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Pathways across Asia : exploring the history of *Panicum* and *Setaria* in the Indian subcontinent

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Introduction

'Millet' is a generic term applied to a range of small-seeded cereal crops, spread among a number of tribes in the Poaceae. They are typically C4 grasses, tolerant of ecological stresses, and with a short growing season. Millets are minor crops today in terms of global yield, but constitute a significant agricultural component in many developing countries and on land which cannot support more demanding crops. Millet usage in South Asia incorporates a wide variety of species, and includes both domesticated and cultivated species and those gathered from the wild. The most important are *Eleusine corocana*, *Setaria italica*, *Paspalum scrobiculatum*, *Panicum miliaceum*, *Panicum sumatrense* and *Echinochloa colona*, although *Brachiaria ramosa, Digitaria cruiciata*, *Echinochloa crus-galli, E. stagnina,* other *Panicum* spp., *Paspalidium flavidum*, *Pennisetum glaucum*, *Pennisetum alopecuroides*, *Setaria glauca*, *Setaria verticillata* and *Urochloa* spp. are also of local or occasional importance, for example in conditions of famine.[1] *Sorghum bicolor* is also considered a millet - *jowar* or great millet - in South Asia.[2] In this region, unlike some other parts of the world, millet grain remains a staple in the human diet,[3] and is grown predominantly by poor farmers for consumption by their own households, particularly in marginal areas where the climate or soil is unsuitable for growing other cereals, since millets tolerate wide range of environmental conditions, and can set seed in a short time-frame and on a low water requirement. Millets are grown right across India, but around 95% of the crop comes from the nine states of Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Madhya Pradesh, Uttar Pradesh, Bihar and Orissa.[4]

The diverse assemblage of millet species seen today includes both native wild and domesticated species, and those introduced from outside South Asia, specifically from centres in China and Africa.[5] The arrival of the latter into South Asia has been traced in the archaeobotanical record, and particular attention has been given to the so-called 'African millets', namely *Sorghum bicolor* (sorghum, *jowar* or great millet), *Eleusine corocana* (*ragi* or finger millet) and *Pennisetum glaucum* (*bajara* or pearl millet), which have been reported in South Asia from the beginning of the Harappan period, with *Eleusine* at Rojdi from 2500 BC.[6] The introduction of the African millets

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has been interpreted as significant in two respects: first, as initiating a putative 'agricultural revolution' in facilitating the switch away from nomadic pastoralism to a sedentary lifestyle in Early Harappan societies,[7] and secondly, for what can be inferred about long-distance trade networks between the Indus valley civilizations and East Africa.[8]

In view of the debate engendered by the presence of *Eleusine, Pennisetum* and *Sorghum* at Harappan sites, it is perhaps surprising that there has been very little comparable discussion on the introduction of the so-called 'East Asian millets' - primarily *Panicum miliaceum* and *Setaria italica*, also *Echinochloa crus-galli* - to South Asia. Both *P. miliaceum* and *S. italica* have been reported from Late-Harappan/ Post-Harappan sites in Gujarat, and from Harappa itself,[9] i.e. in the same broad time-period as the African millets. This article will review the issues relating to the domestication and spread of the East Asian millets, with particular focus on *Panicum miliaceum*, contextualize their presence in the archaeobotanical record, and identify questions requiring further work.

Panicum miliaceum and *Setaria italica* - archaeobotanical evidence for an East Asian origin

The designation of *Panicum miliaceum* and *Setaria italica* as 'East Asian' or 'Chinese' millets[10] oversimplifies the ongoing uncertainty regarding the domesticated origins of these two cereals.[11] The available archaeological and botanical data both provide partial information as to where and when they were taken into cultivation, and their subsequent spread; in the case of *Setaria italica*, genetic analyses[12] have begun to fill in further pieces of the puzzle; to date, virtually no genetic work has been done on Eurasian *Panicum*, and relationships both within and among species remain unresolved.

