ISBN: 978-81-19149-19-3

1. History and Domestications of Millets

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Abstract:

Climate change and biodiversity loss will push us to revolutionise and transform our existing food systems to feed the global population and provide sustainable nutrition. Alternative crops such as millet present a viable option to diversify our diet and contribute to food security. Over the years, millets have enjoyed the tag of "poor man's food grain" because of their sheer affordability. Millets have been classified into two groups on the basis of their grain size major millets and minor millets. Major classification includes sorghum (Sorghum bicolor), pearl millet (Pennisetum glaucum), foxtail (Setaria italica), proso (Panicum milliaceum), and finger (Elusine coracana) millets whereas the minor ones being the kodo millet (Paspalum scrobiculatum), little millet (Panicum sumatrense), barnyard millet (Echinochloa frumentacea) millets that belong to the family Poaceae and kingdom Plantae. This year is declared as International year of Millets and theme for the International Year of Millets 2023 (IYM) is "Harnessing the untapped potential of millets for food security, nutrition, and sustainable agriculture". The theme reflects the goals of the initiative to raise awareness about the nutritional, ecological, and cultural value of millets, promote sustainable farming practices, and encourage their consumption as a healthy and sustainable alternative to other grains. The theme also highlights the potential of millets to contribute to food security and nutrition, particularly in regions where they are culturally relevant and deeply rooted in Indigenous Peoples' culture and traditions. Thus to know the history and domestication millets is very important for study. Plant domestication is associated with major morphological modifications to fit human needs. The theme emphasizes the need to harness the untapped potential of millets to achieve *sustainable agriculture, empower smallholder farmers, promote biodiversity, and transform agrifood systems.*

Keywords:

Millets, History, Domestication, Conservation, Germplasm.

1.1 Introduction:

In today's scenario, climate change, malnutrition and food security are burning issues around the world. As the population increases day by day, it becomes very important to address these issues to maintain the food balance among all. Millet represent a diverse group of versatile cereals that have long been a part of many agricultural ecologies in Africa and Eurasia. 'Millets' refers to a diverse group of annual cereal crops that produce small seeds. They include several foods, fodder, and biofuel grasses, such as sorghum (Sorghum bicolor), pearl millet (Pennisetum glaucum), foxtail millet (Setaria italica), proso millet (Panicum miliaceum), kodo millet (Paspalum scorbiculatum), finger millet (Elucine coracana), barnyard millet (Echinocloa sp.), etc. (Dwivedi et al. 2012).

The major distinctive character of the millets is their adaptability to cope with adverse agro-ecological conditions such as a semi-dry environment and nutritionally poor soil, the requirement of minimal inputs, and highly nutritious seed content (Lata et al. 2013). Millets, despite their therapeutic properties and agro-economic potential, they are denominated as "underutilized," "forgotten," or "orphan" crops due to their coarse character and minimum usage in convenience foods along with poor research and novel techniques for the development of food products (Dey et al. 2022).

This is primarily because of the lack of awareness of their nutritious qualities among most people and the non-availability of customer friendly and ready-made millet-based products. In the past few years, global attention and efforts have been applied to millets to acquire expedient and value-added processed products in consumer markets (Singh et al 2017).

Millet grains are also called "famine reserves" as they could be stored up to two years or more. They are considered among the sixth most important cereals. The world's highest production of millets is in India. Millets are sown and produced in countries of warm and tropical regions such as Africa, Asia, Eastern and Southern Europe, and some parts of America. The total area for the production of all types of millets is nearly equal in both Africa and Asia. Among the many of its properties, one characteristic is being gluten-free, which helps patients in curing celiac disease and gluten allergy. They are nutricereals, highly nutritious on the basis of protein, dietary fiber, vitamins, and minerals.

The plant domestication process is associated with considerable modifications of plant phenotype. The identification of the genetic basis of this adaptation is of great interest for evolutionary biology. One of the methods used to identify such genes is the detection of signatures of selection. However, domestication is generally associated with major demographic effects. It is therefore crucial to disentangle the effects of demography and selection on diversity.

