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DIVERSITY AND DOMESTICATION OF MINOR MILLET SPECIES IN INDIAN SUB-CONTINENT

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The Indian sub-continent and African continent are the most important centres of millet cultivation. The Indian sub-continent has several endemically domesticated millet species such as little millet (Panicum sumatrense). *Indian barnyard millet* (Echinochloa frumentacea Link), *kodo millet* (Paspalum scrobiculatum *L.) and foxtail millet* (Setaria glauca *L. Beauv)and others. The millet species originated in Africa and those domesticated in Eurasia are also cultivated as important millet crops in this region. These include* Sorghum bicolor *(L.) Moench. (sorghum),* Eleusine coracana *Garetn. (finger millet),* Pennisetum typhoides *(pearl millet),* Setaria italica *(L) Beauv. (foxtail millet).* Panicum miliaceum *L. (proso millet) and* Coix lacryma-jobi *L. (Job's tear) respectively. Minor millet species are grown from extreme southern tip of India at sea level to the temperate north Himalayan areas upto an altitude of* ca *3000 meters with consequent variation in photoperiod from short to long days. Out of total area of 126.67 m ha under food grain, the minor millet area in India is just 5.78 m ha. In production, their contribution was 3.85 m tons of total 146.22 m tons of food grains in the country. Japanese barnyard millet, proso and foxtail millet have all been important in the past, and are still important particularly in Asia. Finger millet is an old tropical millet still widely grown in eastern Africa and south Asia. Kodo and little millets continue to be important in Asia in time of famine or difficulty. This paper reviews the account of domestication and diversity of different minor-millet species in Indian sub-continent.*

The antiquity of Indian sub-continent as a seat of domestication/ diversification of agri-horticultural plants is well known. The Indian gene centre is characterised by among others, specific minor millet genetic wealth exhibiting diversity in *Coix lacryma-jobi* (soft shelled forms). *Digitaria cruciata* var. *esculenta, D. sanguinalis, Echinochloa colonum, Eleusine coracana, Panicum sumatrense* and *Paspalum scrobiculatum* (Paroda and Arora, 1986).

DISTRIBUTION AND DOMESTICATION OF CROP SPECIES

In India, seven species of minor millets are cultivated from time immemorial and used as grain and fodder in different parts of the country. Paradoxically these crops have always grown on marginal lands with poor soil nutrients. Their survival in competition with rice and wheat attests to the significance of these millets in agro-ecosystem of south-east Asia (Umesh Chandra and Thomas, 1989). Two of these, *Panicum miliaceum* L. and *Setaria italica* (L.) Beauv. are grown across temperate Eurasia, with foxtail millet extending into the semi-arid tropics of Asia. Raishan (*Digitaria cruciata*) is cultivated by the Khasi tribes is Assam (endemic to Shillong plateau, Khasi hills). Hooker and Stapf (1896) recognised this as a species of *Paspalum* and Bor (1940) mistakenly included it in *Digitaria corymbosa* (Roxb.) Merrill. Later Bor (1955) correctly transferred raishan to *D. cruciata* and recognised the cultivated types as *var esculenta*. Raishan persists as millet in Assam probably because it provides excellent and essential food for livestock during winter when grazing is scarce. Individual plants produce as many as 30 flowering culms with each inflorescence maturing at slightly different times. It yields upto 800 kg/ha. The species was probably domesticated by hill tribes in Assam, south-east Asia (Singh and Arora, 1972). The genus *Echinochloa* widely distributed, and includes 20 species, several of which are weeds. The most abnoxious weed *E. oryzoides*, invades paddy, mimics the crop in vegetative morphology and flowers a few days earlier than the cultivar it accompanies as weed. Barnyard millet (*E. crus galli*) is common weed and is cultivated in China, Korea and Japan. Archaeological records indicate that it was grown in Japan dating back some 5000 years ago (Watanabe, 1970). *E. colona* has yet not been identified from among the plant remains of numerous sites excavated in India (Vishnu-Mittre, 1977). The species is, however extensively grown in central India where it is commonly known as sawa (de Wet *et al.*, 1983 a). Sawa is indigenous millet to India. The species is weedy, spontaneously invades cultivated fields, and is often unintentionally harvested with other minor millets. Sawa is grown from Kashmir to Sikkim in north and to Tamilnadu in south and Orissa in the east. In paddy fields, *Paspalum* species with small sized grains, *Panicum* spp., *Echniochloa colona* and other spp. and mimic type of *Coix gigantea* to rice plants were found. Upland rice have mimic types of *Paspalum scrobiculatum* with large sized grains, *Setaria glauca*, weedy *Panicum sumatrense* and *Echinochloa colona* (Kobayashi, 1987).