In the archaeobotanical record, *Panicum miliaceum* has an intriguing distribution (Fig. 1), with the earliest sites forming two loose clusters in northern China and eastern Europe. Traditional interpretations of northern China as a centre of millet agriculture have focused on the Huanghe (Yellow River), with the Middle Neolithic sites of Dadiwan, Peiligang, Xinle and Cishan dated to the 7^{th} millennium BC.[13] Recent excavations in northern China confirm these early dates, but also subtly shift the geographic focus away from the valley bottoms, with excavations at Xinglonggou, Inner Mongolia Province, recovering over 1500 carbonized seeds of *Panicum miliaceum*.[14] Xinglonggou, and other sites of the Xinglongwa culture in the region, occupy a more upland location in the foothills constituting the wider catchment of the Huanghe. The topography and hydrology of these sites resonate with Sherratt's model of early Neolithic foothill catchment sites in the Fertile Crescent of Southwest Asia, which associate with soft alluvial sediments, which capture rainwater draining from the higher slopes.[15] The ongoing excavations at Xinglonggou and other sites including Dadiwan[16] may stimulate a reinterpretation of the dynamics of the adoption of millet agriculture in northern China, but its establishment prior to the Yangshao culture (5000-3000 BC) seems increasingly certain.

At the western end of the Eurasian steppe, remains of what is assumed to be broomcorn millet have been reported from 6^{th} millennium BC Starcåvo-Cris Körös and LBK sites in Georgia, Romania, Czechoslovakia, Poland and Ukraine/Moldova,[17] although a degree of uncertainty remains regarding the identification and dating of some of these finds;[18] in particular, identification is frequently to '*Panicum*

