

Immature wild rice harvesting at Kuahuqiao, China?

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Early Neolithic rice dating to 8000 BP from the Kuahuqiao site in the lower Yangzi region has played a significant role in the recent discussions on rice domestication (Fuller *et al.* 2007; Liu *et al.* 2007a). As a member of the Kuahuqiao research team, I was puzzled by Fuller *et al.*'s (2007) case for immature wild rice harvesting because neither the Kuahuqiao nor Hemudu publications mention immature rice. The problem is a mistaken translation. Although Liu *et al.* (2007b: 1063) have already argued that the rice remains do not necessarily indicate immature rice harvesting, I want to correct the impression that the principal investigators have reported immature rice at the sites, as claimed by Fuller *et al.*'s (2007) article. This is important because Fuller *et al.* (2008) still believe that the rice being harvested during the Early Neolithic in China was an immature wild form. One key passage in Fuller *et al.* (2007: 322), a translation from the Chinese texts, requires clarification:

'At Hemudu finds included "abundant empty husks of immature spikelets" (Zhou 2003: 430 [Chinese original]). Similarly at Kuahuqiao, quantified rice remains included about 18 per cent grains, 47 per cent empty (dehusked) spikelets and 35 per cent intact spikelets (immature without full grain formation) (Zheng et al. 2004a).'

The argument for hunter-gatherer rice exploitation in Fuller *et al.* (2007; 2008) hinges on this translation, said to be the '*Chinese original*'. The Chinese statements are actually rather different:

For the Kuahuqiao rice remains:

(1) *'In the sample comprising more than 1000 pieces of rice remains, there are 196 intact spikelets [daogu 稻谷], accounting for 18.4%; 369 rice grains [daomi 稻米], 34.7%; and 498 husks [daoguke 稻谷壳], 46.9%'* (Zheng *et al.* 2004: 121).

(2) *'The excavated rice contains 40% husks [daoguke]' and; 'In comparison with the spikelets, the grain is on average 26.5% shorter in length and 22.8% thinner in width. This phenomenon is rarely seen in modern domesticated rice in normal conditions'* (Zheng *et al.* 2004: 123).

For the Hemudu rice remains:

(3) *'The deposits in the same stratum include abundant empty husks of bidao 粃稻, rice leaves, stems and water caltrop. The rice has proven to be domesticated annual rice instead of wild rice foraged by humans or perennial wild rice'* (Zhou 2003: 430).

In paragraph (1), Fuller *et al.*'s translation does not correspond with the original categories and percentages (Table 1). The term *daomi* (grain) was translated to mean *'intact spikelets (immature without full grain formation)'*.

Original report (Zheng <i>et al.</i> 2004)	Fuller <i>et al.</i> 's interpretation (Fuller <i>et al.</i> 2007)
18.4% 稻谷 <i>daogu</i> spikelets	18 per cent grains
34.7% 稻米 <i>daomi</i> grains	35 per cent intact spikelets (immature without full grain formation)
46.9% 稻谷壳 <i>daoguke</i> husks	47 per cent empty (dehusked) spikelets

Table 1. Comparison of original Chinese text with Fuller *et al.*'s translation relating to Kuahuqiao rice remains.

In paragraph (2), Zheng *et al.* (2004) indicate that the smaller grains are a result of conditions that are not normal (normally, the grains fill the husks), rather than the grains being immature and/or wild progenitors as interpreted by Fuller *et al.* (2007: 322). In paragraph (3), *bidao* was interpreted to mean '*empty husks of immature spikelets*'. The translation of the Chinese word, *bidao*, to '*immature rice*' is critical for Fuller *et al.*'s (2007: 320-3) argument that the rice from Kuahuqiao and Hemudu represents hunter-gatherer targeting of immature wild rice.

In the first two statements there is no reference to immature rice in the original Chinese text; the phrase '*immature without full grain formation*' in the parenthetical note was added by Fuller *et al.* (2007: 322) as their interpretation for '*intact spikelets*'. However, if the spikelets are relatively intact, this situation would have been potentially related to a key trait of domesticated grasses such as rice: non-brittle rachillae that prevent spikelet shattering. They also interpret the significant number of empty rice husks at Hemudu to be immature (Qin *et al.* 2006: 330). Clarification is in order.

Zheng Yunfei, the rice expert who examined the remains from Kuahuqiao, in fact did not use the Chinese term for '*immature*' (PICAZ & XM 2004; Zheng *et al.* 2004; 2007). The Chinese terms '*bidao*' or '*bigu*' (秕谷)¹ are causing the confusion. *Bigu* refers to the shriveled, intact spikelets that sometimes include relatively intact empty husks (PICAZ & XM 2004: 273, 325; Zhou 2003: 430). The term is borrowed from ancient Chinese and is not commonly used today. *Bigu* actually means *buyun xiaosui* 不孕小穗, which translates to '*sterile spikelet*' (You 1995: 69). If sterile spikelets are immature neither the grain nor the husk is mature, so not only would the spikelets appear to be shriveled but the husks would be fragile and likely would not be preserved. The sterile spikelets are actually evidence of abnormal growth rather than immaturity. Considerable research has been done on the causes of sterility and reduced seed development in cultigen rice spikelets (e.g. Gu 1995; Wang 2005; Jagadish *et al.* 2007). Such sterile spikelets are well known in grasses such as rice and may result from a shortage of nutrients, diseases and

¹ The term '秕谷' occurs in the archaeological report of Kuahuqiao site and was used by Qin *et al.* (2006).