Kodo millet (*Paspalum scrobiculatum* L.) is another indigenous cultivated millet in India. The species is weedy, distributed in damp habitats across the tropics and sub tropics of the old world. It is known to have grown in southern Rajasthan and Maharashtra for atleast 3000 years ago (Kajale, 1977). It is grown today from Uttar Pradesh to Bangla Desh in north and

Maharashtra and eastern Madhya Pradesh in central India and Kerala and Tamilnadu in south India (Umesh Chandra *et al.*, 1987 b).

The most common kodo millet is characterised by recemes with the spikelets arranged in two rows on one side of a flattened rachis. Variations on spikelet pattern often occur in the same field with spikelets arranged in two to four irregular rows along the rachis and in other, the lower part of each raceme has four irregularly arranged rows of spikelets, while spikelet arrangement becomes more regularly two rowed in the upper part of raceme (de Wet *et al*, 1983 b.) Hybridization between cultivated types and between cultivated and weedy types are common. This explains the absence of clear racial differentiation, even after 3000 years of cultivation as millet in India. In kodo millet fields of south India, the mimic type of *Setaria glauca* **(varagu-sakkalathi)** was observed. In Orissa, *Brachiaria* sp. called **chusara-mata** meaning strong associated plant with kodo millet, and *Echniochloa colona* called **dhera** were found. They showed little or no behaviour, like the domesticated plants. This explains, kodo millet, cultivated *S. glauca* and *Brachiaria* sp. called **korne**, are speculated to be secondary crops in origin through their associated or mimic weed. Further, strongly different characteristics of cultivated *S. glauca* in south India and in Orissa indicate that they evolved separately. One with short spikes and slender leaves, a mimic to little millet in south India, probably evolved as secondary crop of little millet. The other with long spikes and wide-long leaves resembling weedy *S. glauca* in upland rice, may indicate its origin as a secondary crop of upland rice (Kobayashi, 1987).

Job's tear (*Coix lacryma-jobi* L.) is grown under shifting cultivation as a rainfed crop by the hill tribes of tropical Asia from Assam to the Philippines (Arora, 1977). White, greyish, black, creamish and other types-both smooth and striped shelled forms occur. In Assam, the grain is ground into flour and used to make bread or a sweet dish is prepared by frying the grain and adding sugar.

Foxtail millet (*Setaria italica* (L. Beauv.) is highly variable apparently because of its long record of domestication. It is considered that weedy green foxtail *Setaria italica* sub sp. viridis is the ancestor of *S. italica* from which the latter is distinguished by the size of its grain (Umesh Chandra *et al.*, 1987 a). The more robust *S. italica* is characterized by the larger, lobate panicles, which produce smooth, shiny seeds that disarticulate above the glumes in *S. viridis* and the fertile lemma is finally transversely rugose. Wild and cultivated *S. italica* cross naturally and produce fertile hybrid (de Wet Oestry-Stidd and Cubero, 1979). Derivatives of such hybrids are abnoxious weeds. The antiquity of foxtail millet cultivation is uncertain. The species could have been domesticated anywhere across its natural range extending from Europe to Japan. It is absent from known early

farming sites in India (Vishnu-Mittre, 1968). This however does not necessarily indicate a late introduction of foxtail millet into the tropics and sub-tropics in south Asia. Its wide distribution and morphological variation suggest a long history of cultivation in Indian sub-continent. Cultivars from India are morphologically distinct from those of Europe and far east and are recognised as race *indica* (Prasada Rao *et al.*, 1987). Plants are typically robust with inflorescence bearing branches that are loosely arranged along the primary axis. Collections from Meghalaya have long, slender inflorescence with small spikelets. Karnataka collections have slender erect inflorescence with short lateral branches somewhat resembling *S. pumila* in inflorescence & spike structure. A domesticated form of *S. glauca* found in a very localized area between Chittoor of Andhra Pradesh and Kolar of Karnataka, may be considered to have attained the characteristics of non-shattering grains and the position as a secondary crop in minor millet fields or as a main crop in the mixed cropping with minor millet, weedy *S. glauca*, associated with kodo millet and finger millet, generally displays non shattering grains which is a characteristic of domesticated types (Kobayashi, 1987).

