature

	Century					
	-1 to 1	5-6	8-9	12-13	14-16	18-19
Size	-	As large as <i>Danwan</i>	-	As large as <i>Zhan</i>	Still larger	As large as <i>Yu</i> , weight up to 1549 g
Shape	-	Round	-	Round, oval	Round, oval, long	Round, ovoid, long, and other shapes
Taste	-	Not palatable	Delicious	Sweetish and delicious	Still sweeter	Sweeter and more delicious

cultivars were pictured in the famous botanical magnum opus *Zhiwu Ming Shi Tu Kao* (Wu, 1848; Fig. 2D). It seems that more different shapes of eggplant fruit were selected and preserved as the domestication process continued.

Taste. In the early 6th century AD the taste of eggplant fruit was described as ‘like the flavour of small beans’ in the *Qimin Yaoshu* (Jia, 6th century), and according to other records of that time (Li, 659), the eggplant was not considered a very palatable vegetable. Later, however, in *Youyang Zazu* (Duan, 9th century), a book written in the Tang Dynasty, it was chronicled that ‘Buddhist monks roasted and ate eggplants, the taste was very delicious’. In the 12th and 13th centuries (South Song Dynasty), some books on agriculture (e.g. Wu, 12th and 13th centuries) recorded the method of using sulfur to make the fruit flesh sweeter (less bitter). Huang Ting-Jian, a poet of the South Song Dynasty even wrote several poems in praise of silver-coloured (white) eggplant cultivars with a delicious taste that could be eaten raw (Huang, 12th and 13th centuries). All of these references show that the Chinese farmers selected for improved taste in a variety of ways, but particularly for the elimination of bitter flavour in the fruits.

Some selective forces during the domestication process

As eggplant cultivation spread across China by the 6th century AD, many advanced techniques for eggplant were developed by Chinese farmers. Three main kinds of cultivation methods were adopted in the 6th century (Jia, 6th century), including ‘planting in beds (rectangular pieces of land in a field, separated by ridges) in the second month’, ‘planting in the 10th month’ and ‘planting in spring but not in beds’. Water selection of good seeds for reproduction based on the difference in density between plump and shrivelled seeds was practiced (Jia, 6th century). A complex fertilization method involving the use of ashes from old leaves as mulch called ‘Jia Qiezi (嫁茄子)’ was also developed in the 9th century AD (Tang Dynasty) to improve fruit yield (Duan, 9th century). In the 14th century (Yuan Dynasty), a technique for growing seedlings in a temperature-controlled room in winter for early harvest was developed (Lu, 1330).

Diversity of the eggplant in China

Both the intensive and exuberant activities of ancient Chinese farmers in the domestication of the eggplant, and

the vast territory of China are clearly factors resulting in the large number of modern eggplant cultivars in China. Today, more than 200 native eggplant cultivars of fine quality are formally registered (Institute of Vegetables and Flowers of the Chinese Academy of Agricultural Sciences, 2001). The vast expanse of China has also led to many vernacular names for the eggplant and its varieties. The following names can be found in ancient Chinese literature: ‘Qie (茄)’, ‘Qiezi (茄子)’, ‘Zipengheng (紫膨亨)’, ‘Zigua (紫瓜)’, ‘Aigua (矮瓜)’, ‘Qiegua (茄瓜)’, ‘Kunwei (昆味)’, ‘Luosu (落苏)’, ‘Luosu (酪酥)’ and ‘Xiaogu (小菰)’. ‘Luosu (落苏)’, first recorded in the 7th century, is still used in vernacular dialect of the Shanghai and Zhejiang areas for eggplants with long, thin fruits.

DISCUSSION

From the historical evidence we have collected from the ancient Chinese literature, a vivid picture of the process of the domestication and evolution of the eggplant in the region has emerged. These records reveal that the cultivation of the eggplant took place in China not later than the 1st century BC; that the fruit size of the eggplant was actively and gradually selected and changed from small to large; that the taste changed from not palatable to what was termed at the time sweetish and that, over time, more kinds of shape of the eggplant were selected and preserved (Table 1).

Some of these domestication traits (fruit size and shape) have been shown to be controlled by a very limited number of target loci. Using QTL analyses, Doganlar *et al.* (2002b) showed that fruit size of the eggplant was controlled primarily by only two loci (*fw2-1* and *fw9-1*) on linkage groups 2 and 9, and diversification in fruit shape primarily controlled by two loci (*fs2-1* and *fs7-1*) on linkage groups 2 and 7. The two other domestication traits investigated – prickliness and fruit + plant colour – were shown to be determined primarily by a single locus on linkage group 6 (*lp6-1*), and a major locus on linkage group 10 (*fap10-1*, *pa10-1*), respectively (Doganlar *et al.*, 2002b). Documentation of these latter two domestication traits in the ancient Chinese literature, however, is too incomplete to infer any evolutionary trends. This may reflect to some extent the lower importance given to prickliness and colour (of both fruit and plant) than to fruit size and shape during selection of cultivars in ancient China. Further research is needed to clarify this. Taste of the eggplant, another important domestication trait, however, was not examined in Doganlar *et al.*’s QTL analyses

(Doganlar, 2002b). Our investigations in southern China confirmed that fruit taste of weedy forms and the primitive cultivars of eggplant are usually unpalatable and more bitter than that of more advanced cultivars with larger fruit. Fruit bitterness in eggplant is caused by two kinds of steroidal saponosides (Aubert *et al.*, 1989). It will be interesting and challenging to explore the genetics of taste modification from bitter to less bitter (sweet) taste that have occurred during the domestication of eggplant.

The processes of artificial selection on vegetables are usually slow and gradual (Ladizinsky, 1998). The specific stages of eggplant domestication described in the ancient Chinese literature are not unambiguously delineated. But, as the Chinese history and civilization is relatively continuous and independent, the stages described may have been an extension of early domestication in the region. It is amazing that many details of our findings based on historical records support the suppositions about the domestication process inferred by other authors (Choudhury, 1995; Lester and Hasan, 1991; Daunay *et al.*, 2001). Furthermore, from this detailed ancient literature, we now have insights into some selective forces by which Chinese eggplant farmers brought about these changes through agricultural practice. The present data provide the earliest direct evidence for the domestication process of the eggplant occurring in Asia, and represent a novel approach to understanding the process of plant domestication. These indicate that, in addition to data gleaned from archaeology and genetics (Zeder *et al.*, 2006), evidence as to changes in key traits occurring during the process of plant domestication and selective forces responsible for these changes can be traced through the ancient literature in some civilizations.

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