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The ancient dispersal of millets in southern China: New archaeological evidence

Zhenhua Deng,[1] Hsiao-chun Hung,[2] Xuechun Fan,[3] Yunming Huang[3] and Houyuan Lu[1,4,5]

Abstract

This study presents the first direct evidence of millet cultivation in Neolithic southeast coastal China. Macroscopic plant remains and phytoliths, together with direct accelerator mass spectrometry (AMS) radiocarbon dates on crops, have shown that both foxtail millet and broomcorn millet were cultivated with rice in the Huangguashan and Pingfengshan sites in Fujian province around 4000–3500 cal. BP. Ratios of different parts of crop remains revealed that crop processing activities such as dehusking and sieving were conducted within the site and thus demonstrated the local production of these crops. The new data, especially the discovery of foxtail millet and broomcorn millet, have greatly changed the current knowledge about the ancient distribution of millet in South China and have now identified southeast China among the potential source-region of Neolithic crops transported overseas to Taiwan and Island Southeast Asia. This study further draws a potential dispersal route of Austronesian languages and people from southern China through Taiwan throughout Southeast Asia.

Keywords

crop distribution and dispersal, late Neolithic, macroscopic plant remains, millets, phytolith, southeast coastal China

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Introduction

Current archaeobotanical evidence has proved that foxtail millet (*Setaria italica*) and broomcorn millet (*Panicum miliaceum*) were both cultivated in northern China no later than 8000 cal. BP (Liu et al., 2012; Lu et al., 2009; Stevens et al., 2016; Yang et al., 2012; Zhao, 2011a, 2011b). After 5000 cal. BP, they had spread widely in the Eurasia continent and surrounding islands. Broomcorn millet appeared in Europe after 3600 cal. BP as indicated by recent direct dating work on broomcorn millet grains from many sites (Motuzaite-Matuzeviciute et al., 2013). In the south, both foxtail millet and broomcorn millet appeared in Mainland Southeast Asia ca. 4500–4200 cal. BP (Weber et al., 2010). Another route of millet dispersal into Taiwan probably occurred at the same time (Hsieh et al., 2011; Tsang et al., 2017; see more discussions below). These findings far beyond northern China generally suggest at least three main dispersal routes of millets from their origin center(s) in northern China (Figure 1).

When we consider these southern routes of millet dispersal into Southeast Asia and Taiwan, respectively, the main source of millets in Thailand should be through Yunnan and possibly Guangxi province of southwestern China. This route eventually could be traced back to Sichuan and then Gansu province in northwest China (Guedes, 2011; Guedes and Butler, 2014; Zhang and Hung, 2010, 2015; Figure 1). By contrast, how millets diffused into Taiwan has long been an unsolved issue in the research of crop dispersal, owing to the lack of evidence in southeast China.

Regarding the source for Taiwan millets and Austronesian origins, one proposed possibility is that millets were introduced into Taiwan together with rice by maritime route from Shandong/Jiangsu farther to the north in Mainland China, which is also thought to be the first dispersal route of proto Austronesian speakers (Fuller, 2011; Sagart, 2008; Figure 1). Recently, this maritime route hypothesis proposed by linguistic research (Sagart, 2008) has been tested through a new genetic study (Wei et al., 2017). However, so far no archaeological evidence has been identified of long-distance interactions between Shandong/Jiangsu and Taiwan around 5000–4500 cal. BP. Although the tooth evulsion practices found in both Dawenkou people in Shandong (ca. 6500–4500 cal. BP) and Nanguanli people in Taiwan (ca. 5000–4500 cal. BP) could be one line of supporting evidence for this scenario, nevertheless tooth evulsion in fact has been reported from some Neolithic sites in coastal southeast China (Han and Pan, 1981; Han and Takahiro, 1996; Peng, 2009). Previously, this Shandong/Jiangsu hypothesis was based on the lack of evidence of co-occurring rice and millet cultivation in any sites of coastal southern China closest to Taiwan. Additionally, the latest genetic

[1]Institute of Geology and Geophysics, Chinese Academy of Sciences, China
[2]Department of Archaeology and Natural History, Australian National University, Australia
[3]Fujian Museum, China
[4]Center for Excellence in Tibetan Plateau Earth Science, Chinese Academy of Sciences, China
[5]University of Chinese Academy of Sciences, China

Corresponding author:
Zhenhua Deng, Institute of Geology and Geophysics, Chinese Academy of Sciences, No. 19, Beitucheng Western Road, Chaoyang District, 100029 Beijing, China.
Email: zhenhua_deng@126.com