The domestication of wild plant species to produce cultivated species is thought to begin with gathering seeds from the wild species, wild relatives, land races before progressing to deliberate planting and gathering. Gradual genetic changes in the wild plant lead to domestication-related characteristics that are desirable for human cultivation, such as suppression of seed shattering and selection of appropriate flowering time. There is also other methods available to make it under human cultivation like pre-breeding, bridge crossing techniques. The majority of millet grown worldwide, or 65% of all millets, is sorghum. Sorghum production between 60.18 and 58.70 million metric tonnes in 2010 and 2020, respectively. In India nearly 21 States grow millets. Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala, Uttarakhand, Jharkhand, Madhya Pradesh, Haryana and Gujarat are all seeing significant momentum. Millets are grown on 12.45 million hectares in India, yielding 15.53 million tonnes. More than 50% of the nation's territory is planted with millets. In 2020-21, India exported millets worth USD 26.97 million against USD 28.5 million in 2019-20. The FAO estimates that 89.17 million metric tonnes of millets will be produced globally from an area of 74.00 million hectares in 2020 (Kumar et al. 2023)

1.2 Sorghum (*Sorghum Bicolor*):

Plant domestication is a process not an event. It comes about through inter-action of man with the plants he uses. Man also influences the evolution of species he does not use. These evolve as weeds adapted to all habitats being disturbed by man. Domesticated species resemble weeds in habitat adaptation, and the ecological boundaries of wild, weed, and crop plants are often poorly defined. As with most cereals, a major step in the process of sorghum domestication was the loss of the shattering habit. Vavilov considered the old Abyssinian (Ethiopian) area as the center of origin, but Harlan suggests that sorghum arose across a large area, where it was likely domesticated a number of times over a period of years. Snowden thought that sorghum arose in several separate centers and from different species: races durra and bicolor from S. aethiopicum, guinea from S. arundinaceum, and kafrr from S. verticilliflorum. De Wet questions whether race virgatum, a desert grass, and arundinaceum, a forest grass, were involved with the direct origins of sorghum, since they grow outside the major habitat of the crop. He suggests that S. verticilliflorum was the first to be domesticated some 3,000 to 5,000 years ago (de Wet, 1986).

It is difficult to determine when and where domestication occurred. But Murdock (1959) has suggested that the mande people around the headwaters of Niger River may have domesticated sorghum. The archaeological evidences suggest that the practice of cereal domestication was introduced from Egypt to ethopia about 3000 B.C. It is possible that domestication of sorghum began about that time (Dogget 1995).

The sorghum had a diverse origin and probably arose from S. verticilliforum, S. arundinaceum, is a grass of the tropical forest and S. aethiopicum and S. virgatum are found in desert regions. These habitats are outside the major sorghum areas and probably contributed less to its domestication. S. verticilliforum is usually found in areas where sorghum is cultivated. There is tremendous variation in S. verticilliforum and it as well as the other wild species readily crosses with cultivated sorghum. It yields well and was probably collected and used before the advent of agriculture.

The races durra, guinea and kafir are closely allied and may have arisen from aethiopicum, arundinaceum and verticilliflorum respectively Snowden 1936 and Porteres 1951). Morphological differences between races may have arisen because of the ethnic isolation. Kafir is widely grown in Africa, while durra is not found. Caudatums are most common in central Sudan and Guinea found primarily in West Africa. Distribution indicates that the races kafir and caudatum were derived from verticilliflorum and that durra possibly could have come from arundinaceum. and not found where sorghum is extensively cultivated. Introgression studies indicate that cultivated sorghums probably developed through disruptive selection (Doggett 1955). Crossing easily occur between wild and cultivated types however they form distinct populations. It is speculated that, as man began to select there ws substantial gene flow between improved and umimproved types. This gene flow would decrease as field size become larger. The selection by man nature would provide a forces have been continuously active through time influencing cultivated and wild populations. The process of domestication involved a change in several characteristics of the plant. A tough rachis and persistence of the sessile spiklet were probably introduced early in the process. It is likely that the transformation of loose and open inflorescence into a compact type involved several changes. An increase in the number branches per node, increase in number branches per primary inflorescence branch and third a decrease internode length on the primary axis (rachis). An increase in seed size also was probably a product of domestication the seed becoming large enough to protrude from the glumes.

