

Sorghum and Millets: Chemistry and Technology

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CHAPTER 1

SORGHUM AND MILLETS: HISTORY, TAXONOMY, AND DISTRIBUTION

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INTRODUCTION

The grasses (Poaceae) include some 8,000 species within 600 genera. It is estimated that historically some 300 species were harvested, but only 35 species in 20 genera have been domesticated (de Wet, 1986). Of greatest importance and mentioned in this chapter are sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*, formerly *P. miliare*), barnyard (sawa) millet (*Echinochloa colona*, formerly *E. frumentacea*), kodo millet (*Paspalum scrobiculatum*), teff (*Eragrostis tef*), and fonio millet (*Digitaria exilis* and *D. iburua*) (Prasada Rao et al, 1991).

Excluding sorghum and pearl millet, these millets account for about 1% of the food grain used in the world but fit important niches that are generally marginal for other agriculture (de Wet, 1986).

SORGHUM

(*Sorghum bicolor* (L.) Moench)

History

As with most cereals, a major step in the process of sorghum domestication was the loss of the shattering habit (Mann et al, 1983). 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 kafir 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).

Taxonomy

Pliny (ca. 60 to 70 A.D.) was the first to give a written description of sorghum, and after that there was hardly any mention until the 16th century. During this period the genus name *Milium* was used, followed by several different species names. The words *sorghum* and *sorgo* were used in the early 1600s. Michelli in 1729 used sorghum as a generic name, and the word *dora* was used for a cultivated sorghum about 10 years later; this led to the word *durra*. Linnaeus in 1737 used the generic name *Holcus*. During the 1700s, several species were described: *H. dora*, *H. dochna*, and *H. cafer*. Moench in 1794 established the genus *Sorghum* and brought the sorghums under the name *S. bicolor*. *S. halepense* was described in 1848. Sorghum was also described under the genus *Andropogon*, which replaced the name *Holcus*. Alefold in 1866 and Koernicke in 1885 brought all cultivated sorghums in under *Andropogon sorghum*. Chiovenda in 1912 and Stapf in 1917 reworked the sorghums and, following Moench, brought them under the genus name *Sorghum*. (See Snowden [1936] for more detailed history.)

The most detailed classification of sorghum was made by Snowden (1936). While recognizing that sorghum could be subdivided into many races, he gave species status to 48 different taxa (31 cultivated species and 17 related wild species) to stress that they can individually be defined by a number of distinct characteristics. Snowden subdivided *Sorghum* into the following sections, subsections, and series:

Section *eu-sorghum* Stapf emend. Snowden

Subsection *arundinacea* Snowden

Series *spontanea* Snowden (10 wild species)

Series *sativa* Snowden (31 cultivated species)

Subsection *halepensis* Snowden (four wild grasses)

Section *para-sorghum* Snowden (eight to 10 annual and perennial grasses)

De Wet (1978) listed 28 of Snowden's cultivated taxa in subspecies *bicolor*, seven weedy taxa in subspecies *drummondii*, and 13 wild taxa in subspecies *arundinaceum*. Harlan and de Wet (1971) developed a simplified classification that is in common use. The cultivated taxa, including 28 (out of 31) species of Snowden's series *sativa*, are partitioned into the following races under *S. bicolor* subsp. *bicolor*:

Basic races—*bicolor*, *guinea*, *caudatum*, *kafir*, *durra*

Hybrid races—*guinea-bicolor*, *caudatum-bicolor*, *kafir-bicolor*, *durra-bicolor*, *guinea-caudatum*, *guinea-kafir*, *guinea-durra*, *kafir-caudatum*, *durra-caudatum*, *kafir-durra*

These 15 races can be identified by mature spikelet characteristics alone, although head type is frequently helpful (Harlan and de Wet, 1971).

