Collection and Evaluation of Pearl Millet (*Pennisetum americanum*) Germplasm from Ghana[1]

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An expedition to Ghana was undertaken during August 1981 to collect mainly the early-maturing pearl millet, Pennisetum americanum. *The collection team travelled extensively in most of the pearl millet-growing areas of the eastern and northern provinces of Ghana. The mission was planned to coincide with harvesting so that early-maturing landraces could be obtained from farmers' fields. Seed samples of late-maturing pearl millet were also obtained from local markets. Early-maturing pearl millet is traditionally intercropped with groundnut (*Arachis hypogaea*), sorghum (*Sorghum bicolor*) or late-maturing pearl millet. Pearl millet grain is used in several traditional food preparations: thick porridge called* tô, *a thin, fermented porridge called* koko, *and a deep-fried pancake called* marsa. *Landrace populations grown by the farmers were mixtures of several types. The material collected varied considerably for shapes, sizes and colors of spikes and grains. Of the 284 samples collected, 227 were grown in a uniform nursery at Patancheru: they flowered in 39–140 days, grew 120–315 cm tall, spikes were short (6–53 cm) and conical, grains were large, globular and gray with starchy endosperm. The samples belong to race* globosum *and serve as a good source of genes for earliness and large-grain size.*

Pearl millet, *Pennisetum americanum* (L.) Leeke, is grown in Ghana over an estimated 230,000 ha (FAO, 1979). It was reported to have been introduced to Ghana by invaders from the north and was grown at Ntesero in northern Ghana as early as 1250 B.C. (Davies, 1968). It is confined to the upper and northern regions of the country. Germplasm from Ghana has provided valuable breeding material. Mass selection in earlier collections from Ghana yielded a new open-pollinated variety called 'Improved Ghana' (Joshi et al., 1961). When used as testers, Ghanaian cultivars were found to have good combining ability (Ahluwalia and Patnaik, 1963). They also possessed several useful characters, such as dwarfness, early vigor, early flowering and bold grain (Murty et al., 1967). Unfortunately, this pearl millet germplasm has become contaminated and modified by allogamy, and so Harlan (1973) suggested that a new start be made to assemble germplasm from West Africa. When the available lines were grown and compared with the published catalog (Murty et al., 1967), only one of the earlier collections agreed with the catalog description, while the rest had lost their identity (Appa Rao, 1980). Hence, a germplasm collection expedition to the northern regions of Ghana was launched by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). This paper describes the expedition, as well as the variability observed in the farmers' fields, the cultural practices followed, the various food

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preparations made from pearl millet, the evaluation carried out at ICRISAT, and the comparison of this collection with others in West Africa.

PLANNING AND COLLECTION PROCEDURES

The areas to be explored and the dates of collection were planned in consultation with the staff of the Crops Research Institute (CRI), Kumasi, Council of Scientific Industrial Research (CSIR), Ghana. A station wagon with fuel, a driver and local guides were provided by the German Agency for Technical Cooperation (GTZ), Ghana.

The collecting team consisted of S. Appa Rao, ICRISAT, and either D. Sharma or W. Shipprock of GTZ. Messrs. Bunkpurima, Sampson and Joe of CRI, Nyankpala, served as local guides. The team was usually accompanied by local agricultural officers and German volunteers who were familiar with the area of collection. Their knowledge of places and people of the region was helpful in several ways.

