Rainfall Seasonality and the Spread of Millet Cultivation in Eurasia

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Broomcorn millet (*Panicum miliaceum*) was known throughout Eurasia in the second millennium BC in regions with warm, moist summers, where its cultivation reduced agricultural risk. Its cultivation during the warm, but dry months at Kyzyltepa and other Iron Age sites in western Central Asia was probably made possible through irrigation practices that were long known and originally developed in the winter-wet, summer-dry climate of West Asia. The adoption of millet by sedentary people of Central Asia is likely associated with intensification of agricultural production rather than as a strategy to reduce agricultural risk.

Keywords: *archaeobotany, Kyzyltepa, Uzbekistan, broomcorn millet, foxtail millet, Panicum miliaceum, Setaria italica*

Introduction

Many factors influence crop choice: climatic conditions, agronomic and culinary qualities, agricultural and processing technology, social relationships between source and receiving regions, and cultural factors such as status, ritual, and appropriateness to the local cuisine (see, e.g., van der Veen 2010). Although the first known millet finds in Central Asia come from a ritual context (Frachetti *et al.* 2010), millet can be a very useful crop: its small grains cook quickly, with relatively little fuel, and in its place of origin, millet is commonly considered a warm-season, drought-resistant crop whose cultivation hedges against the risk of total crop failure. In Central Asia, however, millet must be irrigated. This raises the question of when, where, and whether it was grown primarily to reduce agricultural risk or to intensify production. The introduction and spread of millet in Central Asia provides a case study of the effect of climatic factors and cultural circumstances on agricultural development.

This paper was inspired by the discovery of millet remains from Kyzyltepa, which is an Achaemenid site in Uzbekistan (Wu *et al.* 2015). The millets are a diverse group of small-seeded cultivated grasses. Even though they are not the earliest crop plants in Central Eurasia, they can serve as an entry point to a discussion of new crops and the intensification of agricultural production. Of the two millets cultivated across western and Central Eurasia, broomcorn (*Panicum miliaceum L.*) is the more common and more firmly identified. Foxtail millet (*Setaria italica* (L.) P. Beauv.) is less commonly found (Hunt *et al.* 2008).

Broomcorn and foxtail millet require similar growing conditions. Both are warm season plants. Seeds are sown in spring or summer and mature in two or three months. In regions with summer rain, they are considered drought resistant, so millet cultivation can reduce agricultural risk (Oelke *et al.* 1990). On the other hand, over much of west and central Asia, millet can be grown only under irrigation. That is because the warm season is also the dry season. In this zone, irrigated summer millet production increases the total amount of carbohydrate-rich food produced on the same amount of land; that is, its cultivation signifies intensive land use.

There are ethnographic examples of mobile pastoralists engaging in small scale cultivation in order to diversity production and reduce risk (e.g., Salzman 2002). Possible archaeological examples come from the late third-millennium site of Begash (Frachetti *et al.* 2010) and second-millennium Ojakly and 1211/1219 (Spengler *et al.* 2014), where millet has been found.

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Vegetation and climate

The Indo-Turanian vegetation that covers much of Eurasia is adapted to cold winters and warm summers, with most precipitation falling in the winter (Zohary 1973). Vegetation responds to the two major climate systems of Central Asia. The Westerlies bring winter moisture and summer drought; the monsoonal system of south Asia is characterized by warm, rainy winters (Fig. 1). A recent study integrating phytogeography and bioclimatology shows that continentality, winter temperature, and seasonality of precipitation are the main determinants of vegetation zones in Eurasia (Fig. 2; Djamali *et al.* 2012: fig. 1): Indo-Turanian zone 1 and much of Indo-Turanian zone 2 overlap with Anatolia, northern Mesopotamia, and the Zagros, approximating the area of dry-farmed winter wheat and barley. Summer monsoonal precipitation characterizes the Indian subcontinent.