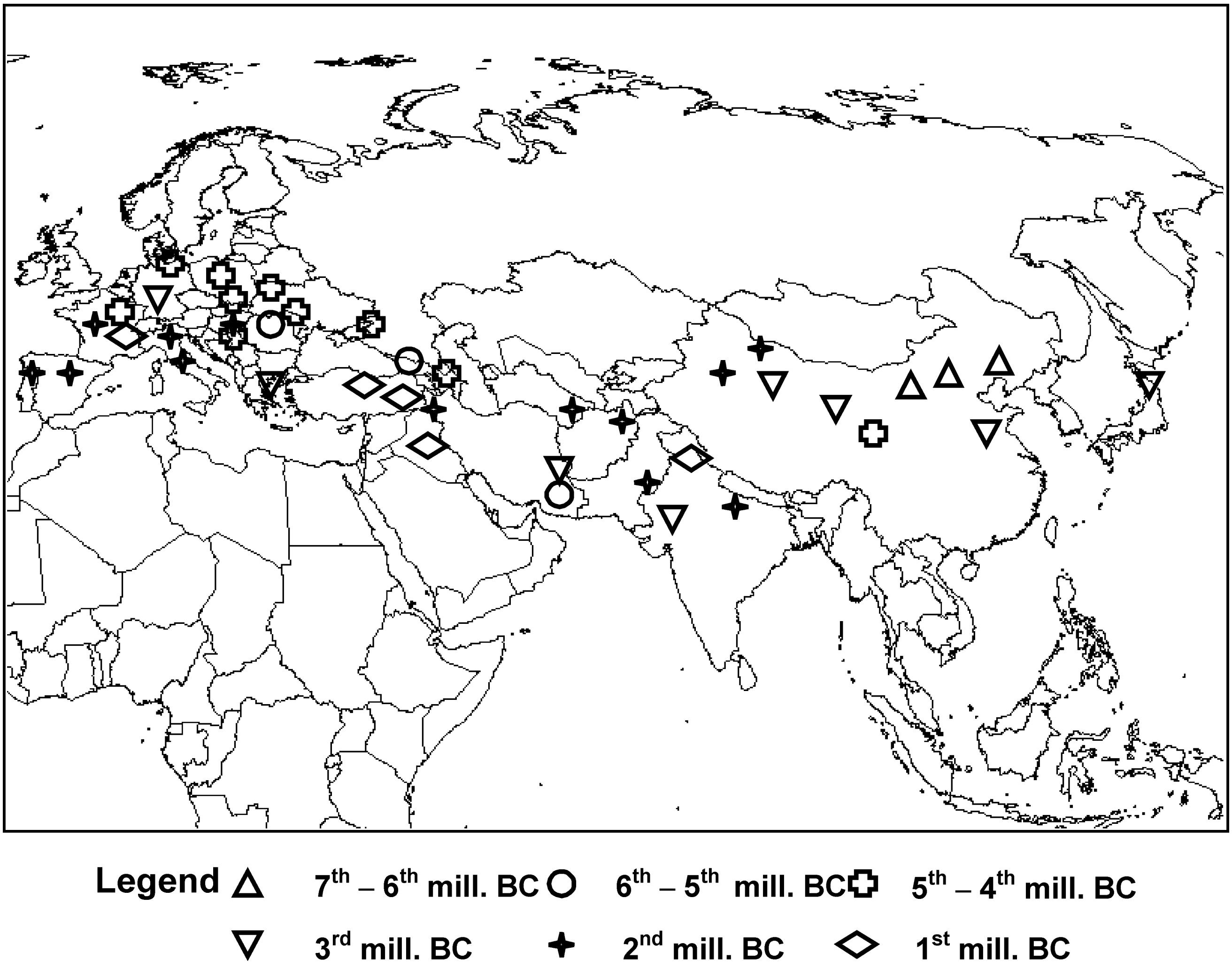

Fig. 1. Published archaeobotanical records of *Panicum miliaceum* up to the end of the 1st millennium BC.

sp.' or '*Panicum* cf. *miliaceum*'. Assuming that these records do indeed represent cultivated *P. miliaceum*, there are three hypotheses for its distribution in the 7th and 6th millennia BC.[19] Two of these propose a single origin in northern China; in the first, we assume the current dates as correct, in which case the westward spread of millet agriculture must have occurred many times faster than has been estimated for the rates of spread of other Neolithic farmers and their crops.[20] Alternatively, it has been suggested that agriculture in China may be extremely ancient, predating the Southwest Asian centre by at least a few millennia,[21] and further work may elicit earlier dates for millet cultivation. The third plausible explanation is that the Eastern European and East Asian clusters represent separate independent domestications of *Panicum miliaceum*.[22]

In subsequent millennia, *Panicum miliaceum* spreads in a predominantly westward direction in the archaeobotanical record both in Europe and East Asia. It turns up in the Bronze age (approx. 2000-

500 BC) sites of Sidaogou, Wubao, Tala, Lajia and Kanuo, in western and northwestern China,[23] and also seems to have moved eastward to Japan where it is known from the late Jomon site of Kazahari (4500 - 3000 B.P.).[24] In Europe, *Panicum miliaceum* becomes more common during the late Neolithic and the Bronze Age, spreading throughout central and western Europe and southern Scandinavia.[25] It does not reach Southwest Asia until the first millennium BC, when it appears in Iron Age sites in Iraq and Turkey.[26] The Central Asian archaeobotanical record is patchy at best, but neither *P. miliaceum* nor *S. italica* seems to have been present in Neolithic Turkmenistan;[27] the former does appear in the late Bronze Age (mid-second millennium BC) at Tahirbaj Tepe.[28] Records of broomcorn millet in South Asia will be discussed more fully below, but an unusually early report comes from Tepe Yahya, southeastern Iran, where grains identified as *P. miliaceum* were recovered from the R37 site dating to the 6th millennium BC, although full details have never been published.[29]

Foxtail millet, *Setaria italica*, is today more widely grown in northern China than *Panicum miliaceum*. Early records from this region include some of the same sites as the latter, including Peiligang, although it is absent from Dadiwan, and much less abundant than *P. miliaceum* at Xinglonggou;[30] it may be less well adapted to upland areas.[31] In Europe, *S. italica* appears later than *P. miliaceum*, in third millennium BC sites of the Gumelnitsa culture in Romania.[32] Like broomcorn millet, foxtail was a late introduction to the Near East, appearing at Tille Höyük, south-east Turkey, in the Iron Age.[33]

Recent excavations where flotation and radiocarbon are securing the identification and dating of these millets would lend support to an emphasis upon northern China as the major location of domestication of both *P. miliaceum* and *S. italica*. A re-examination of samples from the key sites from Eastern Europe is probably overdue, and could revive interest in a putative independent western centre of millet domestication.