1.3 Pearl Millet (*Pennisetum glaucum*):

There are few substantiated early archaeological records of Pennisetum. Studies of the genus, including wild and cultivated types, have considered geographic distribution, morphological similarities, and genetic differences including isozymes and restriction fragment length polymorphism analysis. Domestication probably occurred 5,000 or more years ago in Africa in the savanna south of the Sahara and west of the Nile (Andrews and Kumar, 1992). Domestication may have occurred among different isolated populations over time going back 7,500 to 7,000 years with indication of close coexistence with wild millet 3,000 years ago; however, introgression continues at the present time. Genetic differences have been identified between wild and cultivated types, but domestication is considered to have involved relatively few genes (Andrews and Kumar, 1992). Its introduction into India is uncertain, but is likely some 3,000 years ago. It was cultivated in the United States by 1873, while its introduction into Central and South America likely came from southern Europe and France. Its cultivation there more or less terminated toward the end of the 19th century. It has been grown some in Europe, but its use was more in the 19th than in the 20th century. Pearl millet is known by a number of names: bulrush, cattail, and spiked millet in English; bajra in Hindi; dukhn in Arabic; and mil it chandelles in much of West and North Africa.

Some studies support the hypothesis that the very strong morphological differentiation we observe today was progressively selected over hundreds to thousands of years (Fuller 2007) and surprisingly that the speed of selection by humans was similar to that of natural selection (Purugganan and Fuller 2011). One important pathway for crop domestication, adaptation, and improvement that has been sufficiently well studied from a functional point of view is the pathway governing flowering time.

The current hypothesis concerning its domestication suggests it original. The current hypothesis concerning its domestication suggests it originated in the northern–central Sahel in West Africa.The oldest archaeobotanical evidence of pearl millet cultivation was found in Mali and dated at around 4,500 BP (Manning et al. 2011).The domestication process of pearl millet is associated with common morphological changes among cereals: suppression of spikelet shedding, reduction in the size of bristles and bracts, increase in seed size, increase in spikelet pedicel length, loss of dormancy, reduction in the number of basal tillers, and an increase in spike length. Interestingly, although the origin of cultivation is hypothesized to have occurred in the dry areas of the Sahel, pearl millet is also cultivated further south in more humid areas. Consequently, in West Africa, pearl millet displays a wide range of flowering times.

The wild progenitor of the cultivated pearl millet species has been identified as Pennisetum violaceum (Lam.) Rich. [syn. P. americanum subsp. Monodii (Maire) Brunken] (Brunken et al. 1977). The natural distribution of this species is restricted to the Sahelian zone, from Senegal to northern Sudan (Harlan 1992). However, it is often inferred that domestication occurred in the western part of this range, between Niger and Mauritania (Clotault et al. 2012**;** Dupuy 2014; Fuller 2003). The modeling of modern genomic data fits with the hypothesis of a southwestern Saharan origin for the domesticated form, whence pearl millet spread westward to Mauritania and southward into the savanna south of the Niger River bend (Burgarella et al. 2018). Here, we report new evidence for wild pearl millet, dating back to the middle Holocene (~5000 BC), from northeast Mali within the western Saharan zone, and the subsequent appearance of domesticated traits by midthird millennium BC. These data derive from the conventional study of impressions on sherd surfaces (Fuller et al. 2007) and microCT-scanning of sherds' interior content (following the recently developed methods by Barron and Denham 2018; Barron et al. 2017, 2020a, 2020b). We then combine these data with the available long-term archaeological evidence in western Africa to identify the evolutionary trends of pearl millet's domestication and diversification.