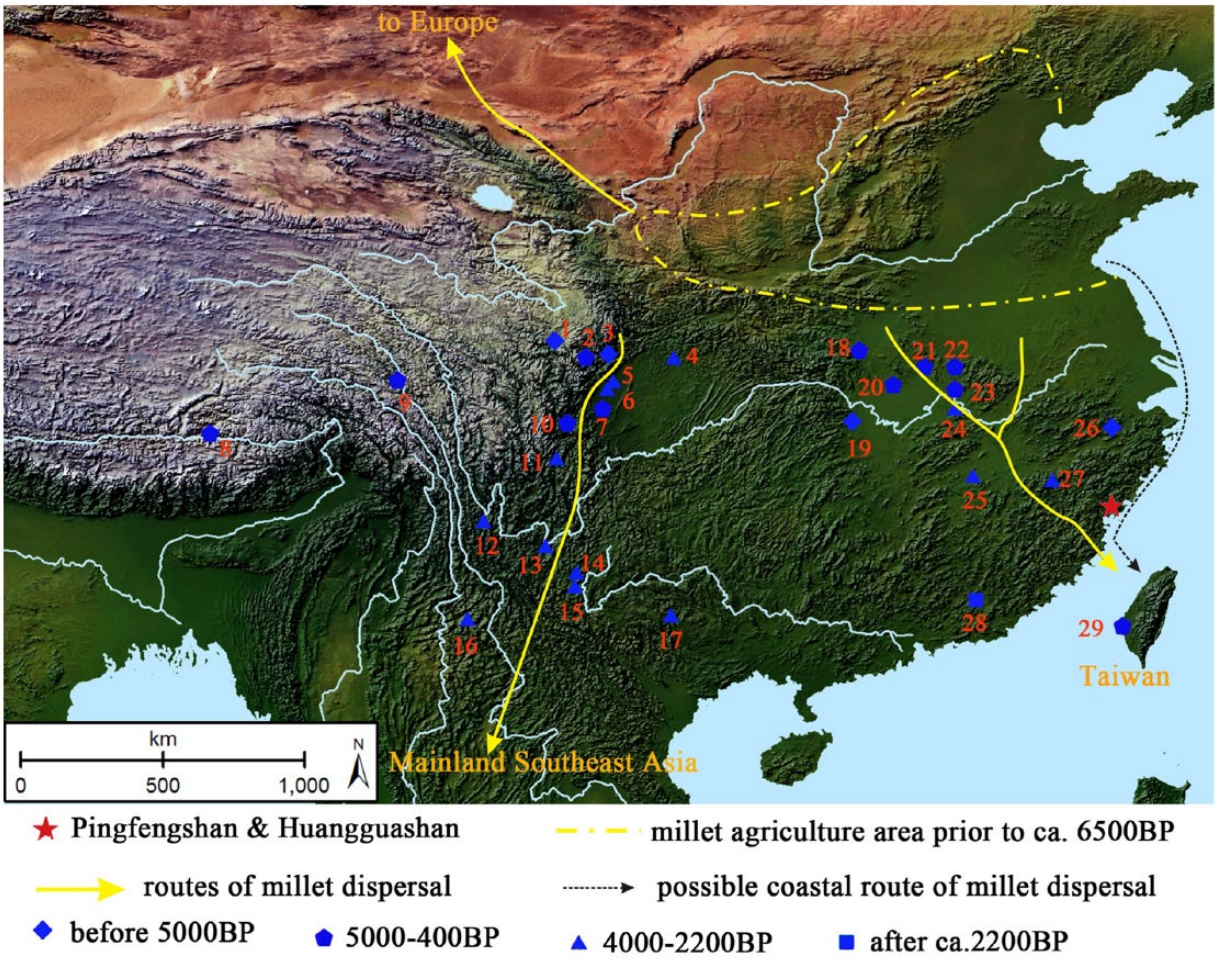

Figure 1. Possible routes of millet dispersal (location of the studied sites and other sites with millets in South China. 1. Haxiu; 2. Jianshanzhai; 3. Yingpanshan; 4. Zhengjiaba; 5. Boluocun, Zhonghaiguoji; 6. Jinsha, Sanguantang; 7. Baodun; 8. Changguogou; 9. Karuo; 10. Maiping; 11. Gaopo; 12. Haimenkou; 13. Dadunzi; 14. Chengjiangxueshan; 15. Guangfentou; 16. Shifodong; 17. Gantuoyan; 18. Xiajiangbianzi; 19. Chengtoushan; 20. Tanjialing, Sanfangwan; 21. Yejiamiao; 22. Lishangang; 23. Chengzishan; 24. Xiezidi; 25. Niucheng; 26. Shangshan; 27. Hulushan; 28. Shixiongshan; 29. Nanguan-lidong, Youxianfang.

study (Wei et al., 2017) may yet reconsider the implication of finding haplogroup O3a2b2-N6 in Hunan of the middle Yangtze Valley, rather than preferring the unidirectional route as emphasized as a singular source in coastal North China.

At least since 5000 cal. BP and even continuing today, coastlines of southeast China consistently have played significant roles in social interaction and human dispersal (Bellwood, 2005; Hung, 2008). In coastal southeast China, such as Fujian province, some studies have confirmed that rice farming first occurred here around 5000 cal. BP by the southward introduction from the Yangtze River region (Fujian Provincial Museum, 2010; Ma et al., 2016; Zhang and Hung, 2010). On the other hand, it was widely suspected that millets never were part of the Neolithic farming system in this region (e.g. Fuller, 2011), but our new findings have changed this perception as we will present here.

This study aimed to fill the gap in our knowledge of the subsistence of Neolithic southeast China. Here, we present the latest results of archaeobotanical work from the Neolithic period, specifically at 4300–3500 cal. BP in Fujian of coastal southeast China. Based on our latest findings of macroscopic plant remains and phytoliths from the dated assemblages, we can open a new discussion of crop processing activities and the related southeast dispersal route of millet. This discussion can further contribute new perspectives on the origins and dispersal of early Austronesian-speaking populations who inhabited one-third of the world.

Regional archaeological chronology and site description

This study focused on the archaeobotanical remains from two sites of Huangguashan and Pingfengshan (Figure 2), both belonging to the locally defined Huangguashan period, dated approximately at 4300–3500 cal. BP. In a larger view of southeast coastal China, the known Neolithic archaeological sites refer to three successive cultural periods, comprising Keqiutou culture (ca. 6500–5000 cal. BP), Tanshishan culture (ca. 5000–4300 cal. BP), and Huangguashan culture (ca. 4300–3500 cal. BP; Fujian Provincial Museum, 2009; Lin, 2003).

Huangguashan (26°47′50.22″N, 119°55′24.74″E) is located in a small hill near a gulf in the east part of Fujian province, approximately 50 m a.s.l. and 1 km inland from the coastal line (Figure 2). It was discovered in 1987, and it was excavated in 1989 and 2002 (Fujian Provincial Museum, 1989, 1994, 2004; Jiao, 2007). Large numbers of pottery fragments, stone tools, bone tools, and other artifacts were unearthed. Besides, large amounts of mollusk shells and fish bones were recovered, revealing the significance of fishing in the subsistence strategy of this site. The primary cultural deposit at this site belonged to the Huangguashan period, while a small portion of cultural materials referred to the Tanshishan period.