Distribution

Sorghum is a tropical grass grown primarily in semiarid parts of the world. In Africa, a major growing area runs across West Africa south of the Sahara almost to the coast and eastward into Sudan, Ethiopia, and Somalia. It is grown in upper

Egypt but is minor along the north African coast. It is commonly grown in Uganda, Kenya, Tanzania, Rwanda, and Burundi. It is fairly important in Zambia, Tanzania, the Shiri Valley of Malawi, and drier areas of Mozambique. It is important in Botswana and Lesotho, common in South Africa, and minor in Namibia. It is an important crop in India and Pakistan, minor in Thailand, and important in central and northern China. It is important in Australia. It has been spreading in South America, particularly in the drier areas of Argentina, the Sao Paulo and northeast areas of Brazil, and drier areas of Venezuela and Colombia. It is important in Mexico and the southwestern United States, north into Nebraska, and in Europe is fairly common in France and Italy. The crop has spread over the drier areas of the world, in China being grown up to 45° north. Gradually, maize and sorghum are finding their places, with sorghum growing in areas too dry for maize. Sorghum does better when it is dry and cool, whereas pearl millet is better adapted to dry hot conditions.

PEARL MILLET

(*Pennisetum glaucum* (L.) R. Br.)

History

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 (Andrews and Kumar, 1992; Tostain, 1992). 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, intergression continues at the present time (Tostain, 1992). 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 (Rachie and Majmudar, 1980).

Pearl millet is known by a number of names: bulrush, cattail, and spiked millet in English; *bajra* in Hindi; *dukhn* in Arabic; and *mil à chandelles* in much of West and North Africa (Rachie and Majmudar, 1980).

Taxonomy

Stapf, in 1934, divided the genus *Pennisetum* into five sections: *gymnothrix*, *eupennisetum*, *penicillaria*, *heterostachya*, and *brevivalvula*. The cultivated taxa belong to the section *penicillaria*, in which Stapf identified 32 species, of which six found in Africa are the likely progenitors of cultivated pearl millet. These are all annual species; there is a rhizomatous perennial, *P. purpureum*. Brunken et al

(1977) simplified the taxonomy of pearl millet by bringing the wild form *P. violaceum* (Lam.) L. Rich and the cultivated *P. glaucum* into the same biological species. In recent times, the cultivated pearl millet has been known taxonomically as *P. glaucum*, *P. typhoides*, and *P. americanum* (Rachie and Majmudar, 1980), but is currently known as *P. glaucum* (L.) R. Br. (Andrews and Kumar, 1992).

Wild and weedy pearl millet subspecies *monodii* and *stenostachyum* are most readily useful to cross with pearl millet for its improvement (Hanna, 1987).

Distribution

The most important countries growing pearl millet are India, Nigeria, Niger, Chad, Mali, Tanzania, Ethiopia, China (including Manchuria), and drier parts of the former U.S.S.R. Smaller producers include Uganda, Burkina Faso, Senegal, and the Sudan (Rachie and Majmudar, 1980). There are many other countries that grow the crop, particularly in Africa.

Early-maturing varieties are found from East Africa to Mali, with the greatest diversity found in Niger. Indian cultivars have cultural similarity to those found in southern Africa, and are more similar to the late-maturing cultivars of West Africa (Chowdhury and Smith, 1988).

Five geographically diverse groups have been identified among the wild types of northern Africa: 1) Darfur, Sudan, and eastern Chad; 2) western Chad and Nigeria; 3) the Air region of Niger; 4) eastern Mali and Niger; and 5) Senegal, Mauritania, and western Mali (Tostain, 1992). These groups are isolated from each other geographically.

Pearl millet is sown on about 15 million hectares in Africa and 12 million in Asia (Riley et al, 1993).

FOXTAIL MILLET (*Setaria italica* (L.) P. Beauv.)

History

Seeds of foxtail millet have been found in Neolithic sites in eastern and central Asia, Europe, and the Middle East, suggesting that it is one of the most ancient cereals domesticated in Eurasia. *Setaria viridis* is a probable ancestor. Evidence suggests that domestication likely occurred from central Asia to Europe. Movement westward into Europe and eastward into east and southeast 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). Seeds of foxtail have been found in early sites in Switzerland and Austria dating back 3,600 years, and it was widely used as food during the Bronze age. Remnants of foxtail have not been found in the Near East or ancient Egypt, nor in ancient sites in India (Prasada Rao et al, 1987).