A native of the old world tropics, it reaches its greatest importance in the dry sahel zone which stretches across sub-Saharan Africa and in the semiarid regions of northwestern India. Throughout its distribution, pearl mil- let serves a multitude of traditional societies which would otherwise be hard pressed for their sustenance. In describing the region of Abyssinia (the Upper Nile), he mentions that two types of millet, durra and dokhn, are commonly cultivated. The first name refers to cultivated sorghum and the second to pearl millet. Both of these crops are grown under these same names in the Upper Nile today. The earliest mention of pearl millet in west- ern literature is attributed to Leo Africanus, a 16th century Moorish slave in the service of Pope Leo X for whom he wrote an account of Africa north of the forest zone (Pory, 1600). In his classic work on the origins of crops, Vavilov (1949/1950) placed pearl millet in the Ethiopian center of domestication. The high- lands of Ethiopia are today an agriculturally diverse region in which crops from many parts of the world are grown. The wild progenitor is adapted to the sandy, semiarid conditions of the sahel and very likely would have been absent from the high rainfall and high altitude environment of the Ethiopian highlands. Today pearl millet is a minor crop in Ethiopia and is probably the product of post-domestication introduction. A second theory as to the origin of pearl millet was proposed by Murdock (1959). Using primarily linguistic evidence, he postu- lated that pearl millet was one of several West African crops domesticated by the Mande people near the headwaters of the Niger River between 4000 and 5000 B.C.

Murdock's general hypothesis has been the center of considerable controversy since its publication. During the period suggested by Murdock, the headwaters of the Niger probably exhib- ited a climax, tropical rain forest type of vegetation. It is highly unlikely, therefore, that a dryland crop such as pearl millet would have been domesticated there. The greatest morphological diversity in pearl millet occurs today in West Africa south of the Sahara Desert and north of the forest zone. The wild progenitor also occurs in the drier, northern portion of this zone. Taking these facts into consideration, Harlan (1971) suggested a third center of origin for the crop in a diffuse belt stretching from western Sudan to Senegal. On the basis of present-day distributions, the sahel zone of West Africa does appear to be the original home of pearl millet.

Pearl millet was domesticated along the southern margins of the Saharan central highlands at the onset of the present dry phase some 4000-5000 years ago. Soon after domestication it was distributed widely across the semi-arid tropical areas of Africa and Asia [I). The primary centers of diversity for pearl millet arc in Africa, where cross fertile wild species exist. In West Africa, the wild species *P. glaucum* spp. *monodii* (Maire) Brunken (*Pennisetum violaceums* is distributed along the margins of southern Sahara and crosses freely with the cultivated pearl millet, leading to the formation of the adapted hybrid swarms of the weedy species *Pennisetum glaucum* spp. *stenostachyum*. Pearl millet is the fourth most important crop in India. after rice. wheat. And sorghum. It is important in the stales of Rajasthan. Gujurat, and Haryana. In India the annual rainfall of the millet growing regions varies from 150-750 mm, most of which occurs from June through September.

1.4 Finger Millet (*Eleusine coracana*):

Finger millet is the second most important millet in Africa after pearl millet. It was domesticated in Africa, with archeological records going back some 3,000 years. In approximately the same period it was introduced into India. Five races are recognized and likely all arose in Africa; there has been little diversification in India (de Wet, 1978). Finger millet was firstly documented by Linnaeus in *Systema Naturae*, where he identified it as *Cynosurus coracan* hence, the name *Cynosurus coracanus* L. The genus *Eleusine* was later described in detail by Gaertner (1788) in *De Fructibus et Seminibus Plantarum* and hence the appellation, *Eleusine coracana* (L.) Gaertn. Kingdom: Plantae Subkingdom:

Tracheobionta Superdivision: Spermatophyta Division: Magnoliophyta Class: Liliopsida Subclass: Commelinidae Order: Cyperales Family: Poaceae Subfamily: Chloridoideae Genus: *Eleusine* Gaertner Species: *Eleusine coracana* (L.) Gaertn. The genus *Eleusine* includes nine annual and perennial species as recognized by Phillips (1972), with eight African species and one New World species (*E. tristachya* Lam.) native to Argentina and Uruguay (Lovisolo and Galati 2007). The range of the genus has been extended by wide spread introduction of the crop (*E. coracana*) throughout the tropics, and the common weed often associated with cultivation, *E. indica* (L.) Gaertn. East Africa is considered the center of diversity of the genus and eight species (*E. africana, E. coracana, E. kigeziensis, E. indica, E. floccifolia, E. intermedia, E. multiflora and E. jaegeri*). The species of *Eleusine* Gaertn. are distributed in the tropical and subtropical areas of India, Myanmar, Sri Lanka, Nepal, China and Japan in Asia; while in Africa, it is grown in Uganda, Kenya, Tanzania, Ethiopia, Eritrea, Rwanda, Zaire and Somalia (Upadhyaya et al. 2010).

1.5 Foxtail Millet (*Setaria italica*):

The genus Setaria has approximately 125 species widely distributed in warm and temperate parts of the world, and this includes S. italica (foxtail millet). This genus belongs to the subfamily Panicoideae and the tribe Paniceae. It contains grain, wild, and weed species with different breeding systems, life cycles, and ploidy levels (Lata et al. 2013).

Evidence suggests that domestication likely occurred from central Asia to Europe. Movement westward into Europe and eastward into east and south east Asia and the Pacific Islands was gradual and accompanied by plant differentiation. Differentiation may have occurred in East Asia but not domestication. Findings from Neolithic Yang-shao suggest the possibility of a Chinese center of origin (Sakamoto, 1987).

In the eighteenth-century, Linnaeus (1753) classified green foxtail and foxtail millet into the genus *Panicum*, but named them as two different species, *Panicum viride* and *Panicum italica*, respectively. Later they were transferred to the genus *Setaria*, and their botanical names were changed to *S. viridis* and *S. italica*, respectively, remaining as two independent species (Austin 2006).

The classification of foxtail millet (*Setaria italica*) is as follows: Kingdom: Plantae Subkingdom: Tracheobionta Superdivision: Spermatophyta Division: Magnoliophyta Class: Liliopsida Subclass: Commelinidae Group: Monocots Order: Poales Family: Poaceae Subfamily: Panicoideae Genus: *Setaria* Species: *italica.* Botanical name: *Setaria italica* L.

Setaria italica is among the oldest crops who's farming possibly began about 5900 BC in the Gansu Province of Northwestern China. Geographically, the region ranging from Afghanistan to India is believed to be the crop's origin for domestication. Afterwards, the crop spread is thought to have been both eastward and westward (Sakamoto 1987). According to Vavilov (1926), the principal center of diversity for foxtail millet is East Asia, including China and Japan. Several hypotheses concerning the origin and domestication of foxtail millet have been proposed (De Wet et al. 1979; Kawase and Sakamoto 1987; Vavilov 1926) but the multiple domestication hypotheses are widely accepted based on three centers of origin: China, Europe and Afghanistan.

Foxtail millet is one of the oldest cultivated crops in the world, the earliest archaeo-botanical macro remains indicating its origin in Cishan and Peiligang ruins in Yellow River Valley in the northern province of China, approximately 7,400–7,900 years before present (BP) (Doust et al. 2009). Green foxtail (S. viridis) is the wild ancestral form of modern cultivated foxtail millet (S. italica). It has been proposed by Vavilov (1926) that the prime center of evolution and diversification of foxtail millet was East Asia, specifically China and Japan. Currently, foxtail millet is distributed in most of China, some parts of India, USA, Canada, the Korean Peninsula, Japan, Indonesia, Australia, and the northern part of Africa (Doust et al. 2009; Li and Brutnell 2011). In the United States, foxtail millet is primarily produced in the northern and western Great Plains, midwest, Colorado. Foxtail millet can be found grown mainly for feed purposes in some part of southern Europe. In India, it is cultivated primarily in Karnataka, Andhra Pradesh, Rajasthan, Madhya Pradesh and Chhattisgarh, and Tamil Nadu.