The Pingfengshan site (26°48′37.89″N, 119°59′45.37″E) is situated atop a mountain near the east coast of Fujian province, about 163 m a.s.l., and roughly 8 km to the northeast of the Huangguashan site (Figure 2). A small-scale excavation was conducted in 2016 on the north slope of the mountain. According to the artifacts

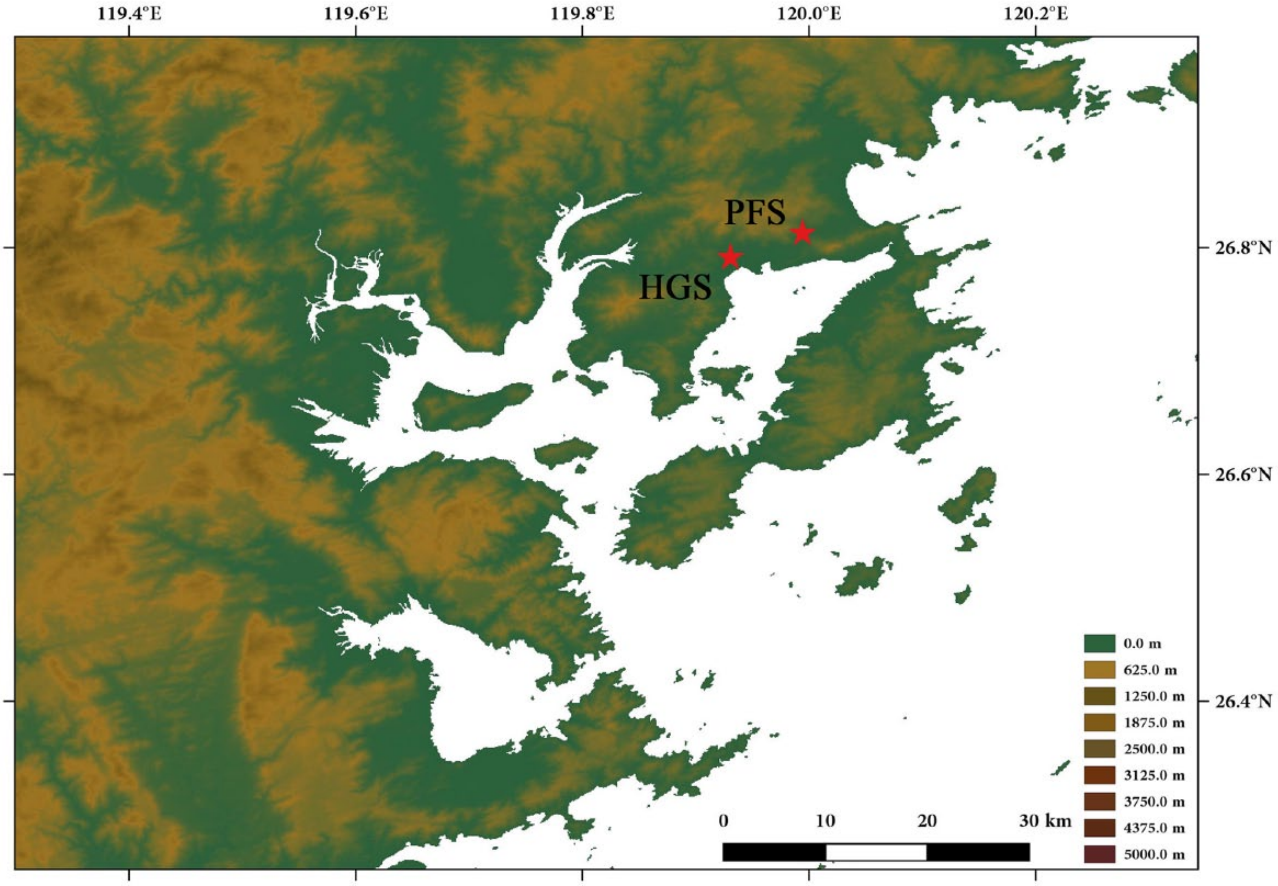

Figure 2. Location and the surrounding terrain of the Huangguashan and Pingfengshan sites discussed in the text.

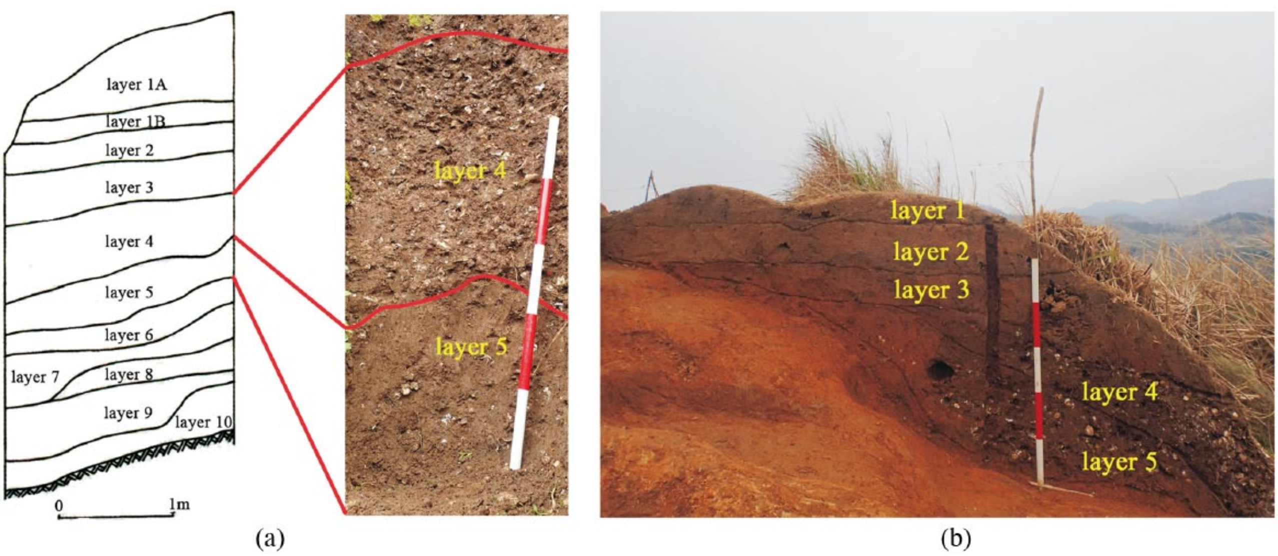

Figure 3. Sampling profile of (a) Huangguashan (line graph modified from Fujian Provincial Museum, 2004) and (b) Pingfengshan.

excavated from this site, the primary represented material referred to the terminal portion of the Huangguashan period (Fujian Provincial Museum & Xiapu County Museum, 2017). Similar to the Huangguashan site, fishing–gathering was a major subsistence contribution, as indicated by the dense remains of shells and fish bones at this site.

Material and methods

Samples of the Huangguashan site were collected from an exposed profile of one square of the 2002 excavation. Compared with previous records, the upper layers (1–3) of this profile had not been preserved, and the lower layers (6–10) had already been reburied. As a result, samples for flotation and phytolith analysis were taken from the remaining accessible layers 4 and 5 of the profile (Figure 3a). Flotation samples were taken separately from each cultural layer, and phytolith samples were extracted at 10-cm intervals. In total, 35.5 L of sediment samples for flotation and 12 samples for phytolith analysis were collected.