The progenitor of proso millet (*Penicum miliaceum*) is native to Manchuria. Little millet (*P. sumatrense*) is grown as millet in the eastern ghats of India. This species represents the domesticated complex of the weedy *P. psilopodium* (de Wet *et al.*, 1984). The commonly cultivated type differs from wild *P. psilopodium* with which it crosses to produce fertile hybrid. The race of *same* is highly tolerant to heat and drought stress.

The cultivation and diversity of finger millet in Africa as well as in India led to considerable controversy over time and place of domestication and as to its progenitor. De Condolle considered it to be an Indian domesticate. Because of long history and morphological diversity in India, it was concluded that finger millet is of Indian origin since several wild species are common there (Hilu and de Wet, 1976 a). Finger millet first occurs in the archaeological records of early African agriculture dating back some 3000 years. (Hilu and de Wet, 1976 b.), and was introduced in India atleast 3000 years ago (Vishnu-Mittre, 1968). Two groups of cultivars of *E. coracana* are recognised; (a) African highland types bearing a resemblance to *E. indica* sub sp. *africana* with long spiklets, long glumes, long lemmas and grains enclosed within the florets, (b) Afro-asian types with a close resemblance to *E. indica* sub sp. *indica* with short spikelets, short glumes, short lemmas and the mature grains exposed distally. Mehra (1963 a, b) considers it probable that both types originated from sub sp. *africana* and the African highland forms were selected from large-grained mutants. Mehra believes that afro-asian cultivars then evolved from African highland forms by mutations for short glumes and exposed grains. On the basis of

this hypothesis, Perseglove (1974) considered that Uganda or neighbouring territory could have been the centre of origin. India became secondary centre of evolution of the crop. Cultivated finger millet is extensively variable, and this variation is recognised as five races (de Wet, Prasada Rao, Brink and Mengesha, 1984). Race *coracana* is particularly well-adapted in eastern highlands in Africa and Ghats of India. Other races *vulgaris, elongata, plama* and *compacta* probably evolved from race *coracana* under cultivation. The indigenous weed of *Eleusine* in India, *E. indica* (L.) Gaertn; is now a cosmopolitan species found in tropical to warm temperate regions all over the world but this weed is not able to produce fertile hybrids in cross with *E. coracana* (Kempanna, 1969). There is a belief in Kumaon farmers that **madua** (*E. coracana*) becomes **jhhadua** (off type-probably hybrid of sub sp. *coracana* and sub sp. *africana*) in a few years and then becomes **khadua** (*E. indica* and *E. coracana* sub sp. *africana*)-highly sterile, widely spread spikelets on spike and shattering of grains (Sakamoto, 1987).

CROP DIVERSITY IN INDIAN SUB-CONTINENT

India possesses rich and diverse native genetic wealth specially in kodo-millet (*Paspalum scrobiculatum* L.), little millet (*Panicum sumatrense*), Indian barnyard millet (*Echinocloa frumentacea* Link) and in foxtail millet (*Setaria italica* (L.) Beauv). Studies/collections made so far, point out to the prevalence of considerable genetic variability in kodo millet in the states of Madhya Pradesh, Rajasthan, Uttar Pradesh, Kerala and Tamil Nadu; finger millet in Karnataka, Tamilnadu, Andhra Pradesh, Orissa, Maharashtra, Uttar Pradesh, Bihar and Gujarat. These eight states, together account for more than 95 per cent of total area under this crop. The other minor millets, viz., foxtail, proso, little and barnyard are mainly grown in Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka, Uttar Pradesh, Maharasthra and Orissa and in small patches in the hilly region of Himachal Pradesh and Uttar Pradesh, Jammu and Kashmir and north-eastern states. The major area under little millet (*Panicum sumatrense*) is in the states of Andhra Pradesh, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Tamil Nadu and Uttar Pradesh. Germplasm represents reasonably diverse material collected from different regions in the country but it does not include all the minor millet growing areas and to fill these gaps, priority areas were identified for minor millet crop species germplasm collection which include largely tribal dominated belts as follows :

(a) Finger millet : Western Ghats of Maharashtra, southern peninsular region, Sikkim and north Bengal, in north-eastern region; sporadic hill pockets of west western Himalayas in mid-elevation zone.