There is a broad relationship between the major vegetation zones and seasonal precipitation. For example, Indo-Turanian zone 3 is bounded on the south by the limits of winter precipitation and on the north by summer precipitation. The boundaries are not exact, and presumably they have shifted over time. Nevertheless, modern conditions do provide an approximation at the broad scale of this analysis. Indo-Turanian zone 4 is approximately where the winter-wet and the summer-wet systems meet.

The climate and vegetation data inform the discussion of the history of broomcorn millet. Broomcorn was domesticated in northern China as early as 8000 BC (Lu *et al.* 2009). Recent direct AMS dating of broomcorn finds suggests it had arrived in eastern Europe by 3000 BC (Motuzaite-Matuzeviciute *et al*. 2013).

Kyzyltepa

The Kyzyltepa remains do not relate to the initial expansion of millet out of east Asia, but they do relate to the intensification of agricultural production associated with the rise of imperial systems during the first millennium BC. The botanical material comes from the American-Uzbek Joint Excavation led by Wu Xin and Leonid Sverchkov (Wu forthcoming; Wu *et al.* 2015). The site is located in the Surkhandarya region of Uzbekistan. Annual precipitation of about 230 mm falls mainly in the winter. It is insufficient for dry-farming the winter cereals, wheat, and barley, so farming in the valley bottom requires irrigation. The surrounding upland areas provide summer pasture for transhumant flocks (Stride 2005).

Kyzyltepa is a walled site with an area of 12

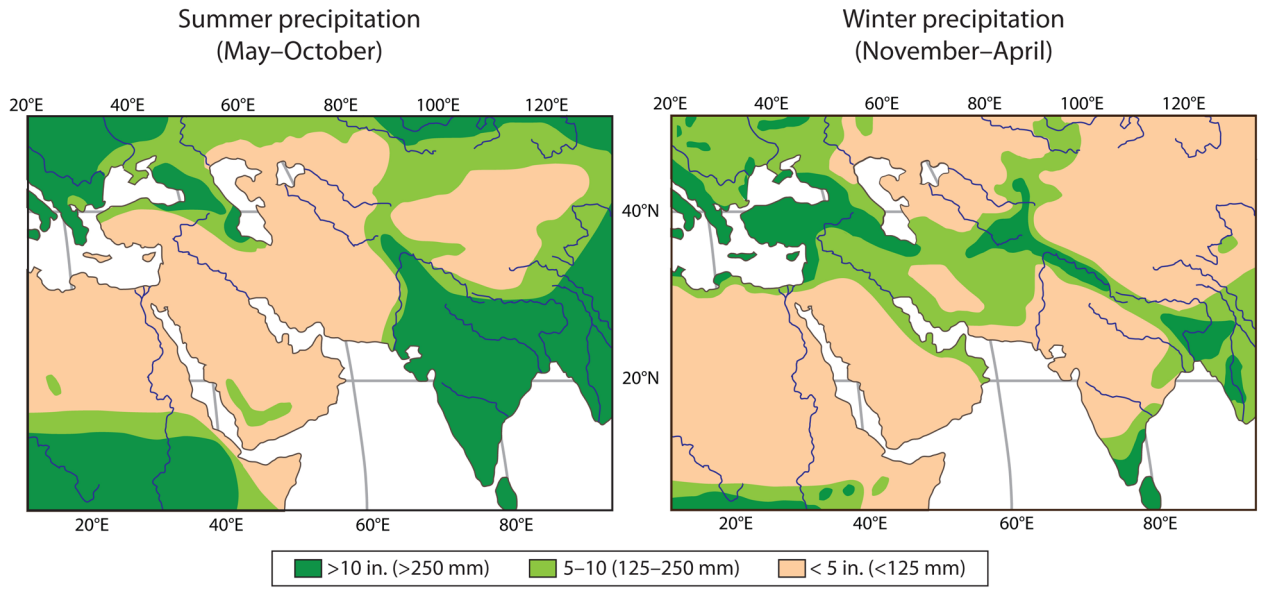


Fig. 1: *Seasonal Precipitation (modified from Robert Encyclopedia n.d.). Compare*