The expedition was planned for August 1981 to coincide with the harvesting of early-maturing pearl millet. The expedition started from Tamale, progressed northeast through Bolgatanga to Bawku, from where it proceeded west to Tumu and then returned to Tamale (Fig. 1). During the second stage, the team travelled to Nakpanduri, Gambaga, and other areas in the east. Spike samples of early-maturing pearl millet were collected from the farmers' fields. Seed samples of late-maturing pearl millet, sorghum (*Sorghum bicolor* [L.] Moench) and groundnut (*Arachis hypogaea* L.) were obtained from farmers' grain stores and local markets. A sampling method was used by which at least one spike of each variant, occurring in the target population (individual fields) with a frequency greater than 0.05, was collected, as suggested by Marshall and Brown (1975). Samples were listed in sequence as they were collected and prefixed by "DSA" to identify the collectors. Information on local cultural practices, special characteristics of the cultivars grown, and their use in food preparations was obtained from the farmers who donated the samples. Such information given by the farmers often furnishes clues that lead to the identification of special traits, such as sweet-stalk pearl millet (Appa Rao et al., 1982). Environmental data were recorded for all accessions. Particular attention was paid to soil characteristics and agronomic eliteness of accessions in their native habitats, following the standard descriptors (IBPGR/ICRISAT, 1981).

Most of the pearl millet-growing areas in northern Ghana were covered, and 284 pearl millet, 48 sorghum and 80 groundnut samples were collected. Post-collection operations, such as drying, threshing, cleaning and dividing, were carried out at the CRI, Ghana. All samples collected were shared among CRI, IBPGR, and ICRISAT.

Crop ecology

The general agroclimatic conditions of Ghana were described by Hilton (1976). Most of the millet-growing areas lie between latitude 8° and 11°10′N and longitude 1°12′ and 3°14′E. Pearl millet is grown at elevations around 300 m, within an altitude range of 100–400 m. The annual mean maximum temperature is 35°C, but the maximum temperature during February-April exceeds 40°C at Navrongo.

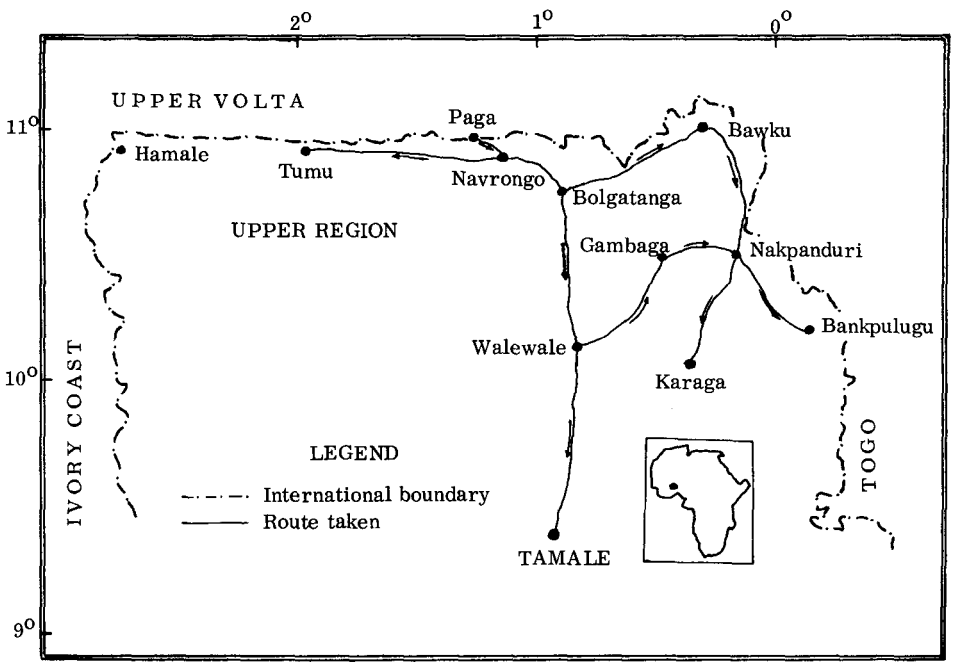

Fig. 1. Map showing the route followed by the collecting team and the location of samples collected in Ghana.

The mean annual rainfall is 1,000–1,200 mm. Generally, there are 2 rainy seasons with peaks in May-June and October and several dry intervening periods.

Although several tribes grow millet, the Kusasi and Fra-Fra tribes of Sudanese origin are reported to have a special affinity for millet cultivation (farmers' remarks). As these tribes migrate to new areas, they carry pearl millet seeds with them and introduce its cultivation to nontraditional areas. Harlan (1975) reported association of particular tribes and groups of people with particular kinds of sorghum.