The Pingfengshan flotation samples were taken by cultural layer during the 2016 excavation (Figure 3b). Phytolith samples were collected from the west profile of the excavation square after

Table 1. Radiocarbon dating results from Huangguashan and Pingfengshan.

Site	Laboratory code	Context no.	Sample type	Conventional radiocarbon age	Calibrated date (2σ range)	Reference
Huangguashan	BA02152	Z101	Charcoal	3920 ± 60 BP	4520–4157 cal. BP	Fujian Provincial Museum (2004)
	NZA16011	Layer 9	Charcoal	3687 ± 60 BP	4227–3855 cal. BP	
	NZA16010	Layer 9	Charcoal	3634 ± 55 BP	4145–3829 cal. BP	
	BA02155	Layer 9	Charcoal	3640 ± 60 BP	4149–3780 cal. BP	
	BA02154	Layer 9	Charcoal	3620 ± 100 BP	4235–3645 cal. BP	
	BA02153	Layer 4	Charcoal	3430 ± 80 BP	3887–3490 cal. BP	
	BA02156	Layer 4	Charcoal	3440 ± 60 BP	3857–3565 cal. BP	
	UGAMS#27095	Layer 5	Rice	3610 ± 25 BP	3980–3846 cal. BP	This study
Pingfengshan	Beta-434878	Layer 5	Charcoal	3400 ± 30 BP	3716–3572 cal. BP	Fujian Provincial Museum & Xiapu County Museum, 2017
	Beta-434877	Layer 5	Charcoal	3290 ± 30 BP	3582–3450 cal. BP	
	Beta-434876	Layer 4	Charcoal	3360 ± 30 BP	3691–3495 cal. BP	
	Beta-434875	Layer 3	Charcoal	3260 ± 30 BP	3565–3403 cal. BP	
	UGAMS#27094	Layer 3	Rice	3380 ± 25 BP	3692–3570 cal. BP	This study
	UGAMS#27093	Layer 4	Rice	3350 ± 25 BP	3684–3494 cal. BP	
	UGAMS#27092	Layer 5	Rice	3440 ± 25 BP	3826–3632 cal. BP	

the excavation had finished. In all, 188.5 L of sediment samples was collected from layers 3 through 5 for flotation, and 22 samples were collected for phytolith analysis.

Samples were floated at the site by flotation buckets, and macroscopic plant remains were collected by mesh bags with $300 \times 300\ \mu m^2$ apertures. All samples were dried at the site before sending to the laboratory. Sorting and identification of macroscopic plant remains were conducted under stereomicroscope, referring to modern collections and atlas of modern seeds in China (Guo, 2009; Wang, 1990).

Procedures for phytolith extraction were performed according to previous studies, with slight modification (Lu et al., 2002; Pearsall, 2000; Piperno, 1988). Small samples (2 g each) were weighed by analytical balance, and then the samples were treated with 30% H_2O_2 to remove organic matter, followed by three distilled water rinses. Next, 15% HCl was used to remove carbonate aggregates and certain oxides. After three distilled water rinses, heavy liquid (ZnBr2, density 2.35 g/cm^3) was used to separate phytoliths from the sediments. The suspension with separated phytoliths was removed into a new tube and washed twice with distilled water and one more time with 30% ethyl alcohol. Finally, the phytoliths were removed from the tubes by pipette and mounted on a slide with Canada Balsam. Phytolith identification and counting were performed using a Leica microscope at 400× magnification. For each sample, at least 300 phytoliths were identified and recorded.

Four charred rice grains from different cultural layers of the two sites were sent to the Center for Applied Isotope Studies at the University of Georgia for accelerator mass spectrometry (AMS) radiocarbon dating.

Results

AMS radiocarbon dating results

All samples used for direct radiocarbon dating produced AMS radiocarbon dates successfully. These dates were calibrated by OxCal v4.2.4 (Bronk Ramsey, 2013), using IntCal13 atmospheric curve (Reimer et al., 2013), and presented with previous published radiocarbon dates in Table 1. From Huangguashan, the new dating was obtained from a middle part of the stratigraphy, post-dating the oldest component of its associated cultural layer, but it proved rice at 3980–3846 cal. BP. This result may be compared with the overall dating of the site extending back to 4520–4157 cal. BP.

Macroscopic plant remains

In all, 3491 seeds and other parts of plants were recovered from the Huangguashan and Pingfengshan samples, comprising cereal crops, fruits, grasses, and other weeds. Most plant remains can be identified into species or genera, while a small portion could be recognized only into family. On the whole, 25 different types of macroscopic plants were found (Table 2, Figure 4).

All samples produced a large proportion of Brassicaceae seeds, which accounted for 74.25% of all macroscopic plant remains. However, given their preservation condition and size (about 0.45–0.5 mm in diameter) and large number found in all samples, they are possibly refiltrations from much later or even modern depositions. Besides this, cereals were the most numerous type (Table 2). Three different kinds of crops have been identified, including rice (*Oryza sativa*), foxtail millet (*Setaria italica*), and possibly broomcorn millet (*Panicum* cf. *miliaceum*). A total of 272 rice grains and fragments and 162 rice spikelet bases have been recovered from the two sites. In contrast, 14 foxtail millet grains and three possible broomcorn millet grains were found, which represented extremely low proportions of crop remains in all samples (Figure 5).

Amygdalus sp., *Rubus* sp., *Sambucus* sp., and *Broussonetia papyrifera* were the four identifiable fruits at these two sites. They referred to just a small proportion (1.23%) of all plant remains from the studied samples. Each appeared in only one or two samples.

Eighteen kinds of grasses and other weeds have been identified. The most common types were Brassicaceae, *Setaria* sp., *Eleusine indica, Chenopodium* sp., *Oxalis corniculata*, and Solanaceae. Except for Brassicaceae, the amounts of other seeds generally were quite limited.

Phytoliths

Sufficient phytoliths have been extracted from both Huangguashan and Pingfengshan samples. In all, 23 morphotypes of phytoliths have been identified in all samples, while the majority of them were unidentifiable to genera or species. Four crop types included rice bulliform, double-peaked, scooped bilobate phytoliths, as well as phytoliths from broomcorn millet husks (Figure 6). Scooped bilobate phytoliths appeared only randomly in a few samples, and the proportions of other three types were quite high. Nevertheless, the distribution of these specific crop morphotypes differed greatly between samples from these two sites.

