

Diversity in Kodo Millet, *Paspalum scrobiculatum*¹

J. M. J. DE WET,² K. E. PRASADA RAO,³ M. H. MENGESHA,³ AND
D. E. BRINK²

Paspalum scrobiculatum is widely distributed in damp habitats across the Old World tropics. It is harvested as a wild cereal in west Africa and in India. The species was domesticated in India some 3,000 yr ago. It is grown in India from Kerala and Tamil Nadu in the south, to Rajasthan, Uttar Pradesh and West Bengal in the north. Kodo millet is variable but lacks racial differentiation. The species was apparently domesticated across its range of present-day cultivation. Hybridization with wild *P. scrobiculatum*, which commonly invades fields of kodo millet, obscures racial differentiation. Weedy kodo is harvested with the crop, making it difficult to distinguish wild and cultivated complexes of *P. scrobiculatum*. Wild, weed and cultivated kinds merge in all characters studied.

The genus *Paspalum* (Gramineae) includes some 400 species that extend across the warmer regions of the world. *Paspalum scrobiculatum* L. occurs throughout the Old World tropics. It is cultivated in India. Cultivated plants are grown as annuals, but many cultivars root at the lower nodes and, under favorable conditions, continue to produce culms after the older shoots have flowered and matured their inflorescences. Wild *P. scrobiculatum* is perennial. In southern India wild plants invade fields of planted kodo millet, and the spikelets of these weeds are often as large as those of the crop.

Paspalum scrobiculatum occurs in moist or shady places across the tropics and subtropics of the Old World. The species is recognized, as demonstrated by Clayton (1975), to include the African *P. orbiculare* Forst. f., *P. polystachyum* R. Br., and *P. cartilagineum* Presl with usually smaller spikelets (1.8–2.5 mm long) than those of Indian wild specimens (2.5–3.5 mm). These taxa merge completely, not only in spikelet morphology, but also in overall inflorescence morphology and vegetative traits. Plants are slender to stout, up to 90 cm tall, and often root from the lower nodes. Leaf blades are linear, glabrous or pubescent, up to 40 cm long, with the basal leaf sheaths glabrous or pilose. Inflorescences are composed of rarely more than 5 racemes (3–7) that are alternately arranged on a short to elongated primary axis. Racemes are up to 13 cm long, with the sessile spikelets arranged in 2 rows along one side of a flattened rachis. Spikelets are glabrous, orbicular to broadly elliptic in outline, conspicuously plano-convex, 1.8–3.5 mm long, and never awned. The lower glume is absent, and the upper glume is as long as the spikelet. The lower lemma is almost flat, more or less membranaceous and without a palea or floret. The upper lemma is crustaceous, often brown and shiny when grains are mature, and embraces the crustaceous palea. The grain is elliptic-orbicular in outline and 1.5–2.5 mm long.

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² Crop Evolution Laboratory, Turner Hall, Department of Agronomy, University of Illinois, Urbana, IL 61801.

³ Genetic Resources Unit, ICRISAT, Patancheru P.O., Andhra Pradesh 502324, India.

Indian collections differ from the cultivated kodo millet in usually having smaller spikelets that disarticulate more readily at maturity than those of the cultigen. Spontaneous and cultivated kinds, however, merge completely in all characters studied.

Selected herbarium specimens from India: Wild: *Mooney 11*, K; *Thein Lwin 3092*, K. Cultivated: *Pancgrahz 20546*, L; *Haines 3671*, K; *Drummond 21134*, K; *Mooney 12*, K; *Calder and Ramaswami 536*, K.

DOMESTICATION OF KODO MILLET

Cereal agriculture was introduced into India from the Near East (Vishnu-Mittre, 1977). The major cereals of India are not native to the Indian subcontinent. The Harappan culture introduced *Triticum turgidum* L. (emmer), *T. aestivum* L. (bread wheat), and *Hordeum vulgare* L. (barley) from the Near East into the Indus and Ganges Valleys some 4,000 yr ago. Rice (*Oryza sativa* L.) entered the Ganges Valley as a cereal from southeastern Asia about the same time. The widely grown *Sorghum bicolor* (L.) Moench (sorghum), *Pennisetum americanum* (L.) Leke (pearl millet), and *Eleusine coracana* (L.) Gaertner (finger millet) are native African cereals. They probably have been grown in India for at least 3,000 yr. It is not known when the Eurasian *Setaria italica* (L.) Beauv. (foxtail millet) or *Panicum miliaceum* L. (proso millet) became part of the Indian cereal complex. The native *Setaria glauca* (L.) Beauv. (*samai*) and *Echinochloa colona* (L.) Link (*sawa*) are unknown in the archaeological records of cereal cultivation in India. The indigenous kodo millet is known to have been grown in southern Rajasthan and in Maharashtra for at least 3,000 yr (Kajale, 1977; Vishnu-Mittre, 1977).