Taxonomy

Cultivated foxtail was recognized by Linnaeus in 1753 as *Panicum italicum*. A number of taxa were recognized and brought into *Setaria italica* by Beauvois in 1812. The species is now classified as shown in Table 1.

TABLE 1
Taxonomic Classifications of the Minor Millets

Genus Species	Subspecies	Race	Subrace
Foxtail millet ^a <i>Setaria</i> <i>pumila</i> <i>italica</i>	<i>viridis</i> (wild) <i>italica</i> (cultivated)	moharia maxima assamense indica	aristata, fusiformis, glabra compacta, spongiosa ereeta, glabra, nana, profusa
Finger millet ^b <i>Eleusine</i> <i>coracana</i>	<i>africana</i> <i>coracana</i>	africana spontanea elongata reclusa sparsa plana compacta vulgaris	laxa serriata, confusa, grandigluma liliacea, stellata, incurvata, digitata
Proso millet ^a <i>Panicum</i> <i>miliaceum</i>	<i>miliaceum</i>	miliaceum patentissimum contractum compactum ovatum	
Little millet ^a <i>Panicum</i> <i>sumatrense</i>	<i>psilopodium</i> <i>sumatrense</i>	nana robusta	laxa, erecta laxa, compacta
Sawa millet ^a <i>Echinochloa</i> <i>colona</i>	<i>colona</i> <i>frumentacea</i>	stolonifera intermedia robusta laxa	
Japanese barnyard millet ^a <i>Echinochloa</i> <i>crus-galli</i>	<i>crus-galli</i> <i>utilis</i>	crus-galli macrocarpa utilis intermedia	
Kodo millet ^c <i>Paspalum</i> <i>scrobiculatum</i> <i>orbiculare</i> <i>commersonii</i>		regularis irregularis variabilis	
Teff <i>Eragrostis</i> <i>tef</i>			
Fonio <i>Digitaria</i> <i>iburua</i> <i>exilis</i>			

^aPrasada Rao et al (1991).

^bPrasada Rao et al (1987).

^cPrasada Rao et al (1991) and Christopher (1987).

Distribution

Race moharia is found in Europe, southeastern Russia, Afghanistan, and Pakistan. Race maxima is grown in eastern China, Japan, and Korea and has been introduced into the United States. It also occurs in Nepal and Assam, the foothills of the Himalayas, northern India, and in Georgia of the former U.S.S.R. Race indica is found throughout India and Sri Lanka and likely arose from crosses between moharia and maxima (Prasada Rao et al, 1987).

FINGER MILLET

(*Eleusine coracana* L. Gaertn. subsp. *coracana*).

History

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).

Taxonomy

The species *E. coracana* is divided as shown in Table 1.

Hybrids between subspecies *africana* and *coracana* form seeds that occur with the cultivated crop in Africa. These hybrids belong to race spontanea.

Distribution

Finger millet is most intensively grown around Lake Victoria in eastern Africa, in the southeastern parts of Karnataka, parts of Tamil Nadu, and Andhra Pradesh in southern India, and in Nepal. In eastern Africa, finger millet is most commonly found in Uganda, Tanzania, Rwanda, Burundi, eastern Zaire, Kenya, and to a lesser degree in Ethiopia, Sudan, and Somalia. It is also cultivated in Zimbabwe, Malawi, Zambia, Tanzania, Botswana, and Madagascar (Gupta et al, 1986). It is a minor crop scattered in provinces of south and southwest China (Jiaju, 1986). It is cultivated to a limited extent in Bangladesh (Majid et al, 1986) and Sri Lanka (Ponnuthurai, 1986).

PROSO

(*Panicum miliaceum* (L.))

History

The wild ancestor of proso has not yet been satisfactorily identified, but domestication is likely to have occurred in Manchuria (de Wet, 1986). 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).

Taxonomy

The species is subdivided as shown in Table 1. Race *miliaceum* resembles the wild *Panicum miliaceum* in panicle characteristics. The other races have different morphological characteristics.