Crop phytoliths from the Huangguashan samples were characterized by large proportions of rice double-peaked phytoliths and relatively high proportion of phytoliths from broomcorn millet husk as well. Moreover, other Panicoideae husk phytoliths were found in most of the Huangguashan samples. The majority of

Table 2. Macroscopic plant remains from the Pingfengshan and Huangguashan sites.

Site name		Pingfengshan			Huangguashan		Total counts
Context no.		Layer 5	Layer 4	Layer 3	Layer 5	Layer 4	
Flot. vol.		58	123	7.5	17	18.5	224
Cereals	Rice spikelet base dom.	4	16		90	9	119
	Rice spikelet base wild				4		4
	Rice spikelet base imm.				5		5
	Rice spikelet base unidentifiable				30	4	34
	Oryza sativa	1	14		2		17
	Oryza sativa frag. (>1/2)		236	6	13		255
	Panicum cf. *miliaceum*		2		1		3
	Setaria italica		5		1		6
	Setaria italica frag.		3		3		6
	Setaria italica (immature)					2	2
Fruits	*Amygdalus* sp.		1		1		2
	Rubus sp.		27	1			28
	Sambucus sp.		3				3
	Broussonetia papyrifera		1				1
	Unidentified endocarp frag.		9				9
Grasses	*Setaria* sp.	1	5	1	1		8
	Setaria sp. with husk				20	10	30
	Panicum sp.		2		1		3
	Panicoideae		1				1
	Eleusine indica	3	28	3			34
	Gramineae				3		3
Other weeds	Brassicaceae	434	1813	54	183	108	2592
	Chenopodium sp.	64	28	1	16	4	113
	Polygonaceae	6	4	2			12
	Cyperus iria	3	11				14
	Portulacaceae	1	6	5		2	14
	Oxalis corniculata	1	67	6			74
	Solanaceae		17				17
	Caryophyllaceae		12				12
	Labiatae				1		1
	Molluginaceae		1				1
	Galium sp.		2				2
	Acalypha australis		5			5	10
	Leguminosae		1				1
	Unidentified seeds		12		26	17	55
Total counts	518	2332	79	401	161	3491	

these morphotypes were probably from broomcorn millet or associated grasses, as indicated by the strong correlation between the numbers of these two types ($R = 0.94$). By contrast, rice bulliform phytoliths were found only in four samples from the Huangguashan site, and the proportions were quite low. Additionally, one scooped bilobate phytolith appeared at this site.

Different from the Huangguashan samples, the phytolith assemblage of the Pingfengshan site was characterized by low proportions of crop phytoliths. Rice bulliforms appeared in most samples of this site, and double-peaked bulliforms were discovered in only one sample (Figure 7). Moreover, the proportions of these rice phytoliths were very low, mostly counted at less than 0.5%. Besides these limited discoveries, no other crop phytolith was found.

Discussion

Crop assemblages in the late Neolithic period of the southeast coastal China

The southeast coastal region of China has been regarded as an integral part of the ancient rice agriculture region. Today, more than 90% of farmland in Fujian province has been dedicated to rice cultivation. Nevertheless, the introduction, transition, and development process of rice farming in this region has remained unclear, not to mention the possible utilization of other types of crops in ancient periods. The Huangguashan and Pingfengshan sites, for the first time, have provided systematic archaeobotanical evidence to investigate this problem.

Both macroscopic plant remains and phytoliths demonstrated that rice, foxtail millet, and broomcorn millet were cultivated in the southeast coastal area at least as early as 4000 cal. BP. An even earlier dating may yet be discovered for the co-occurrence of rice and millet in coastal Fujian, pending further studies of the deeper and older portions of the site stratigraphic sequences.

In all samples from both sites, the assemblages of crop seeds and spikelet bases revealed a high proportion of rice consumed by late Neolithic populations in this region. Although foxtail millet and suspected broomcorn millet grains both were observed at the two sites, their percentages were quite low (Figure 5).

Different from the macroscopic plant remains, phytoliths revealed quite distinct results (Figure 7). The Huangguashan samples were characterized by high proportions of double-peaked phytoliths from rice husks and relatively low proportions of phytoliths from broomcorn millet husks. In contrast, not a single broomcorn millet phytolith was found at the Pingfengshan site, where instead the main crop phytolith was rice bulliform, although the proportions were not very high in all samples.