(b) Foxtail millet : North-eastern region, peninsular tribal zone, sporadic in north-western part.

(c) Kodo millet :	Parts of Maharashtra, Gujarat, Madhya Pradesh, Bihar, Andhra Pradesh and Tamil Nadu-drier belts mainly.
(d) Little millet :	Orissa, Bihar, Uttar Pradesh, Madhya Pradesh and Maharasthra, eastern and central peninsular tracts mainly.
(e) Proso millet :	Bihar, Uttar Pradesh, north-western Himalayas in J & K & H.P. and U.P. hills upto 3000 m.
(f) Barnyard millet :	Maharasthra, Uttar Pradesh, eastern peninsular tract.

The National Bureau of Plant Genetic Resources (NBPGR), during the past 10 years, has been engaged actively in exploring the areas extensively in the states of Madhya Pradesh, Maharasthra, Karnataka, Orissa, Tamilnadu and Andhra Pradesh to collect the available diversity in minor millets. Three crop specific missions in collaboration with Japanese team were also undertaken. Over 4,500 diverse landraces (viz., *Setaria italica* spp. 964; *Eleusine coracana*-1,285; *Paspalum scrobiculatum* -346 and *Panicum sumatrense*-438; *Echinochloa* spp.-266; *Panicum miliaceum*-321 and miscellaneous minor millet species-911 collections) were collected from north eastern hill region, western coastal part, north-western Himalayas, western and eastern ghats areas, southern Indian states, Chhotanagur region and central peninsular region of India (Table-1).

Minor millet crop species are in general, drought hardy, short duration that can be grown in arid semi arid regions and in situations of delayed rains where growing period gets reduced. These can also be cultivated on soils of low fertility and can give economic yield, on soils too poor to support other economically important grain crops. They are cultivated mostly inter-mixed with other crops or different minor millet crops species.

In *Eleusine coracana* (finger millet), variability is conspicuous in plant height, tillering potential and length of fingers. This crop has wide range of adaptability for varying temperature, moisture and soil types and it exhibits great diversity in ear shape, size, bristling, pigmentation, grain size, grain colour and maturity duration. In predominant ragi growing areas of Karnataka, several high yielding improved varieties/hybrid derivatives such as INDAF series 1 to 12 have replaced the local landraces. The native landraces are still under cultivation mainly for fodder purposes as the improved types produce fodder of non palatable type where the straw is more fibrous and stiff. *E. indica*-a wild relative of *E. coracana* occured in the field of dwarf *E. coracana* which seemed to be a sterile hybrid of them. In *Setaria italica* (navana in Kannada), variation was significant for characters such as anthocynin pigmentation, bristle length and grain

Table 1. Diversity collected in different minor millets species in India (1976-1990)

Areas/regions explored	Finger millet	Foxtail millet	Kodo millet	Barnyard millet	Proso millet	Little millet	Misc. millet sp.	Total
North-eastern Hill region	150	89	01	01	03	–	108	352
Western Coastal region	53	38	20	–	–	35	–	146
North-western Himalaya	239	203	02	95	106	36	256	937
Central peninsular India	164	324	158	83	29	158	319	1,235
Western Ghats	43	07	06	23	03	33	–	115
Eastern Ghats	278	64	09	25	37	56	51	520
Saurashtra areas	–	–	–	–	–	–	24	24
Southern India (Andhra Pradesh, Tamil Nadu and Kerala)	351	231	141	34	138	110	153	1,158
Chhotanagpur region	07	08	09	05	05	10	–	44
Total	1,285	964	346	266	321	438	911	4,531