ha. The excavators think that it was established as an Achaemenid ritual and administrative center serving at least ten small sites in the immediate area. Archaeological survey by Soviet scholars shows a great increase in the number of settlements during the Iron Age. Sebastian Stride and Wu Xin associate this period of growth with the expansion of Achaemenid power during the mid-first millennium BC (Stride 2005; Wu, forthcoming). Wu Xin advises caution in using the settlement data to estimate population, since the possible role of transhumant pastoralists is unknown.

The archaeobotanical samples have varying proportions of wood charcoal, plant parts, crop seeds, and wild seeds. The crops include six-row barley and bread wheat, both of which are sown in the fall to take advantage of winter rains. Even so they would need supplemental irrigation. There were two samples with quite a bit of millet. One had about 1500 foxtail millet seeds, along with barley, charcoal, and wild seeds. The other had had over 2000 broomcorn mixed with other items. The context and sample composition do not allow us to say for certain that the seeds are accidentally burned food remains, but they are definitely cultigens (Miller 2013). Of special interest was the presence of foxtail millet rachis fragments. Millet rachises are very delicate and rarely survive charring. The presence of rachis fragments strongly suggests that the crop was grown locally; we are not dealing with imported seeds. Therefore, the Kyzyltepa people must have practiced summer irrigation in addition to the expected irrigation of winter wheat and barley (see also Wu *et al.* 2015).

Risk Reduction or Intensification of Production

Broomcorn millet is found on sites in the open woodland regions of northern Anatolia across to Iran by the 2nd millennium BC (see Nesbitt and Summers 1988) (Table. 1). The earliest millets in west and Central Asia appear where summer precipitation is greater than 125 mm. Climate map data are coarse, so phytogeographical zone and seasonal precipitation data from nearby modern cities provide a check (Fig. 3, Table. 2). With some exceptions, it is not until the first millennium that domesticated millets appear on archaeological sites in the steppe and steppe-desert lands from Anatolia to Central Asia. This preliminary study seeks broad patterning, both spatially and temporally. I suggest that the early sites with millet in the summer dry zone represent small-scale irrigation aimed supplementing agropastoral production on a small scale.

Archaeobotanical evidence of millet can be mapped in relation to seasonal climate and vegetation. Table 2 lists sites according to summer precipitation; in the dry area, summer millet