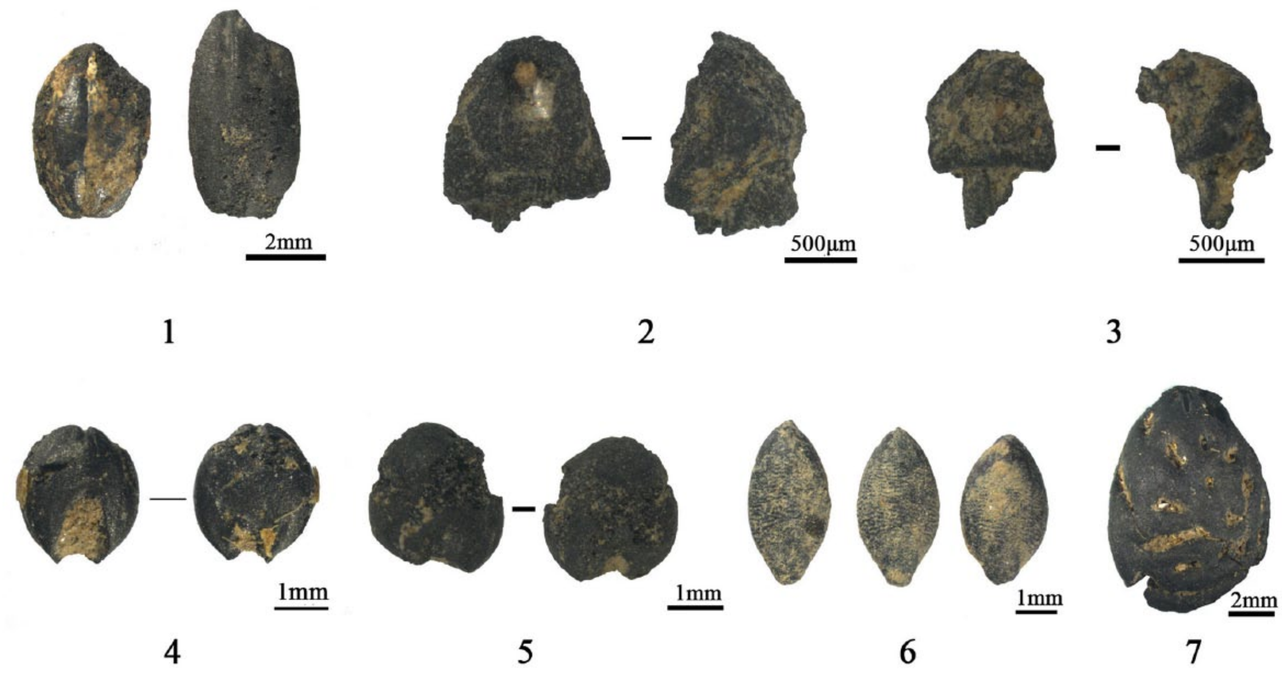

Figure 4. Representative crops and fruit from Huangguashan and Pingfengshan.
1. *Oryza sativa*; 2. rice spikelet base (domesticated type); 3. rice spikelet base (immature type); 4. *Setaria italica*; 5. *Panicum* cf. *miliaceum*; 6. *Setaria* sp.; 7. *Amygdalus* sp.

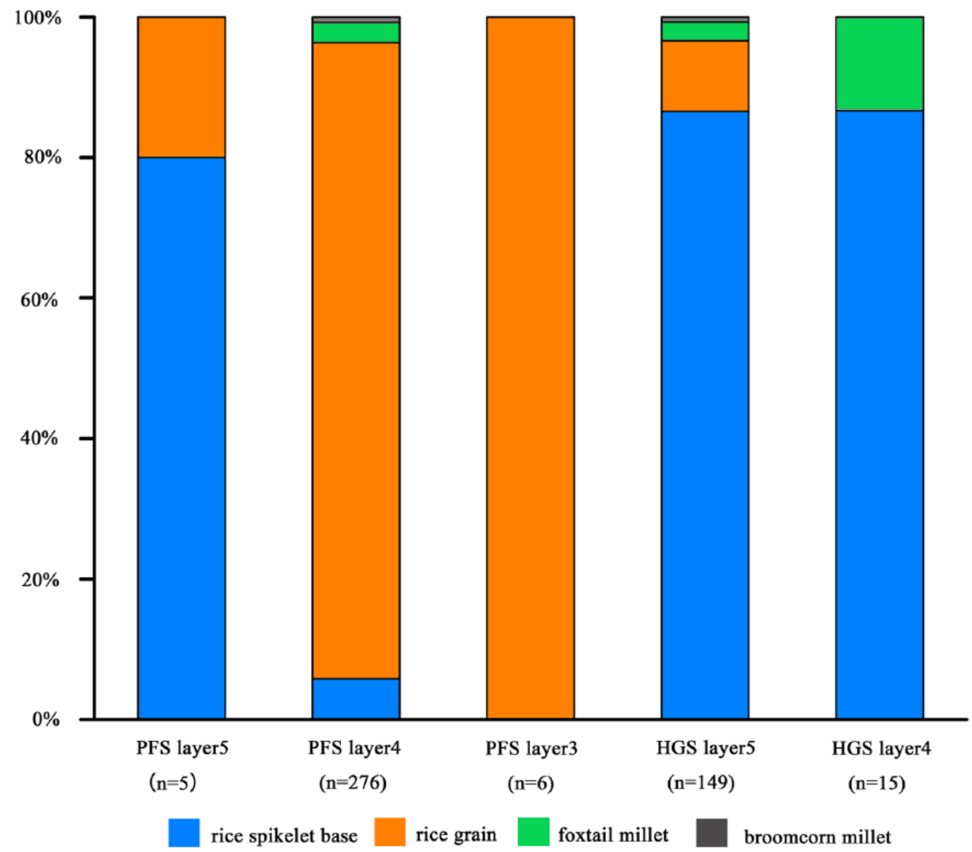

Figure 5. Crop assemblages from different layers of Pingfengshan (PFS) and Huangguashan (HGS).

Although macroscopic plant remains have confirmed the existence of foxtail millet at these two sites, diagnostic phytoliths from its husk were totally absent in all samples. Specific phytolith morphotypes may have preserved differently in certain preservation environments. Alternatively, the sediments may have formed by residues from different activities associated with different crops or different stages of crop processing at these sites.

Overall, macroscopic plant remains together with phytoliths demonstrated that rice was the main staple crop in the late Neolithic period of coastal southeast China. In addition to the rice, both foxtail millet and broomcorn millet were cultivated in small

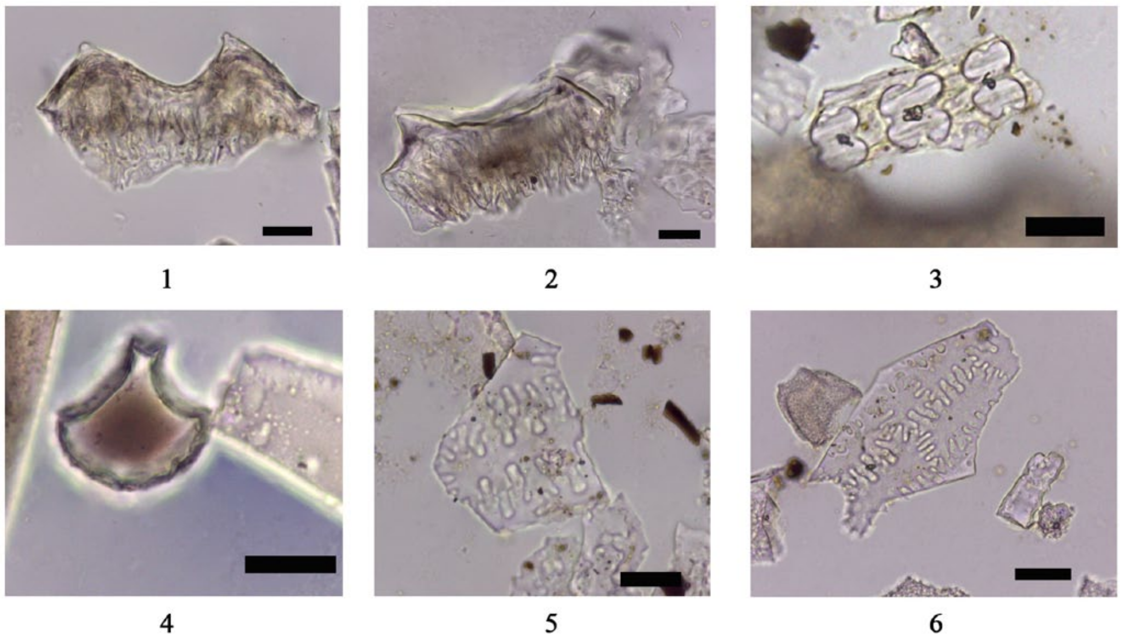

Figure 6. Crop phytoliths from Huangguashan and Pingfengshan. All scale bars are 20 μm.
1, 2. Double-peaked phytolith from rice husks; 3. scooped bilobate; 4. rice bulliform; 5. broomcorn millet husk; 6. Panicoideae husk.