Paspalum scrobiculatum occurs throughout the Old World tropics (Clayton, 1975). It is an aggressive colonizer of disturbed habitats and commonly invades agricultural fields. In west Africa it is a weed of rice and is harvested as a wild cereal. It is grown as a cereal only in India. The cereal is known as *kodo* in Hindi, *khoddi* in Urdu, *arugu* in Telugu, and as *varagu* in Tamil. In southern India a small-seeded kind (*karu varagu*) and large-seeded kind (*peru varagu*) are recognized. These often grow together in the same field, with the small-seeded kind resembling the weed that grows along paths and around cultivated fields in damp habitats. The species was probably first harvested as a weed, and later became domesticated across most of its range in India. It is today grown from Kerala and Tamil Nadu, north to Rajasthan, Uttar Pradesh, Bihar and West Bengal.

Farmers believe that kodo millet is poisonous after a rain. It is known to produce unconsciousness or delirium with violent tremors of the voluntary muscles. There are reports that elephants have died from eating kodo millet. Kodo millet is cooked as rice. To prevent poisoning, the grains are carefully removed from the glume, lemma and palea before cooking. Bhide and Aimen (1959) suggest that the spikelets produce a poisonous alkaloid. It is also possible that poisoning results from a smut that invades and eventually replaces the developing grain. This infection is common in farmers' fields, and some cultivars seem to be particularly susceptible to the disease. The spore masses are about the same size as mature grains and are not easy to detect at harvest time. Removing the husks and winnowing scatter the spores, so only clean and healthy grains are used as food.

TABLE 1. MORPHOLOGY OF KODO MILLET (*PASPALUM SCROBICULATUM*).^a

Character	Mean	Std. dev.	Range
Days to flowering	87.7	10.5	68-110
Plant height (cm)	52.5	10.3	30-90
Number of tillers	23.6	7.8	10-48
Leaf-blade length (mm)	251.6	63.7	100-400
Leaf-blade width (mm)	9.9	2.0	5-15
Upper leaf-sheath length (mm)	154.2	22.6	80-220
Length of upper internode (mm)	142.9	26.0	80-250
Inflorescence length (mm)	59.0	19.5	20-120
Number of racemes per inflorescence	3.9	0.7	3-7
Length of lowest raceme (mm)	63.6	15.4	20-130
Spikelet rows per raceme	2.6	0.8	2-4
Fruit length (mm)	2.5	0.5	2-3

^a Data are based on a study of 300 populations collected from across India and grown in a uniform nursery at Patancheru, India.

MORPHOLOGY OF CULTIVATED KODO MILLET

Three hundred collections of cultivated *Paspalum scrobiculatum* in the germplasm bank of the International Crop Research Institute for the Semi-arid Tropics (ICRISAT) were grown in a uniform nursery at Patancheru near Hyderabad in India. The collections were assembled from across the range of kodo millet cultivation. In addition to the 12 characters listed in Table 1, notes were taken on degree of plant senescence when the oldest racemes reached maturity, disease resistance, and degree of lodging at time of harvest. Plants were also studied in farmers' fields in southern Andhra Pradesh.

In Andhra Pradesh, the species is grown on clay soils, often in fields that are subject to occasional flooding. It is grown as a single crop, or as the major cereal with *Setaria glauca* as a secondary crop. Most genotypes studied require at least 4 mo to mature.

The cereal is morphologically variable, but farmers usually grow relatively uniform populations. The most common kinds observed in farmers' fields were robust plants (over 60 cm tall) that frequently lodge at maturity, and smaller plants (less than 50 cm tall) with decumbent culms even before flowering. No other characters studied are correlated with growth habit.

Raceme morphology allows for the recognition of 3 complexes. The most common kodo millet is characterized by racemes with the spikelets arranged in 2 rows on one side of a flattened rachis (Fig. 1, 2). In most fields of kodo millet, plants with irregularly arranged spikelets also occur. Rarely are these aberrant kinds grown as pure stands. Two kinds of aberrations occur. In one kind, the spikelets are arranged along the rachis in 2-4 irregular rows (Fig. 3). In the other aberrant kind, the lower part of each raceme is characterized by irregularly arranged spikelets, while spikelet arrangement becomes more regularly 2-rowed in the upper part of the raceme (Fig. 4). Increase in spikelet number at a rachis node is associated with elongation and branching of the pedicel. Terminal inflorescences are composed of 3-7 racemes that are more or less alternately arranged along a 20-120 mm long primary axis. Racemes are peduncled and up to 130 mm long. The inflorescence may, or may not be subtended by a well developed leaf or leaf