Botanical arguments for a Central Asian millet centre

Despite the lack of archaeobotanical records of either *Panicum* or *Setaria* in this region, some authors[34] have argued for a diffuse domestication centre on the Central Asian steppe. These arguments usually make reference to the putative progenitor of *P. miliaceum*, the weedy form *P. miliaceum* subsp. *ruderale*. One archaeobotanical textbook[35] gives the distribution of subsp. *ruderale* as stretching from the Aralo-Caspian basin in the west to Xinjiang province and Mongolia in the east, and comment that 'Very probably the vast semi-dry areas in central Asia harbour not only weedy, but also genuinely wild *miliaceum* forms'. *Panicum miliaceum* subsp. *ruderale* is also known from Manchuria;[36] it is sometimes assumed to be the wild progenitor of cultivated *P. miliaceum,*[37] although in fact the degree to which it represents a wild species or a feral derivative of cultivated broomcorn millet is entirely unresolved.[38] Weedy forms of *P. miliaceum* are also recorded from central Europe and North America.[39] In North America, weedy biotypes are generally referred to as 'wild proso millet',[40] although this has no bearing on its evolutionary origins; cultivated *P. miliaceum* was not introduced to the New World before the 17th century,[41] and the first records of weedy forms are from 1970.[42]

The great pioneer of studies of the geography of crop domestication, Nikolai Vavilov, argued that the botanical data support an East Asian domestication of *Panicum miliaceum*, based on the increased phenotypic diversity he observed in varieties from that region.[43] Vavilov's equation of centres of cultivated plant diversity with centres of origin has been enormously influential in the study of early agriculture, although it is now recognised that genetic diversity in domesticates can evolve in secondary centres, removed from the locality of their initial domestication.[44] It has been suggested that both broomcorn and foxtail millet were domesticated within the triangle Central-Asia-Afghanistan-India, and that East Asia represents a secondary centre of diversity.[45]

More is known about the wild ancestry of *Setaria italica* than *Panicum miliaceum*. It is generally accepted that the wild species *S. viridis* is the wild ancestor of cultivated foxtail millet, based on evidence from cytological studies, morphology, and interfertility.[46] *Setaria viridis* is a common weed across Eurasia,[47] so the geography of *S. italica* domestication cannot be narrowed down by this consideration. However, recent analysis of 16 RFLP loci in 62 *S. italica* landraces from across Eurasia defined five major clusters which show some association between genetic and geographic differentiation, and high levels of variation among Chinese landraces.[48] The data are difficult to reconcile with a single Central/South Asian domestication of *S. italica*; they are more consistent with a multiple-domestication scenario,[49] although the lack of samples of *S. viridis* in this study hinders a full interpretation.

The archaeobotanical data are difficult to reconcile with the hypothesis of Central Asia as the sole or major domestication centre for either *Panicum miliaceum* or *Setaria italica*. The designation of these millets as 'East Asian' or 'Chinese' is surely at least partially correct, although one or more additional domestications of each species may have occurred in Eastern Europe or Central Asia.[50] More speculative suggestions, including a statement on the website of the Missouri Botanical Garden[51] that *P. miliaceum* was 'introduced into East Asia from ancient India long ago, passing through the northern mountains of Southeast Asia and eastward, eventually reaching north China and Manchuria' are largely devoid of supporting evidence, but worth mentioning given the discussion below of the reverse route of spread.