The first phase of foxtail millet domestication occurred from approximately 23,000 YBP to around 9000 YBP. No intact foxtail millet grains corresponding to this phase have been found, but there is ample evidence of plant starches and stone tools for processing green foxtail and/or foxtail millet and specific evidence of foxtail millet starch (Liu et al. 2013; Yang et al. 2012). The second phase of foxtail millet domestication took place between 9000 and 6000 YBP, in the middle phase of the Chinese Neolithic Age. The oldest foxtail millet grains found to date were retrieved from the Donghulin site in Beijing, and dated back to 11,000 to 9000 YBP (Zhao 2014). The third phase of foxtail millet development was its expansion after domestication, from approximately 6000 YBP. Carbonized foxtail millet remains have been recovered from hundreds of archaeological sites in China, with large quantities found at many sites. Typical sites of this phase are the mid- and late Yangshao Culture sites (6000–5000 YBP) located in the middle of the Yellow River region in Henan Province. Foxtail millet remains were found at the Chengtoushan site (6000 YBP) in the middle region of the Yangtze River in Hunan Province, south of the Yellow River region where foxtail millet was first domesticated.

A second hypothesis (Li et al. 1995) suggested that the landraces from Afghanistan and Lebanon had been domesticated independently and relatively recently, because they had primitive morphological characters. This idea was supported by ribosomal DNA data (Fukunaga et al. 2006). Furthermore) reported that foxtail millet landraces in central Asia, Afghanistan, Pakistan, and Northwest India not only had primitive morphological traits, but also showed relatively high cross-compatibility with foxtail millet from other regions (Kawase and Sakamoto 1987). Based on those results, they suggested that the original center of foxtail millet domestication was located somewhere in those regions, and China may be the secondary center of diversification. This is the only hypothesis that places China as the secondary center of foxtail millet domestication.

1.6 Proso Millet (Panicum Miliaceum):

Proso millet is one of the oldest cereal crops, the agricultural origin of which dates back to 10,000 BC in the semiarid parts of China (Hunt et al. 2014). It is known by different names depending on the geographic location. Proso, the Pan-Slavic name for millet, is known as common millet and hog millet in the USA, broomcorn millet in China, common millet in Japan, Korea and other counties in the Asia Pacific, hersey millet in Germany and French white in France (Rajput et al.)

The wild ancestor of proso has not yet been satisfactorily identified, but domestication is likely to have occurred in Manchuria. Weedy forms are spread from the Aralo Caspian basin to Sinkiang and Mongolia. More recently, these wild types have spread into Europe and North America. The earliest remains of proso have been dated to the fifth millennium B.C. in eastern and central Europe (Zohary and Hopf, 1988). Sites were found in the Ukraine, Czechoslovakia, and Germany. Other finds dating to the same period have occurred in Georgia. Finds in the fourth millennium B.C. include Yugoslavia, and in the Neolithic Yang Shao villages of north China. Proso was probably introduced into Europe at least 3,000 years ago; remains of spikelet and florets have been found in early farming sites dated around 1600 B.C. (de Wet, 1986). It appeared after this period in the Near East and India (Zohary and Hopf, 1988).

The agricultural origins of the millets are primarily in Africa and Asia. Phylogenetic studies suggest a monophyletic origin of domesticated pearl millet in Western Africa (Dussert et al. 2015; Oumar et al. 2008). Northern China is considered as the agricultural origin for proso millet with the record of cultivation dating back to 10,000 B.C. (Hunt et al. 2014). Finger millet is believed to be of African origin (Fuller 2014).

There is no substantial evidence for the center of origin for foxtail millet cultivation. Proso millet, belonging to the Panicoideae subfamily of the Poaceae family, is considered to be one of the earliest domesticated cereals in human history (Lu et al. 2009).