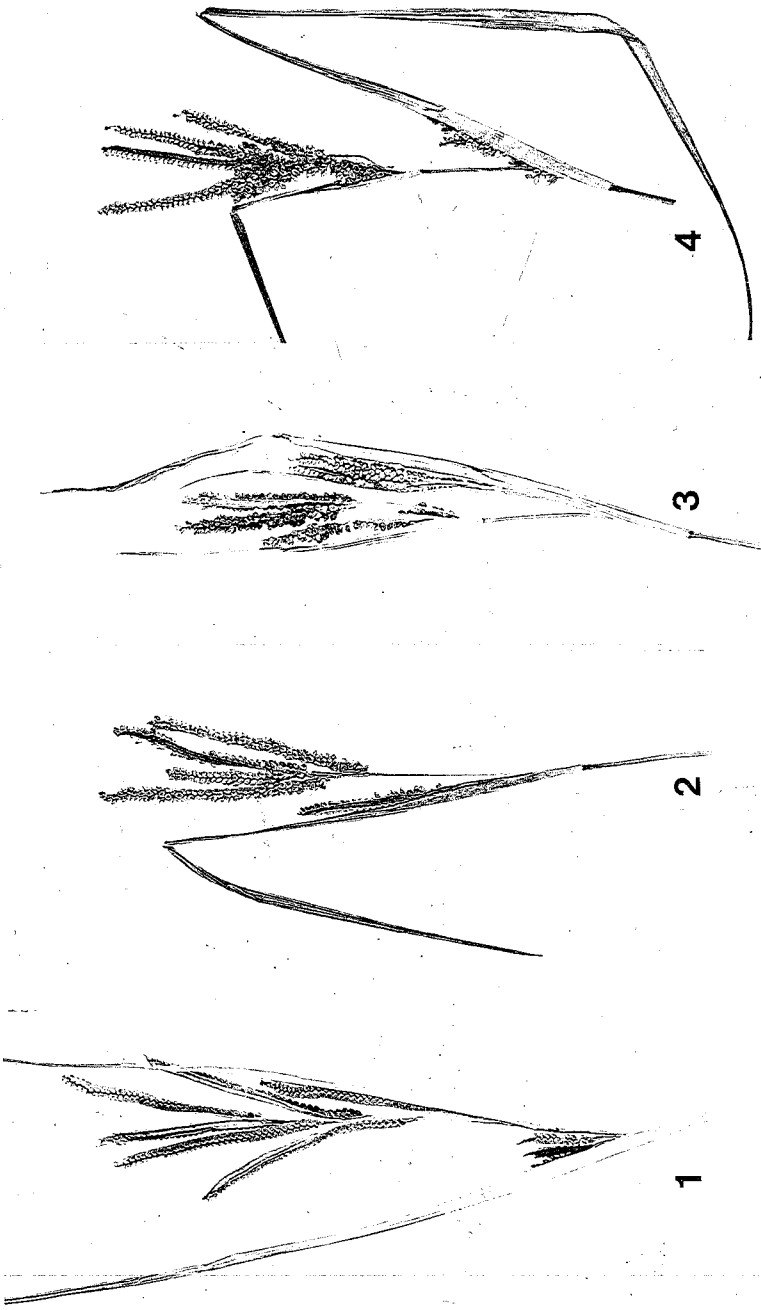


Fig. 1-4. Inflorescence morphology of *Paspalum scrobiculatum* cultivated in Kurnool district, Andhra Pradesh, India. Fig. 1. Spikelets arranged in 2 regular rows (*de Wet 4646*, Oct. 23, 1981, CEL). Fig. 2. Spikelets arranged in 2 irregular rows (*de Wet 4689*, Oct. 24, 1981, CEL). Fig. 3. Spikelets arranged in 2-4 irregular rows (*de Wet 4650*, Oct. 24, 1981, CEL). Fig. 4. Spikelets irregularly arranged at the base, and regularly 2-rowed above (*de Wet 4651*, Oct. 20, 1981, CEL).

sheath. One internode below this terminal inflorescence is a second inflorescence, usually composed of a single raceme that is always subtended by a well developed leaf. Plants are 30–90 cm tall, with the culms often decumbent at flowering time. Robust, erect plants tiller less than smaller, decumbent plants.

The absence of clear racial differentiation in kodo millet is surprising. The species has been grown as a cereal for at least 3,000 yr. The archaeological record indicates that the species was grown from Mysore to the Punjab at least since 600 yr before the beginning of the Christian era. Lack of racial differentiation may indicate that the species was domesticated across the range of its cultivation. Hybridization with wild *Paspalum scrobiculatum*, which commonly invades fields of kodo millet, further restricts racial differentiation within the cultivated complex.

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