Panicum and *Setaria* in the South Asian archaeobotanical record

The millet archaeobotanical record in South Asia has been recently reviewed by various authors.[52] Central to the interpretation of influences shaping South Asian agricultural traditions is the accurate species-level identification of native versus introduced taxa.[53] Although *Panicum miliaceum* and *Setaria italica* are the most important species in their respective genera in world agricultural terms, South Asia has an extremely rich native grass flora, with over 25 species of *Panicum* and around 13 of *Setaria*.[54] For neither genus have the phylogenetic relationships of these and other Eurasian species been comprehensively resolved, and studies of *Panicum* in particular would benefit from insight into the evolution of the genus, including reticulate processes, namely hybridization and polyploidization: the range of chromosome numbers[55] indicates several levels of polyploidy within *Panicum*, and *P. miliaceum* itself is a tetraploid with 2n=4x=36 - whether auto- or allotetraploid is unclear.

A number of native South Asian species are also cultivated or harvested from the wild[56]: *Setaria glauca* (syn. *S. pumila*), *S. verticillata*, *S. intermedia*, *Panicum* *atrosanguineum*, *P.hippothrix, P. paludosum*, *P. trypheron*, *P. turgidum*, and of particular significance, *P. sumatrense* (syn. *P. miliare*) - little millet or *samai* - a regionally important species domesticated from the wild *P. psilopodium*.[57] Archaeobotanical identifications, even when given to species level, have not always detailed the criteria by which these were reached, and rarely considered the possibility of minor congeners.[58] An exception is the recent work by Dr Saraswat[59] on the archaeobotanical remains from the middle Ganga plain, which has provided full details of identification criteria and photographs of specimens, and clear separation of data for cultivated millets and related wild grasses.

Table 1 gives details of sites from which *Setaria* and/or *Panicum* have been reported. Around 30 sites have yielded plant remains attributable to these two genera, including a number originally identified as *Eleusine*. Dorian Fuller[60] has argued that there has been widespread misidentification of finger millet, and many specimens have characters more indicative of *Setaria.* In consequence, the significance of African millets in the Harappan period is undergoing a re-evaluation.[61] *Panicum* and *Setaria* appear in the third millennium BC both in Southern Neolithic (2800-1200 BC) sites[62] at Hallur, Hanumantharaopeta, Sanganakallu and Watgal (primarily *P. sumatrense* and *S. verticillata*, though *P. miliaceum* may be present as a minor component as well[63] and in sites associated with the Harappan culture (from 2600 BC) - Rojdi, Kuntasi, Shikarpur and Oriyo Timbo in Gujarat, Surkotada in Kutch, and Harappa itself (*P. sumatrense)*. By the early second millennium, further Indus valley records appear from Shortughai and Pirak (*Panicum miliaceum*) and Sanghol (*Setaria*). Recent reports indicate the presence of wild *Panicum* and *Setaria* (probably *S. glauca*) species from the middle Ganga plain sites from the late 3rd millennium BC, with putative *P. miliaceum* (at Raja-nala-ka-tila) and *S. italica* (at Malhar and Waina) described in this region in the 2nd millennium BC.[64] *Panicum miliaceum* and *Setaria italica* are present at Semthan, Kashmir, in the late 1st millennium BC and early centuries AD respectively.

Millet ecology and position in agricultural systems

Panicum miliaceum is frequently cited as having the lowest water requirement of any cereal[65] - one source[66] gives a figure of 310kg per kg dry matter produced. *Setaria italica* also demands little water, although we have not found a reference to the precise value. Both millets are C4 grasses and are often described as drought-tolerant, although their ecological strategy rather constitutes a brief life cycle (minimum 60-90 days to seed set for *P. miliaceum*; 75-90 days for *S. italica*[67]) to coincide with the period when water is available. *Setaria italica* appears to have greater osmoregulative capacity than *P. miliaceum,*[68] and this corroborates information from discussions with local farmers in Inner Mongolia, who grow *S. italica* in areas they describe as 'too dry' for *P. miliaceum.*[69] These factors, combined with their requirement for short days to induce flowering, dictate their cultivation as summer crops, which in temperate regions are sown in May-June and harvested in early autumn. In East and South Asia this coincides with the summer monsoon. Eastern Europe and Russia lack a monsoon season, but nevertheless experience a precipitation maximum during the summer months.[70]