Distribution

Proso is important in northwest China, being the main crop in some areas. It is used less in the northeast (Inner Mongolia, Shanxi, Gansu, Ningxia, and Heilong-jing) (Jiaju, 1986).

Main growing areas in the former U.S.S.R. are in the Volga region and parts of Kazakhstan (Ilyin and Zolotukin, 1986). In India, proso is cultivated primarily in the central and southern states of Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Uttar Pradesh, Maharashtra, and Orissa, and to a limited extent in hilly regions of Himachal Pradesh, Uttar Pradesh, and Jammu and Kashmir (Sampath et al, 1986). It is cultivated in Bangladesh (Majid et al, 1986), is of minor importance in the drier districts of Sri Lanka (Ponnuthurai, 1986), and is grown across temperate Eurasia from eastern Europe to Japan (de Wet, 1986).

LITTLE MILLET

(*Panicum sumatrense* Roth. ex Roem. & Schult.)

Taxonomy

Races and subraces of *Panicum sumatrense* are identified in Table 1. The subspecies *psilopodium* includes the wild progenitor of *P. sumatrense* (sama). The two subspecies cross to produce fertile hybrids, which often are found as weeds in sama fields (Prasada Rao et al, 1991). Meiotic behavior in crosses suggests that the genomes of the two species are similar (Hiremath et al, 1980).

Distribution

Sama is cultivated in much of India, in Nepal, and western Burma. 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.

BARNYARD MILLET (*Echinochloa crus-galli* (L.) P. Beauv.)

SAWA (*Echinochloa colona* (L.) Link)

History

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).

Taxonomy

Echinochloa has been classified as shown in Table 1. The species *colona* is weedy and invades cultivated fields. It has been divided into four races that do not have geographical, ecological, or ethnological similarities (Prasada Rao et al, 1991).

Distribution

E. crus-galli occurs as a common weed of the Old and New Worlds, being cultivated in China, Korea, and Japan (de Wet, 1986). It is widely distributed in the temperate parts of Eurasia, and weedy types found in the United States are known as barnyard grass (Prasada Rao et al, 1991).

KODO MILLET **(*Paspalum scrobiculatum* L.)**

History

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).

Taxonomy

The species has been described as shown in Table 1 primarily on the basis of characteristics of the florets (racemes).

Paspalum orbiculare and *Paspalum commersonii* are wild types. *Paspalum commersonii* is thought to be apomictic and of hybrid origin (Christopher et al, 1987). The wild weedy and cultivated kinds merge in all characters evaluated for taxonomic purposes (Prasada Rao et al, 1991). However, irregularities in meiosis in crosses support the identification of the three species (Christopher et al, 1987).

Distribution

Paspalum scrobiculatum is widely distributed across the Old World tropics, particularly in damp areas. As a wild cereal, it is harvested in West Africa and India. It is widely spread in India from Tamil Nadu and Kerala in the south to Rajasthan and West Bengal in the north (de Wet, 1986). Kodo is grown to a limited extent in Bangladesh (Majid et al, 1986).

TEFF
(*Eragrostis tef* (Zucc.) Trotter)

History

Teff is an ancient crop believed to have been domesticated in the northern highlands of Ethiopia. Seeds were found in the pyramids of Dassur built around 3350 B.C. It is thought that teff was grown in Egypt before the eighth century B.C. (Seyfu, 1986).

Teff was likely derived from *Eragrostis pilosa* (de Wet, 1986).

Distribution

Teff is the most important cereal in Ethiopia, occupying a greater area than all other cereals combined (Seyfu, 1986). Teff is also grown in a small area in South Africa and Lesotho, but as a forage crop.

FONIO
(*Digitaria iburua* Stapf, *D. exilis* (Kippist) Stapf)

Black fonio, *Digitaria iburua* is grown primarily by the Hansa tribe of northern Nigeria but occurs in spots across much of semiarid West Africa. This drought-hardy crop is frequently grown between rows of pearl millet or sorghum. True fonio, *Digitaria exilis* is widely grown across the West African savanna (de Wet, 1986).

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