In Chinese '秕' and '粃' both mean 'sterile'; '稻' means 'rice' and '谷' means 'spikelet'. So '*bidao*' and '*bigu*' have the same meaning. However, the latter in a broad sense has a more general meaning than the former. The sterile spikelets of any cereal such as millet, wheat etc. can be referred to as '*bigu*'.

insect pests, failed pollination, inferior assimilate supply during the grain-filling period (Kobata *et al.* 2006) or other stresses such as a lack of rainfall. Therefore the husks of such rice are developed (hard) but the grains are tiny or non-existent. Zheng's view (*pers. comm.*) is that the abundant husks and intact spikelets at Kuahuqiao site represent abnormal growth, not immaturity. Additionally, infertile spikelets are quite common in modern cultivars of rice (e.g. Gu 1995; Kobata *et al.* 2006). Normally, such spikelets account for 10-20 per cent of a modern domesticated rice population (Figure 1). This is not to say the Kuahuqiao rice is *fully* domesticated; however, the case for the rice being harvested in an immature state does not hold up.

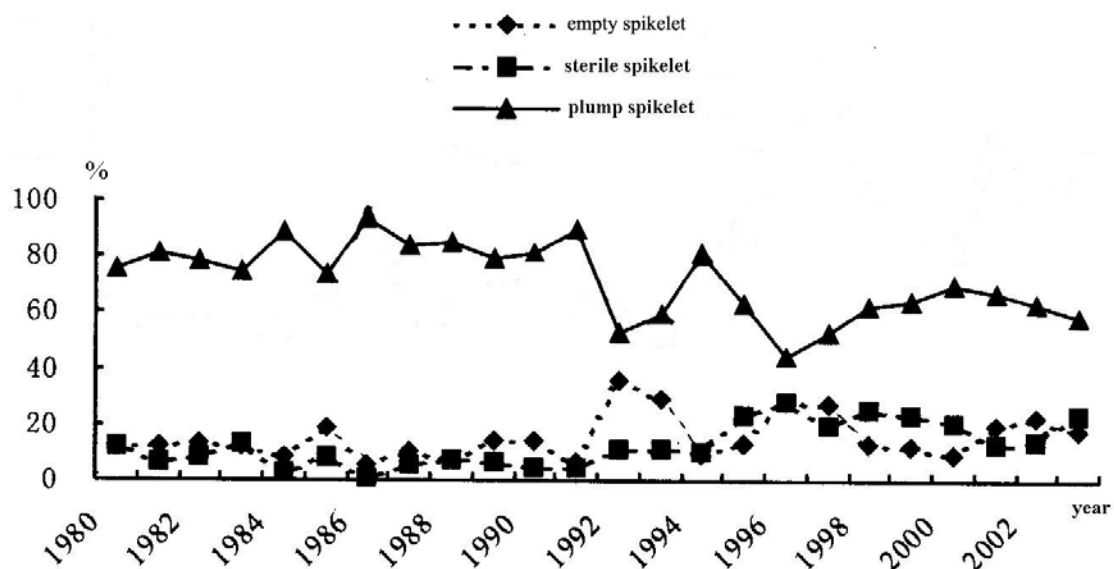


Figure 1. The curves display the proportions of empty husks, sterile spikelets and plump spikelets in a modern cultivar of rice (*Oryza sativa*) population. The horizontal axis represents years; the vertical axis represents percentage of different types of spikelets (adapted from Zhang *et al.* 2005).

Furthermore, Zheng attempts to avoid simply classifying either the husks or smaller/thinner spikelets as '*bigu*' because this term does not particularly refer to either. However, he mentioned *bigu* twice in the archaeological report (PICAZ & XM 2004),

- (1) *'In the sample of more than 1000 pieces of rice remains, there are 196 intact spikelets, accounting for 18.4%; 369 rice grains, 34.7%; and 498 bigu (秕谷), 46.9%.'* (p. 273).
- (2) *'In the stratum of middle period, a bunch of rice with its stalks was discovered and the spikelets are all bigu (秕谷), indicating that the yield of this cultivated rice could have still remained relatively low.'* (p. 325).

Zheng (*pers. comm.*) acknowledges that because the report was prepared in a hurry the term *bigu* was not carefully considered. In the first statement the term should be replaced by 'rice husks.' In addition, even the key Chinese character '秕' was misprinted as '秘'. In the second statement, *bigu* actually refers to '*shriveled spikelets*'.

Fuller *et al.* (2007) argue that the Kuahuqiao rice was harvested by hunter-gatherers but suggest that some cultivation was taking place by the end of the cultural sequence (2007: 325), and they do not explain how they arrive at this interpretation. Their conclusion that immature rice was harvested is based on the incorrect translation of '*bigu*' and '*bidao*' that they interpreted to be immature wild rice. Sensitivity to the Chinese terminology and what it means to the Chinese readership is crucial to this discussion. Zheng *et al.* (2007) do not view the rice as fully domesticated. In fact it was '*primitive cultivated rice undergoing domestication*' (Zheng *et al.* 2007: 4). Fully domesticated rice has not been presumed here (Fuller *et al.* are critical of East Asian archaeologists whom they feel presume domestication). A case for the Kuahuqiao rice being on the way to being cultivated (domesticated) was made in the original reports. Rather than the rice from Kuahuqiao representing part of a continuum of wild rice use by foragers (Fuller *et al.* 2007: 316), Fuller *et al.* (2008) acknowledge that there is a mixture of wild- and domesticated-types at Kuahuqiao '*with nearly half or less being domesticated.*' In their recent study Zheng *et al.* (2007) documented a high proportion of the non-brittle phenotype (cultigen) in the Kuahuqiao rice assemblage although the brittle phenotype (wild) is also very common indicating a mixed population of rice. The discussion of the mixture of wild and domesticated phenotypes in early rice exploitation/cultivation is intriguing and is among the earliest documented rice populations of its type.

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