In South Asia, this summer monsoon cropping season is known as *kharif*, and involves a distinct suite of plants from the *rabi* crops, which are sown in autumn and harvested in spring. The *rabi* agricultural strategy developed first, with the staple crops wheat and barley introduced to the northwest of the region (Indus valley) from the 7th millennium BC. *Kharif* agriculture is generally accepted to have developed from the 3rd millennium BC, and in addition to millets involved rice, summer pulses, cotton and dates.[71] The cropping strategy varies across South Asia with the local and regional climate and hydrology; today, *Panicum miliaceum*, like *P. sumatrense* and other millets, is generally grown as a rainfed crop, sown to coincide with the onset of the southwest monsoon, although in South India it is grown as a *rabi* crop on stored soil moisture, and in Bihar it is grown in the summer months preceding the monsoon as an irrigated crop.[72] In the Himalayan foothills of Uttar Pradesh and Himachal Pradesh it may be grown either as an early- or late-summer crop.[73] Changes in the assemblage of crop species have been used to infer shifts from a single *rabi* cropping season to a two-season strategy at Harappa at approximately 2200 BC, and at west-central Indian sites, e.g. Inamgaon, during the Chalcolithic.[74] Until recently this shift, and the contemporary increase in agricultural settlement sites in Gujarat, were interpreted as a late Harappan 'agricultural revolution' made possible by the arrival of primarily the African millets,[75] which drove agricultural development in west-central India. Lately, however, it has been argued that the relative importance of imported crops, including the African millets, and native domesticates has been misconstrued, and that cultivation of indigenous species, e.g. *Panicum sumatrense*, developed prior to the integration of non-native crops into the *kharif* subsistence strategy.[76]

Any model for millet origins in, or dispersal through, Central Asia must take into account the Mediterranean-type seasonality of this region, much of which experiences a summer rainfall minimum. Precipitation peaks in the summer only in more northerly parts of Kazakhstan, e.g. around Astana (Akmola). Within the summer-minimum zone, however, there is considerable variation both in total annual rainfall, and the severity of the summer drought, as the environment ranges from low-lying desert of the Kara Kum to the mountains of Tajikistan and Kazakhstan.[77] Possible explanations could invoke altered climate earlier in the Holocene (one model finds seasonal amplitude maxima at 9000 and 6000 BP, and increased precipitation at 8000, 7500 and 4500 BP,[78] although its defined Central Asian zone lies further to the north and east than the region discussed here); irrigation; a shift in cropping season; or cultivation localised in less climatically extreme areas. There is clearly scope for investigation of the precise ecogeographical limits to *Setaria* and *Panicum* cultivation, and testing of explicit hypotheses for millet agriculture in this region. According to one source, *P. miliaceum* is today grown widely throughout Kazakhstan and Uzbekistan (whether irrigated or not is not specified), and *S. italica* is grown only under irrigation in the Fergana Basin in eastern Uzbekistan.[79]

The report of *Panicum miliaceum* from 6th millennium BC Tepe Gaz Tavila in southeastern Iran[80] is striking both for its very early date and considering the aridity of the region: the Dautalabad basin receives an annual rainfall of just 150mm - 250-300mm is usually considered the minimum for dry farming in Iran.[81] Although rainfall usually follows a Mediterranean seasonality, the region falls in some years within the shadow of the Indian Ocean monsoons, which can bring heavy rain in July and August.[82] Meadow suggests that broomcorn millet may have been grown here as a spring or autumn crop. *Qanat* irrigation was not introduced to the area before the 3rd millennium BC, but the Yahya VII sites are clustered around the alluvial fan channels of the Rud-i Gushk, suggesting that agriculture during the 6th and 5th millennia BC employed floodwater runoff to supplement rainfall,[83] in a pattern resonant with Sherratt's model[84] and our own observations at Inner Mongolian sites. Detailed local analysis of this kind should underpin future consideration of *Panicum* origins in Central Asia, to determine its possible routes of spread through this critical but underexplored area.