colour. With regards to bristle, three distinct types occur (i) long bristled, (ii) short bristled and (iii) bristles being absent types. *Paspalum scrobiculatum* (kodo millet) is one of the staple food crops in some areas. Ecology of the area where this crop is grown in very typical with sandy soil least moisture availability, slopy and sometimes rocky/stony. Due to relatively high temperature, plants appear bushy with profuse branches and forked inflorescence. Variability is prominent in number of tillers (6-14), leaves (dropping/erect), finger (short/long). *Panicum miliaceum* (Proso millet) is called **baragu** in Karnataka. The panicles are generally very loose with bold grains and drooping branches. In *P. sumatrense*, variation in panicle types, viz., green lax panicle, green dense, purple lax, purplse dense and purple semi-dense are common. There is no variation in grain. In Tamil Nadu, there is variation in panicle shape ranging from open to closed one. In Nilgiri hills, a specific form of *P. sumatrense*-very short plant with deep purplse colour is cultivated (locally known as **batta**). In majority of sites where *Setaria italica* is common, *S. glauca* also occured as weed. *S. glauca* presented two distinct forms-one with long ear-heads and bold seeds while the other with short ear head producing very small seeds. The former did not shatter while latter shatters on maturity. Non-shattering, tall plant type with large number of tillers has a tendency for domestication and it is grown as a regular crop for human consumption on the border of Andhra Pradesh and Tamilnadu in the Chittoor district. Four types of *Panicum sumatrense* (little millet) viz. **manchi-sama, pola-sama, varugu-sama** and **ara-sama** found in Andhra Pradesh. Indian barnyard millet has diversity in ear head type and plant height.

In central peninsular region from Andhra Pradesh and Maharashtra (Vidarbha) and eastern Madhya Pradesh, several collections have early maturing types with longer spikes and better yielding capacity. Good fodder potential types were prevalent in West Bengal and Gujarat areas. *Panicum sumatrense* in Maharashtra usually had very big panicles and transplanted on the borders of finger millet or paddy fields. More variability exhibited in finger millet, mainly in finger size (short, long and straight/curved curling). Dwarf, medium and tall types occurred with both red and white grains (Umesh Chandra *et al.*, 1987 a & b).

In Orissa, finger millet is usually scattered and grown in pure stand or mixed with little millet. In foxtail millet (**kangu**-in Oriya), grain colour has variation from orange to black colour (in rare cases). Little millet with non or red-pigmented plant body and panicles are grown sporadically in finger millet fields. In high moisture fields, little millet and cultivated *Setaria glauca* grow well. Red heads with red bristles and yellowish-white heads are very common. Weedy *S. glauca* with large plant type is prevalent in every millet and upland rice fields. Weedy *S. glauca*-called **ghas lingudi** meaning weedy **lingudi** at west of Koraput, **kukurun lange** of Duliguda

village, **ghoda langi** meaning horse tail and **lota** for bushy type at Ramisharda Tilemal Village, **bilai lang** meaning cat tail at Phulbani, **kukulange** and **bilai lang** at Kolrapaju (Phulbani district). The domesticated type of *S. glauca* found in Orissa had thicker long stems with large, wide leaves, large long heads and short bristles, compared to the domesticated type found in southern India (Kawase, 1987; Kobayashi, 1987). Kodo millet (*Paspalum scrobiculatum*) has many kinds of weeds such as *Brachiaria* sp. called **ghusara pata**, *Echinochloa colona* called **dhera** and *Setaria glauca* called **nehri. Ghusara pata** and **dhera** showed little shattering behaviour. They are eaten with kodo millet.

In Madhya Pradesh, the concentration of diversity was more in finger millet though little millet occurred predominently besides finger millet and barnyard millet. In *Panicum sumatrense*, the variability exhibited in plant height, sparse/ dense rachilla, number of grains per panicle and pigmentation of panicle. In finger millet, the variability was limited to number of fingers and straight/curved nature of fingers. Barnyard millet exhibited distinct variability only in plant height (60-150 cm). In foxtail millet, the populations have diversity in panicle length (10-20 cm.) grain size and grain colour (black, yellow and brownish yellow).

There are areas within and outside the country where large diversity exists and representations from such areas will broaden the existing variability. On the basis of priorities discussed earlier, the germplasm need to be tapped before they are eroded.