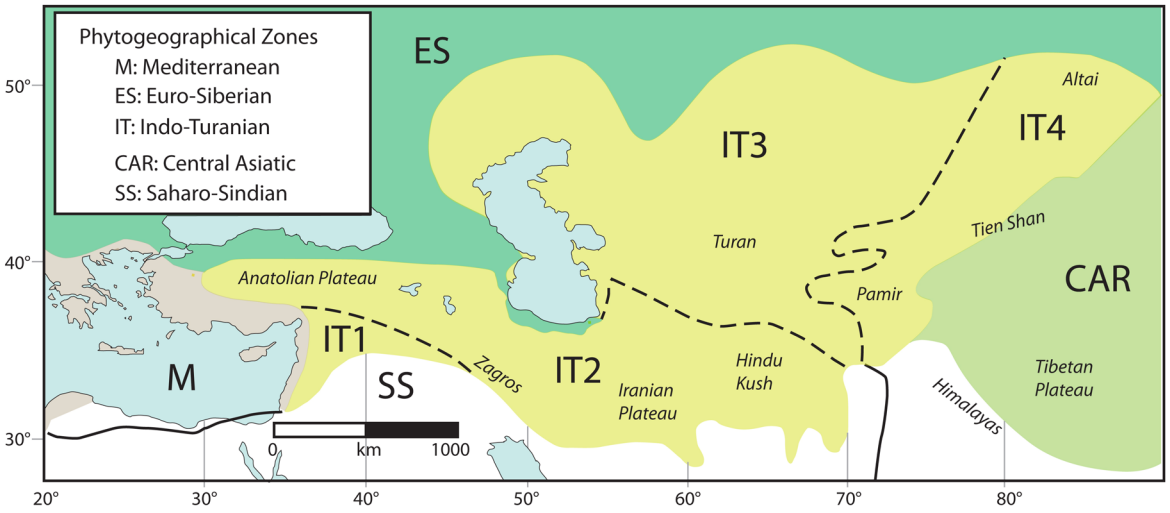


Fig. 2: *Phytogeographical zones,(following Djamali et al. 2012).*

Table. 1: *Sites with millet in West and Central Asia; two sites in Greece added for comparison.*

	3rd Mill. BC	2nd Mill. BC	1st Mill. BC	Source
Summer wet				
Aržan	.	.	P	Neef 2010
Tasbas	.	P, S?	.	Spengler *et al*. 2014
Begash	P	.	P, S	Frachetti *et al*. 2010; Spengler & al. 2014
Tuzusai	.	.	P, S	Spengler *et al*. 2013
Sos Höyük	—	—	S	Longford & al. 2009
Kastanas	.	P	P	Nesbitt and Summers 1988
Assiros Toumba	.	P	.	Nesbitt and Summers 1988
Haftavan	.	P	.	Nesbitt and Summers 1988
Bastam	.	.	P or S	Hopf 1989
Gordion	.	S	P, S	Marston 2010; Miller 2010
Hasanlu	.	.	P	Costantini n.d.
Summer dry				
Kilise	.	P	P	Bending and Colledge 2007
Tille	.	.	S	Nesbitt and Summers 1988
Aşvan Kale	.	.	P	Nesbitt and Summers 1988
Shortugai	.	P	.	Willcox 1989, 1991
Nimrud	.	.	P	Nesbitt and Summers 1988
Kyzyltepa	.	.	P, S	Miller 2012
Kara-Tepe	.	.	.	Brite and Marston 2012
Ojakly, 1211/1219	.	P	.	Rouse and Cerasetti 2014
Gonur	.	P or S	.	Bakkels 2003
Tahirbaj (Merv)	.	.	P	Nesbitt 1994
Gyaur Kala (Merv)	.	.	P	Boardman 1995, 1997, 1999
Erk Kala (Merv)	.	.	.	Boardman 1995, 1997, 1999; Nesbitt 1994

Table. 2: *Sites listed in order of summer (May–October) precipitation.*

	Location	Vegetation	Summer	Winter
Summer Precipitation > 100 mm				
Kyzyl (Tuva)	51.7 N 94.4 E	ES	343	115
Aržan	52.1 N, 93.6 E			
Almaty	43.2 N, 76.9 E	IT4	262	319
Tasbas	45.5 N, 79.6 E			
Begash	44.9 N, 78.5 E			
Tuzusai	45.5 N, 79.6 E			
Erzurum	39.9 N, 43.2 E	IT2	251.6	208.9
Sos Höyük	40.0 N, 41.5 E			
Thessaloniki	40.3 N, 23.4 E	M	193.5	246.4
Kastanas	40.8 N, 22.6 E			
Assiros Toumba	40.8 N, 23.0 E			
Van	38.5 N, 43.3 E	IT2	122	262
Haftavan	38.2 N, 44.8 E			
Bastam	39.9 N, 45.0 E			
Polatlı	39.6 N, 32.1 E	IT2	118.3	228.3
Gordion	39.7 N, 32.0 E			
Urmia	37.6 N, 45.0 E	IT2	104	243
Hasanlu	37.0 N, 45.5 E			
Summer Precipitatiuon < 100 mm				
Mersin	36.8 N, 34.6 E	M	93.7	523.7
Kilise	36.5 N, 33.8 E			
Adıyaman	37.8 N, 32.3 E	IT2	93.6	741.8
Tille	37.7 N 38.9 E			
Aşvan Kale	38.8 N, 38.8 E			
Kunduz	36.7 N, 68.9 E	IT3	38	285
Shortugai	37.3 N, 69.5 E			
Mosul	36.3 N, 43.1 E	IT2	31.4	354.7
Nimrud	36.1 N, 43.3 E			
Denau	37.9 N, 67.6 E	IT3	28.9	269.6
Kyzyltepa	38.1 N, 67.7 E			
Urgench	41.6 N, 60.6 E	IT3	20.2	71.1
Kara-Tepe	41.9 N, 60.7 E			
Bayramaly	37.6 N, 62.1 E	IT3	16.8	138.2
Ojakly, 12ll/1219	38.3 N, 62.2 E			
Gonur	38.2 N, 62.0 E			
Tahirbaj (Merv)	38.1 N, 62.1 E			
Gyaur Kala (Merv)	37.7 N, 62.2 E			
Erk Kala (Merv)	37.7 N, 62.2 E			