There are different theories about the origin of proso millet. Investigations of the charred seed remains recovered in Dadiwan in Northwestern China suggested the possible period of proso domestication to be approximately 5900 BC (Miller et al. 2016). In order to estimate the time of the domestication of proso millet, Lu et al. (2009) studied phytoliths discovered in ancient storage pits at the archeological site of Cishan situated near the boundary between the Loess Plateau and the North China Plain. They opined that the earliest proso millet farming began in the semiarid regions of China by 10,000 years BC based on the carbon-dating results of the 47 archeological samples investigated in the study. Relatively drier environments during the early Holocene probably encouraged the domestication of proso millet over other cereals. Lu and coworkers also suggested that proso was domesticated independently as a staple food in Northern China approximately 10,000 years go, and later spread to other neighboring areas in Russia, India, the Middle East and Europe (Lu et al. 2009). Zhao (2011), however, claimed that the actual age of the samples recovered from an excavation in Cishan is ca. 7600 to 8100 years old. He expressed doubts over the estimations by Lu et al. (2009) as the samples were already in a decayed state.

The samples used for dating were possibly a mixture of different grains, instead of actual millet grains (Zhao 2011). Miller et al. (2016) also questioned the estimate of proso millet origin as it was based on the analysis of *problematic* phytolith identification. Nevertheless, all the evidence indicates that the domestication of proso millet occurred in the semiarid region of the Northeast China. Miller et al. (2016) suggested that proso millet spread to Europe and West Asia towards the end of the first millennium BC because of the changes in agricultural practices in those areas (Miller et al. 2016).

The exact centre of millet domestication in China is still disputed. The presence of early millet sites in Dadiwan in the Loess Plateau and Xinle and Xinglonggou in northeast China, far from the Yellow River valley, does not seem to support the view of a north Chinese agricultural origin for proso millet and foxtail millet that is centered around the central Yellow River valley. However, it can also mean that a different location is the focus of proso millet domestication or there are multiple foci within China. Based on comparisons of landrace genetic diversity between regions in China, inferred a centre of proso millet domestication in the Loess Plateau.

The level of landrace genetic diversity from the Loess Plateau was not significantly higher than those from other regions of China. Sufficient precise geographical information is needed to enable analyses of phylogeography or genetic diversity of many accessions from China.

1.7 Kodo Millet (Paspalum Scrobiculatum):

Kodo millet was domesticated in India almost 3,000 years ago. The species is found across the Old World in damp habitats of the tropics and subtropics. Crossing readily occurs between cultivated and weedy races, and seed from hybrids is harvested along with those of the sown crop; hence, racial differentiation is not distinct despite the years of cultivation in India (de Wet, 1986).

Kodo millets are the coarsest and digestion-friendly millets. It is an ancient millet grain that originated in tropical Africa and was domesticated in India some 3000 years ago (D wet et al. 1983). Indian Crown Grass, Native Paspalum, Ditch Millet, or Rice Grass are a few names by which kodo millet is known. In India, it is also known as Kodra and Varagu. India, Pakistan, the Philippines, Indonesia, Vietnam, Thailand, and West Africa are among the countries that cultivate millets. It serves as the major source of food in the Deccan Plateau of Gujarat, India. Kodo millet is mainly grown in various parts of India such as Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Bihar, Maharashtra, Gujarat, and Orissa. Madhya Pradesh accounts for 33.4 percent of India’s land area and 26.6 percent of the country’s small millet production. In Madhya Pradesh, kodo (70%) and little (24%), together, contribute to 94% of the total area under small millets (Chouhan et. al. 2019). In Madhya Pradesh, there are two districts that have the highest area under the state: Dindori and Mandla for the production of kodo and Chhindwara and Dindori for the production of little millets.

1.8 Barnyard Millet (Echinochloa frumentacea):

Echinochloa crus-galli, commonly known as Japanese millet, according to archaeological records was domesticated in Japan about 5,000 years ago and is found in the temperate regions of Eurasia (de Wet, 1986). E. colona, domesticated in India, spread through the tropics and sUbtropics of the Old World. It was harvested as a wild cereal in predynastic Egypt. While the two species are morphologically similar, hybrids between them are sterile; however, crosses of both species with their respective wild relatives are fertile (de Wet, 1986).