Routes by which the 'East Asian millets' entered South Asia

The prehistoric presence of *Panicum miliaceum* and *Setaria italica* in predominantly the north-west of the subcontinent, together with the Bronze Age sites in northwest China and possible domestications in Central Asia or the Caucasus makes a convincing case for their reaching the Harappan region from the north-west,[85] whether from an initial source in China or further west. Some researchers, in contrast, assume a Central Asian origin and propose a subsequent spread to South Asia, including the Himalayan foothills of Uttar Pradesh and Himachal Pradesh, where millet species underwent diversification before reaching eastern China by a (presumably) trans-Himalayan route,[86] but it is difficult to see how this model can be reconciled with the archaeobotanical data, given that the earliest records from China precede those of Uttar Pradesh and Central Asia by some 3-4 millennia.

If we assume that at least some of the *P. miliaceum* and *S. italica* in South Asia today is descended from populations in northern China, we can propose that a likely route concretely involved westward spread through Xinjiang and the Tien Shan mountains, then south through the uplands of eastern Central Asia towards the upper Indus valley. This route is at least consistent with east and south Asian archaeobotanical records, and generates questions for further research: to what extent did the Taklamakan desert and the Tien Shan or Altai mountains permit or impede millet agriculture, or possibly trade? Do the earlier records of these millets in Gujarat than the Indus valley reflect a separate introduction from Iran or western Central Asia, or perhaps their earlier adoption into an agricultural landscape more dependent on *kharif* crops? Does their spread reflect population dispersals, or contact and trades between societies across Asia? Certain Harappan sites have artefacts made from jade and gold likely to have originated in Central Asia and China, including Dzungaria, northeast China (Shanxi), and Xinjiang.[87]

Two cultivated fruit trees, peach (*Prunus persica*) and apricot (*P. armeniaca*) are thought to be native to temperate mountainous regions of Tibet, western China and Central Asia,[88] and reach the Kashmiri sites of Burzahom and Semthan in the Neolithic (2375-1700 BC) and Indo-Greek (200 BC - 1 AD) phases respectively.[89] At the latter site, *Panicum miliaceum* is present in the same period, and we can suggest that the same societies and transit routes could have been involved in the introduction of these trees and the 'East Asian millets'. The recent reports of non-indigenous *Panicum* and *Setaria* from 2nd millennium BC sites in the middle Ganga plain have provided the first indications of the timing and routes of their arrival in the north-central and eastern Indian states, which remain significant regions for their cultivation in modern times.

Prospects from studies of millet diversity

Work on genetic diversity among *Setaria italica* cultivated in India today suggests that its gene pool represents admixture between Chinese and European lineages.[90] Phylogeographic studies of cultivated plants are proving immensely valuable in understanding their domestication history,[91] and we anticipate that analysis of genetic variability in *Panicum miliaceum* would prove similarly informative with regard to its origins and routes of spread, both into South Asia and elsewhere. Cultivated *Panicum miliaceum* shows considerable morphological variation, particularly in the characters of seed colour and panicle shape, which have formed the basis for classification into varieties. Much of the work of classifying *P. miliaceum* was done by Soviet botanists, e.g. N.I. Lyssov.[92] According to one recent review,[93] *P. miliaceum* in India belongs to the race *patentissimum*, one of five races or subspecies that form Lyssov's primary subdivision, although Lyssov's original text indicates that varieties assigned to other races, particularly *miliaceum*, are more prevalent in India than race *patentissimum.* To what extent the classifications of Lyssov and others reflect phylogenetic relationships between varieties of *P. miliaceum* remains an open question, however. The few molecular studies to date have largely focused on North American cultivated populations, but have showed that DNA fingerprinting methods are able to distinguish between varieties.[94] The application of these tools to Old World landraces, combined with molecular phylogenetic studies of genus-level relationships, will illuminate the evolution of domesticated broomcorn millet.