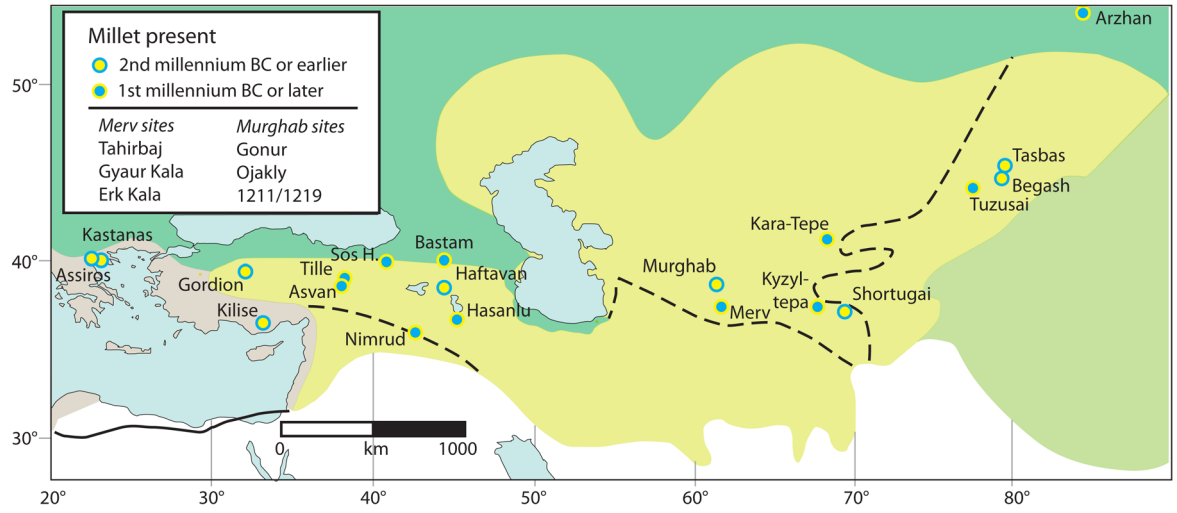


Fig. 3: *Phytogeographical zones in relation to sites where millet has been found in Asia. The sites with the earliest millets in the region lie in Indo-Turanian zone 4.*