WEED RELATIVES *VIS-A-VIS* CROP-WEED COMPLEX

Some weeds grow in association with a particular crop. These weeds are called associated weeds. Most of them develop the characteristics of little or non-shattering which is one of the most typical characteristics of the cultivated crops. Vavilov (1926) stated many kinds of associated weeds with bread wheat, such as *Cephalaria syriaea* (L.) Roemer et Schultes, *Brassica* spp., *Sinapis* spp., *Pisum arvense* (L.) Gaertn, and with emmer wheat as *Avena* spp. and *Secale* spp. He proposed that among these associated weeds, some cultivated plants were resultant as secondary crops, such as *Brassica* spp., *Sinapis alba* L., *Pisum sativum* etc. The study of associated weeds is a key to uncovering the mechanism of the origin of cultivated plants. Millets and their wild relatives contain many important problems concerning crop-weed complexes. Indian barnyard millet (*Echinochloa frumentacea* (Roxb.) Link.), kodo millet (*Paspalum scrobiculatum* L) and little millet (*Panicum sumatrense*) originated and are cultivated in the Indian sub-continent and its surrounding areas.

As discussed earlier, a domesticated form of *Setaria glauca* was found near the boundary between Chittoor of Andhra Pradesh and Kolar of

Karnataka. The association of mimic weeds or weedy types of finger millet, kodo millet, little millet and *Setaria glauca* was found in their fields. Among these associated mimic weeds, association of *Brachiaria* sp. to little millet and weedy *Setaria glauca* to kodo millet suggest a relationship between the mimicry and agricultural methods. Weedy *S. glauca*, associated with kodo millet and finger millet generally displays non-shattering grains which is a characteristic of domesticated millets. In paddy fields, *Paspalum* sp. with small sized grains, *Panicum* sp., *Echinochloa colona* and other spp. and mimic type of *Coix gigantea* to rice plants were found. Upland rice was observed to have mimic types of *Paspalum scrobiculatum* with long grains, *Setaria glauca* and weedy *Panicum sumetrense* and *Echinochloa colona*. de Wet *et al* (1983 b) reported that wild *Paspalum scrobiculatum* invaded fields of kodo millet, that the spikelets of these weeds were often as large as those of the crop and that weedy kodo was harvested with the crop; making it difficult to distinguish a wild and cultivated complex of *P. scrobiculatum*. Grains of weedy *P. scrobiculatum* found in upand rice field were larger than cutlivated kodo millet. Those large and non-shattering grains were the results of (i) winnowing after threshing of rice contaminated with weedy *P. scrobiculatum* (ii) the collection of those grains by labourers to eat in addition to their wages for harvesting and threshng upland rice (iii) originally *Paspalum* spp. had little shattering grains. Weedy ones may have promoted such behaviour to associated weeds. Mimicry is seemed to be achieved mainly through hand weeding practices.

In little millet, *Brachiaria* spp. was observed. Cultivated *Setaria glauca* seems to have evolved as secondary crop for little millet through crop insurance in drought years as illegal wife of *Brachiaria* sp. From the above discussion, kodo millet, cultivated *S. glauca* and *Brachiaria* sp. are speculated to be secondary crops in origin through their associated or mimic weed (Sakamoto, 1987).

REFERENCES

Arora R.K. (1977). Adlay (*Coix*) crop in Meghalaya. *Journal of the Indian Botanical Society* **52** : 95-98.

Bor. M.L. (1940). Graminae. Flora of Assam **5** : 205-207.

Bor. N.L. (1955). The Genus *Digitaria* Heist in India. *Webbia* **11** : 301-367.

de Wet, J.M. J L.L. Oestry-Stidd and J.I. Cubero (1979). Origins and evolution of foxtail millet (*Setaria italica*) *Journal d' Agriculture Traditional et. Botanique Applique* **26** : 53-64.

de Wet, J.M.J, K.E. Prasada Rao and D.E. Brink (1984 a). Systematics and domestication of *Panicum sumatrense* (Graminae). *Journal d' Agriculture Traditional et. Botanique Applique* **30** : 159-168.

de Wet, J.M.J., K.E. Prasada Rao, D.E. Brink and M.H. Mengesha (1984 b). Systematics and evolution of *Eleusine coracana* (Graminae). *American Journal of Botany* **71** : 550-557.

de Wet, J.M.J., K.E. Prasada Rao, M.H. Mengesha and D.E. Brink (1983 a). Domestication of sawa millet (*Echinochloa colona*). *Econ. Bot.* **37** : 283.

de Wet, J.M.J., K.E. Prasada Rao, M.H. Mengesha and D.E. Brink (1983 b). Diversity in kodo millet (*Paspalum scrobiculatum* L). *Econ. Bot.* **37** : 150.