Echinochloa frumentacea showed parallel line of evolution both in India and Africa. It is an annual cultivated in India, Central African Republic, Tanzania and Malawi (Doggett 1989). Its wild progenitor is the tropical grass E. colona (L.) Link, popularly known as Jungle rice, but the exact date of domestication is uncertain. Echinochloa esculenta is annual in habit and is cultivated mostly in the temperate regions (De Wet et al. 1983) of Japan, Korea, China, Russia and Germany. Its wild ancestor is barnyard grass (E. crus-galli (L.) Beauv.) from which it was directly domesticated some 4000 years ago in Japan (Doggett 1989). Archaeological evidence suggests that it was grown in Japan as early as Yayoi period, dating back some 4–5 millennia. Another study puts the earliest records of domestication from Jomon period of Japan in 2000 B.C. Nozawa et al. (2004) showed that E. esculenta was domesticated from a limited part of the E. crus-galli population. They used 13 SSR markers to study the genetic diversity of 170 Echinochloa accessions and grouped E. esculenta accessions into two classes, while ancestral species E. crusgalli was grouped into 11 classes. The domestication syndrome, which refers to all modifications occurring in a crop plant during the course of evolution when it becomes cultivated from the wild form and is dependent on selection pressure (Hammer 2003), is not well studied in barnyard millet although both E. frumentacea and E. esculenta showed marked difference from their respective wild ancestors E. colona and E. crus-galli with respect to reduced vegetative branching, more compact growth habit, larger inflorescence, reduced shattering and larger seed size. Yabuno (1975) considered low seed shattering, lack of seed dormancy, thick culms, wide leaves and round spikelets in E. esculenta were the main characters selected by man during the process of domestication. This suite of traits that constitutes 'domestication syndrome' for closely related foxtail millet (Defelice 2002, Doust et al. 2005 and pearl millet (Poncet et al., 2000) is likely for barnyard millet as well. Increase in seed size in Japanese barnyard millet during domestication is suggested by archaeological data. The mean size of Echinochloa caryopses from the Middle Jomon period (3470 B.C.E.–2420 B.C.E.) was about 20% larger than specimens from Early Jomon period (5000 B.C.E–3470 B.C.E), indicating that selection for larger seed size was taking place over several millennia in Northern Japan. The cross-compatibility between domesticated barnyard millet and their ancestral forms and the existence of naturally occurring intergrades between the two forms provide avenues to understand the mechanisms driving domestication and elucidate the genetics of domestication traits in this crop.

1.9 Little Millet (Panicum sumatrense Roth. ex Roem. & Schult.):

The subspecies psilopodium includes the wild progenitor of P. sumatrense (sarna). The two subspecies cross to produce fertile hybrids, which often are found as weeds in saran fields. Meiotic behavior in crosses suggests that the genomes of the two species are similar. Sarna is cultivated in much of India, in Nepal, and western Bunna. It is of particular importance in the Eastern Ghats of India. Race robusta is grown in northwestern Andhra Pradesh and part of Orissa where it crosses with race nana. Subspecies psilopodium is distributed from Sri Lanka to Pakistan and eastward to Indonesia.

Little millet was domesticated ~5000 yr ago in India (de Wet et al., 1983). It has historically been grown mainly in India, Mayanmar, Nepal, and Sri Lanka (Prasada Rao et al., 1993). Little millet accessions have been classified into two races based on panicle morphology, nana and robusta, with two subraces per race (laxa and erecta for nana and laxaand compacta for robusta) (de Wet et al., 1983; Prasada Rao et al., 1993). Little millet is tetraploid ($2n = 4x = 36$) (Saha et al., 2016). Like kodo millet, little millet can give consistent yields on marginal lands in drought-prone arid and semiarid regions, and it is an important crop for regional food stability (Dwivedi et al., 2012). Little millet is arguably the least studied of these three millets, and we are unaware of any molecular markers developed for it outside of specific single genes (Goron and Raizada 2015) and a small set of RAPD markers whose details were not described (M.S. Swaminathan Research Foundation, 2000).

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