cultivation requires irrigation. Several second-millennium sites with millet are in the "summer dry" zone. These sites might seem to contradict the simplistic idea that millet cultivation expanded into the summer dry zones of west and central Asia only with the introduction of imperial water management projects. Most of these cases can be explained. For example, Haftavan is so close to the 125 mm summer precipitation cutoff point that it is not is problematic as it first seems. At Gordion, the introduction of millet may be associated with the migration of Phrygians into Anatolia at the end of the first millennium BC, and thus represent a culturally valued food brought from their home in Europe (cf. Voigt and Henrickson 2000). With regard to Kilise (Bender and Colledge 2007), the May cut-off point for precipitation is arbitrary. In fact, the the south coast of Turkey is warm in the rainy months of March and April, so early spring planting might permit successful harvest of this fast-maturing crop. Shortugai, with very low summer precipitation, is difficult to explain. The Murghab oasis sites Gonur, Togolok-21, Ojakly, 1211, and 1219 do not fit the pattern at all (see Bakels 2003; Spengler *et al*. 2014). Millet cultivation in this region requires irrigation. One might imagine that year-round farmers at Ojakly grew it for trade with seasonally transhumant people, because it seems unlikely that transhumant people would have kept their flocks in the Murghab delta during the scorching summer. The somewhat later transhumant residents of 1211 and 1219 could be recipients of millet grown locally by farmers. Or they could have grown it themselves with some irrigation during their summer migration to the uplands, and brought it back to the lowland. As the earlier Begash (Frachetti *et al*. 2010), Tasbas (Spengler *et al*. 2014), and perhaps Gonur and Togolok-21 (Bakels 2003) records show, millet seems to have been a ritually important food of Central Asian pastoralists.

The settled people of Central Asia had been irrigating winter-sown cereals for millennia and millet was grown by transhumant people across Eurasia (Spengler *et al*. 2014; Spengler *et al*. 2013; Frachetti *et al*. 2010; Bakels 2003). The farmers of Central Asia had irrigation technology, and the lines of communication and trade exposed them to millet long before the first millennium BC. Ester Boserup (1965) observed that many technologies are known well before they are adopted wholeheartedly out of usefulness or necessity. That observation would seem to apply in this case.

Irrigated millet production does seem to be a feature of central Asian agriculture during the second millennium. But the timing of widespread millet cultivation in Central Asia may lie in the answer to my original question: if the warm season millets are valuable for reducing the risks associated with drought, why would you grow them at all in regions with virtually no summer rainfall? Wilkinson

and Rayne (2010) note that in rainfall agriculture regions, construction of large scale hydraulic works in the first millennium BC is associated with empires and summer irrigation. Although even large systems may be locally organized, Achaemenid Iran also saw increased water management (Wilkinson *et al*. 2012). Whether locally or centrally controlled, agricultural intensification in general and millet cultivation in particular appear to be associated.

The establishment of millet as a crop of sedentary people in summer-dry Central Asia is contemporaneous with the creation of large scale irrigation works. Bactrian documents dating to the Achaemenid period suggest that millet rations were given to servants and slaves, so it was probably a low status food (Wu *et al.* 2015). Millet has a culinary advantage that would be valued by poor people: the whole grains can be prepared with little fuel, since their surface area is so small compared to wheat, barley, and rice.

Conclusions

Dry farming millet in the summer-moist zone would help farmers reduce the risk of total crop failure in the event of drought. In the drier regions of west and Central Asia, the introduction of millet cultivation has two corollaries: first, summer irrigation became important in places already familiar with winter irrigation. Second, farmers had to work harder, because planting, water management, and the harvest would keep them busy in the hot lowlands year-round. Previously, they might have moved to cool summer pastures with their flocks. The intensification of agricultural production we see at Kyzyltepa might be a small example of a much broader pattern. From the beginning, winter-cropped wheat and barley were irrigated in central Asia. The creation of large-scale irrigation systems in the summer dry zone is a more general characteristic of the first millennium. The new system accommodated summer-cropping on a larger scale. It is associated with imperial systems of west Asia from the Neo-Assyrians to the Achaemenids. These agricultural systems could have drawn millets from the established crop repertoires of east or west. The practice of millet cultivation in the summer-dry region is so different from millet cultivation in its place of origin, the motivation may well be different: rather than primarily a risk reduction strategy, millet cultivation provided a way to extract more food from the same amount of land. Judging from the archaeobotanical record, millet was never a major crop in the summer-dry part of Central Eurasia, but it is exactly its unsuitability as a staple crop that helps focus attention on the natural and cultural variables that persuaded people to cultivate it at all.

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