Hilu, K.W. and J.M.J. de Wet (1976 a). Domestication of *Eleusine coracana* (L) Gaertn. *Econ. Bot.* **30** : 199-208.

Hilu, K.W. and J.M.J. de Wet (1976 b). Racial evolution in *Eleusine coracana* sub sp. *coracana* (finger millet). *American Journal of Botany* **63** : 1311-1318.

Hooker, J.D. and O. Stapf. (1896). Graminae. *In* : J.D. Hooker (ed) *Flora of British India*, Vol I, London.

Kajale, M.P. (1977). Ancient grains from Excavations at Nevassa, Maharashtra. *Geophytology* **7** : 98-106.

Kawase, M. (1987). Variation and distribution of millets in S. India. *In* : Sakamoto Sadao (ed). A Preliminary Report of the Studies on Millet cultivation and its agro-pastoral Culture Complex in Indian Sub-continent (1985). Kyoto University, Kyoto, Japan, p. 5-14.

Kempanna, C. (1969). Phytogeographical studies of *Eleusine coracana*. *Mysore J. agric Sci.* **3** (1) : 22-31.

Kobayashi, H. (1987). Mimic and associated weeds with millets and cultivation methods of millets in the Indian sub continent. *In* : Sakamoto Sadao (ed.). A Preliminary Report of the Studies on Millet Cultivation and its Agro-pastoral Complex in Indian Sub-continent (1985). Kyoto Univ. Kyoto, Japan. p. 15-40.

Mehra, K.L. (1963 a). Differentiation of the cultivated and wild *Eleusine* species. *Phyton* **20** : 189-98.

Mehra, K.L. (1963 b). Consideration of the African origin of *Eleusine coracana*. *Curr. Sci.* **32** : 300-301.

Paroda, R.S. and R.K. Arora (1986). Plant Genetic Resources-An Indian Perspective. NBPGR Sci. Monogr. 10, 34 p.

Perseglove, J.W. (1974). Millets, *In* : Evolution of Crop Plants (ed-N.W. Simmonds) p. 91-93.

Prasada Rao, K.E., J.M.J. de Wet., D.E. Brink and M.H. Mengesha (1987). Inter specific variation and systematics of cultivated *Setaria italica* (Graminae). *Econ. Bot.* **41** : 108-116.

Sakamoto, Sadao (ed) (1987). A Preliminary Report of the Studies on Millet Cultivation and its Agro-pastoral culture complex in Indian sub-continent. Kyoto University, Kyoto, Japan 139 p.

Singh, H.B. and R.K. Arora (1972). Raishan (*Digitaria* sp.) a minor millet of Khasi Hills India. *Econ. Bot.* **26** : 376-380.

Umesh Chandra and T.A. Thomas (1989). Evaluation and Utilization of Genetic Resources of Minor Millets. *Indian J. Pl. Genet. Resources* **2** (1) : 32-35.

Umesh Chandra, T.A. Thomas, R.L. Sapra and R.S. Paroda (1987 a). Evaluation studies in Foxtail millet (*Setaria italica* (L.) Beauv.) Germplasm, NBPGR Publication, New Delhi, 84 p.

Umesh Chandra, T.A. Thomas, Ranjana Nagpal and R.S. Paroda (1987 b). Evaluation studies in Kodo millet (*Paspalum scrobiculatum* L.) Germplasm. NBPGR Publication, New Delhi, 66 p.

Vavilov, N.I. (1926). Studies on the origin of cultivated plants. *Inst. Appl. Bot. Plant Breed.* (Leningrad) 16 : 248 p.

Vishnu-Mittre (1968). Pre-historic records of Agriculture in India. *Bose Res Inst. Calcutta Trans.* 31 : 87-106.

Vishnu-Mittre (1977). Changing economy in Ancient India *In* : CA. Reed (ed). Origins of Agriculture. Mouton Press. The Hauge, p. 569-88.

Watanabe, N. (1970). A Spodographic analysis of millet from pre-historic Japan. Faculty of Science, Univ. of Tokyo, 5 : 357-379.