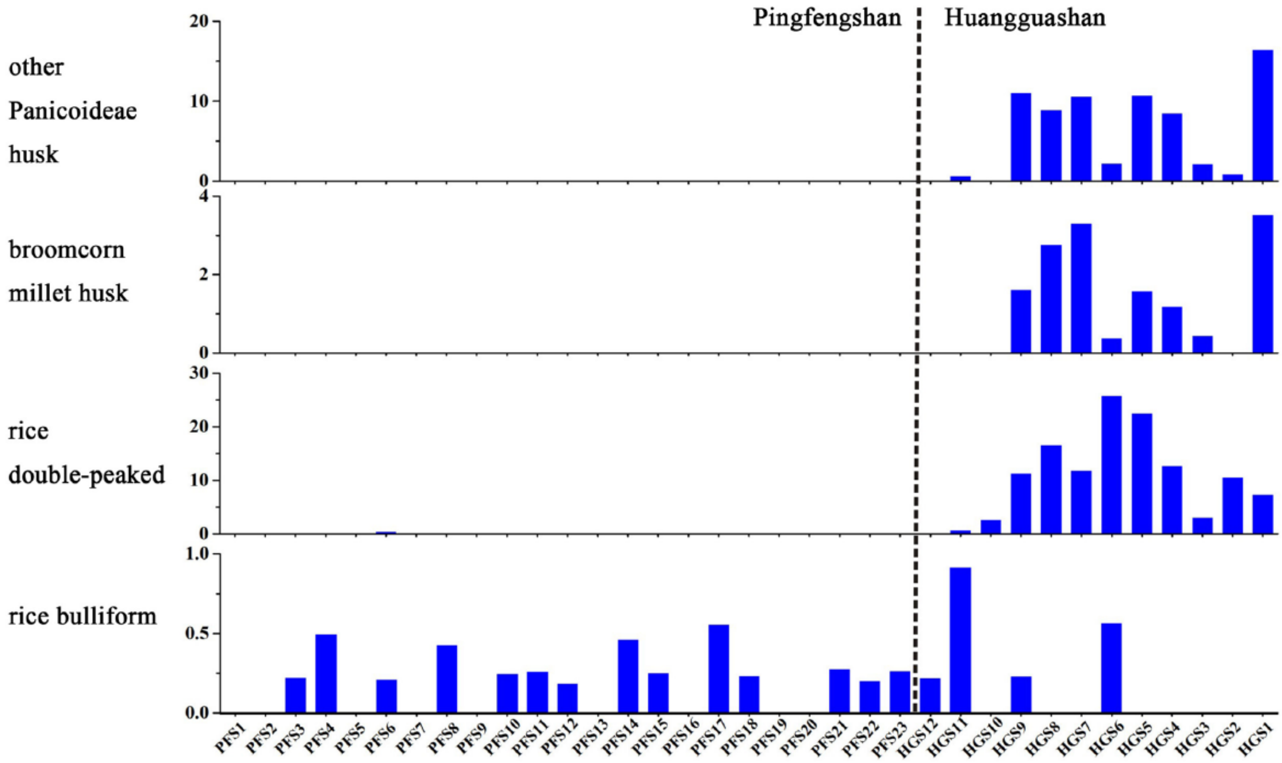

Figure 7. Proportions of crop phytolith morphotypes from Huangguashan (HGS) and Pingfengshan (PFS) (compared with all phytoliths in each sample).

scales in this region. Evidently, a multi-crop agriculture had already been established in the coastal region of southeast China.

Crop processing at the Huangguashan and Pingfengshan sites

Plant remains at archaeological sites mostly can be attributed to activities associated with different stages of crop processing, including threshing, winnowing, pounding, sieving, milling, and cooking. Previous studies have revealed that both macroscopic plant remains and phytoliths could be used as proxies to explore these issues (Fuller et al., 2014; Harvey and Fuller, 2005; Jones, 1987).

In ideal settings, different stages of crop processing can be evaluated through the observed ratios of crops to weed seeds, crop chaffs, and straws. Such is not always possible, for instance, in the assemblages from Huangguashan and Pingfengshan, where most of the samples contained very limited crop and weed seeds, insufficient for this kind of proxy evaluation. Nonetheless, the two samples with the most macroscopic plant remains revealed noteworthy patterns.

In one sample from Huangguashan and another from Pingfengshan, the ratios of rice grains to rice spikelet bases revealed two distinctive patterns (Figure 5). In the sample from layer 5 of the Huangguashan site, 129 rice spikelet bases were discovered, while the amount of rice grains was only 15, overall suggestive of rice dehusking for the major represented activity. In contrast, the sample from layer 4 of the Pingfengshan site yielded 16 rice spikelet bases and 250 rice grains, most of which were fragments, most likely representing the byproducts of ancient sieving.

Similarly, phytoliths from the Pingfengshan and Huangguashan sites reflected different stages of ancient crop processing (Figure 7). Phytoliths from the Pingfengshan site were characterized by low proportions of crop morphotypes, most of which were rice bulliform phytoliths from leaves. Distinct from this pattern, the majority of Huangguashan phytoliths were double-peaked phytoliths from rice husks, with very little discoveries of rice bulliforms in four samples.

Overall, the proportions of rice bulliforms at the two sites were very similar, ranging from 0.2% to 0.6%, thus suggesting that people in the late Neolithic Age of this region harvested only ears of rice instead of the whole plant. Alternatively, rice threshing could have occurred elsewhere in the sites or related areas. On the other hand, the high proportion of double-peaked phytoliths from rice husks and relatively high proportions of phytoliths from broomcorn millet husks showed a strong relationship between these residues and crop dehusking activities at the Huangguashan site. These results were strongly in accordance with the results of macroscopic plant remains.