Conclusions

The obscure and probably complex origins of *Setaria italica* and *Panicum miliaceum* have made it difficult to furnish a clear interpretation of their presence in the South Asian archaeobotanical record, despite their potential significance in the context of contact between the Harappans and agricultural societies elsewhere in Asia. The accurate species-level identification of these millets to distinguish them from indigenous congeners is a key prerequisite in this interpretation, whilst in a wider context data from archaeobotany, botany, ecophysiology, climatology and genetics need to be synthesised rather than treated in isolation, in order to construct robust models of the origins and spread of these millets.

Table 1 : South Asian archaeobotanical records of *Setaria* and *Panicum.* X = present, (X) = uncertain/unlikely identification. E* = records of *Eleusine* which may well be *Setaria* mis-identified as *Eleusine* [(i)] *.* Data from published reviews and research papers[(ii)]

Site	Period	Panicum	Setaria	E*
Hallur, Karnataka	Neolithic (2800-1200 BC)	X	X	
Hanumantharaopeta, Andhra Pradesh	Neolithic (2800-1200 BC)		X	
Sanganakallu, Karnataka	Neolithic (2800-1200 BC)	X	X	
Watgal, Karnataka	2800-1000 BC	X	X	
Rojdi, Gujarat	A (2600-2200 BC)	X	X	X
Harappa, Punjab	Harappan/Late Harappan (2600-1900 BC)	X	X	
Shikarpur, Punjab	Harappan (2500-2200 BC)		X	
Kuntasi, Gujarat	Harappan (2500-2000 BC)		X	
Surkotada, Kutch	Harappan/post-Harappan (2500-1700 BC)	X	X	X
Balathal, Rajasthan	Chalcolithic (2350-1800 bc)	X	X	
Lothal, Gujarat	Chalcolithic per. II (2350-2500 BC)		X	

Shortughai, Afghanistan	2300-1800 BC	X		
Senuwar, Bihar	Neolithic (2200-1950 BC)	X	X	
Rojdi, Gujarat	B (2200-2000 BC)	X	X	X
Senuwar, Bihar	Chalcolithic (1950-600 BC)		X	
Vaghad, Gujarat	?2000 BC	X		
Babar Kot, Gujarat	2000-1700 BC	X	X	
Rojdi, Gujarat	C (2000-1700 BC)	X	X	
Pirak, Baluchistan	Post-Harappan (1950-1550 BC)	X		
Sanghol, Punjab	Late Harappan (1900-1400 bc)		X	
Oriyo Timbo, Gujarat	Late Harappan	X	X	
Kaothe	Chalcolithic (c. 1900 BC)		X	
Malhar, Uttar Pradesh	1900-1700/1600 BC	X	X	
Hulas, Uttar Pradesh	Late Harappan (1800-1300 BC)			X
Daimabad, Maharashtra	Malwa (1700-1500 BC)			X
Inamgaon, Maharahstra	Malwa (1700-1500 BC)			X
Peddamudiyam, Andhra Pradesh	Late Neolithic (1700-1300 BC)		X	
Malhar, Uttar Pradesh	1700/1600-800 BC	X		
Raja-nala-ka-tila, Uttar Pradesh	1600-700 BC	X		
Inamgaon, Maharahstra	Early Jorwe (1500-1200 BC)		X	X
Daimabad, Maharashtra	Jorwe (1500 - 100 BC)		X	X
Narhan, Uttar Pradesh	Chalcolithic-Iron Age (1300-200 BC)	(X)		
Inamgaon, Maharahstra	Late Jorwe (1200-900 BC)	X	X	X
Hallur, Karnataka	Neolithic-Iron Age (c. 1000 BC)	(X)		X
Adam, Maharashtra	Pre-Mauryan (500-300 BC)		X	
Balathal, Rajasthan	Early historic (500 BC - 300 AD)	X	X	
Semthan, Kashmir	III (200-1 BC)	X		
Semthan, Kashmir	IV (1-500 AD)		X	

(i). Fuller, D. Q. 2002. 'Fifty years of archaeobotanical studies in India; laying a solid foundation', 'in S. Settar and R. Korisettar (eds.) *Indian Archaeology in Retrospect, Vol. III. Archaeology and Interactive disciplines*. New Delhi, Manohar: 247-364.

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