On the whole, macroscopic plant remains and phytoliths from the Pingfengshan and Huangguashan sites illustrated two distinct patterns of residues from different stages of rice processing. Similar processing activities could be speculated for the relatively high proportion of phytoliths from husks of broomcorn millet. These findings together indicated local cultivation of these crops.

Southeastward dispersal of millets in Neolithic phase

Plant remains obtained in the past decade have revealed that millets had spread southward into the Yangtze valley around 6000 cal. BP and possibly spread farther during the following millennium. In the middle Yangtze region, the earliest finding of millet cultivation has been at Chengtoushan in Hunan province, dated around 5800 cal. BP (Nasu et al., 2007, 2012). Afterward, foxtail millet appeared at almost all sites in the middle Yangtze valley, identified by numerous archaeobotanical studies in the region (e.g. Deng, 2013; Tang et al., 2014; Wu et al., 2010).

In contrast, in the lower Yangtze region, only five grains of foxtail millet have been found at Shangshan, wherein three of those grains definitely belonged to the Bronze Age, but another two were ascertained as nearly 6500 years old (Zhao and Jiang, 2016). So far, both foxtail millet and broomcorn millet have been absent at all other Neolithic sites in the lower Yangtze, despite the numerous archaeobotanical studies in this region for more than a decade. Under these circumstances, the estimated age of foxtail millet from Shangshan at 6500 cal. BP has been too old to accept uncritically (e.g. Barton et al., 2009; Lu et al., 2009; Zhao, 2011b). In any case, more studies will be needed in the lower Yangtze.

Southward of the middle and lower Yangtze River, systematic archaeobotanical studies have been virtually absent at Neolithic sites, for instance, in most parts of Hunan, Jiangxi, south Anhui, Guangdong, and Fujian provinces. Besides the two sites presented in this paper, the only evidence of southward dispersal of millets from the Yangtze region in the Neolithic Age is from the Hulushan site in the west mountain area of Fujian province (Figure 1). Rice and foxtail millet from the middle period of this site (ca. 4000–3500 cal. BP) have been reported, but detailed information has not been published so far (Fujian Provincial Museum et al., 2016). On the whole, the scale and geographical scope of millet cultivation in the Neolithic period of South China have been unclear, and the process of millet dispersal has not been possible to examine. Nevertheless, plant remains from two later-dated sites in this region may be instructive.

The two potentially instructive site records have been described at Niucheng in Jiangxi province and at Shixiongshan in Guangdong province (Figure 1). At Niucheng, plant remains of foxtail millet, broomcorn millet, and rice all indicated local cultivation during the Bronze Age Shang Dynasty. Moreover, foxtail millet occurred in nearly equal frequency with rice (Chen et al., 2015). At Shixiongshan, foxtail millet was the most numerically abundant cereal crop during the early empire Qin and Han Dynasties, accompanied by lesser representation of rice, broomcorn millet, and wheat (Li et al., 2016).

These studies in total have suggested that millet cannot be ignored in the subsistence of most parts of South China during the Neolithic period, especially in these hilly areas such as Niucheng and Shixiongshan. Even in the middle Yangtze valley, the late Neolithic sites (ca. 5500–3900 cal. BP) for the most part were located in low hilly areas, where the landscape was greatly different from the lower Yangtze delta. These geomorphological factors could explain the need for ancient people to plant millets in South China. In the future, with more archaeobotanical work in Jiangxi and the south part of Anhui province of the middle Yangtze, we expect that millets will be found in more Neolithic sites.

Given the available geographical channels and interregional connections revealed by archaeological cultural remains, millets likely entered Fujian province from Hubei or Anhui through Jiangxi province, although the possibility of a coastal route cannot be definitely excluded with current evidence (Figure 1). To solve this problem, more similar work is needed in the preceding Tanshishan culture sites in the east coast and Niubishan culture sites in the west mountain areas of Fujian province. As to the time of this crop dispersal event, millets arrived in Fujian province at least by 4000 cal. BP.

Across the Taiwan Strait, the exact ages and cultural contexts of rice and millets have been unresolved, although a few important discoveries have begun to change this situation. Grains of foxtail millet, broomcorn millet, and rice were identified at Nanguanlidong in the southwest coast of Taiwan (Tsang et al., 2017), but no direct dating has been attempted for any of those remains. The available C14 dating from Nanguanlidong showed that the oldest cultural layer was dated around 4800–4200 cal. BP (Hung and Carson, 2014). However, phytolith studies on samples from the oldest layers of Nanguanlidong and at its nearby contemporary site Nanguanli found no trace of rice and millet at all (Tsuoting Lee, personal communication in 2016). Through both macro-plant and phytolith studies at other contemporaneous sites, such as Dachangqiao in southwest coast of Taiwan and Changguang in eastern coast of Taiwan, our investigations found no evidence of millet or rice.

Prior to our current findings, one of the main reasons to reject Fujian as a possible source of the Taiwan Neolithic crops was simply because no equivalent ancient millets had been found in Fujian (Fuller, 2011). The new discoveries from Pingfengshan and Huangguashan, as discussed here, have rectified the prior suppositions. In this case, Fujian now can be recognized among an ancient southeastward spread of millets.

Conclusion

Archaeobotanical identifications, together with direct AMS radiocarbon dates from Huangguashan and Pingfengshan, have illustrated ancient crop utilization on the southeast coast of mainland China around 4000–3500 cal. BP. The discovery of foxtail millet and broomcorn millet at these sites most significantly has expanded and changed our knowledge of the Neolithic agriculture system in this region.

Cross-regional research overall has been finding a stronger ancient role of millets in the areas that previously were perceived as purely rice-farming zones. Contributing factors for encouraging millet cultivation may have included the terrain composition of hillslopes and other formations, conditions of temperature and rainfall patterns, groundwater resources, and soil properties. All these factors should be considered toward understanding the ancient dispersals of millets in southern China.

This study has opened a new opportunity for learning about the process of agriculture dispersal overseas into Taiwan and Island Southeast Asia and the significant migration event of proto Austronesian-speaking populations. Potentially, rice and millets arrived at Fujian earlier and then spread into Taiwan as a package. Nevertheless, more evidence, especially concerning millets from coastal southern China, will be needed for exploring this hypothesis.

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