Crops grown

Ghana is the world's major cocoa (*Theobroma cacao* L.)-producing country. Oil palm (*Elaeis guineensis* Jacq.) and coconut (*Cocos nucifera* L.) are found in the forest zone. Cola nut (*Cola accuminata* [P. Beauv.] Schott and Endl.) is a commercial crop grown for both local consumption and export. Some of the major food crops are banana (*Musa* sp.), yam (*Dioscorea* sp.), and cassava (*Manihot esculenta* Crantz). Rice (*Oryza sativa* L.) is usually grown in low-lying areas as a rain-fed crop. The subsistence staples, sorghum, pearl millet and maize (*Zea mays* L.) are grown throughout the interior savanna. Groundnut is grown throughout the country. Intercropping is common in all regions but agricultural practices vary greatly among tribal groups and geographical locations. Subsistence agriculture is the dominant way of life. The hoe and the cutlass are used extensively. Mechanized and animal-drawn implements, such as the mould-board plow, are used sparingly.

Pearl millet, sorghum, and groundnut are extensively grown in the upper region.

Fig. 2-3. Fig. 2. A farmer's field showing the cultivation of early-maturing millet intercropped with late-maturing millet. Fig. 3. General variability of spikes in pearl millet collected from Ghana.

Early-maturing pearl millet is usually mixed with late-maturing millet, sorghum or groundnut. At times groundnut is intercropped with maize. A unique feature of the upper region is compound farming, which comprises the family compound and a few hectares of continuously-cropped and manured area. In compound farming, early-maturing pearl millet is invariably planted in April–May with the onset of the first showers. Late-maturing millet, sorghum, or groundnut is sown in the same field 2–4 wk later with subsequent rains. Early pearl millet matures in about 75–90 days and is harvested by cutting the stems at the base. By the time the early pearl millet is harvested, late millet is in the tillering stage (Fig. 2). As the early millet matures at a time when the farmers have depleted their stocks of food grains, it is called *mil de la faim,* hungry millet.

MORPHOLOGY OF CULTIVATED PEARL MILLET

The most common kinds of millet observed in farmers' fields were robust plants (over 2 m tall), producing 1–3 tillers from the basal nodes. Aerial tillers were almost absent. Stems are thin (5–12 mm) and the internodes are longer (10–23 cm) than the leaf sheaths (7–18 cm). Leaf blades are lanceolate, long (30–60 cm), broad (20–45 mm) and glabrous. All the field samples (212) flowered very early (39–70 days), except 19 market samples from the previous-years' harvest that flowered very late (71–140 days) at Patancheru. These late-flowering millets from West Africa usually flower early under short days indicating their photoperiod sensitivity (Bilquez, 1963). Farmers believe that they possess desirable grain qualities and are less susceptible to insect attack in storage compared to early-maturing kinds. Bono (1972) reported that millets from other parts of West Africa grow over 4 m tall and produce very thick (20 mm) stems. They are called by different names in West Africa (Bono, 1972). In Ghana, the early millet is called *nara,* while the late millet is called *zia.* The collection was grown in a uniform nursery at ICRISAT center, Patancheru and Fig. 4 shows the frequency distribution for flowering, plant height, spike length and spike thickness. Such evaluation data are of considerable value to the breeder in his efforts to broaden the genetic base (Brown, 1983).

The inflorescences are sharply conical though cylindrical and spindle spikes were also found as mixtures but are not grown as pure stands. The spikes are short (6–53 cm) but stout (15–39 mm) and seed set is complete on the spike. Grains are globular, very large (7.9–18.3 g/1,000 grains), more than twice the grain size of commercial hybrid BJ 104. Gray grain is common but white and purple are found as mixtures but are seldom grown as pure stands. Usually, 2 fertile spikelets per involucre were found on a thin rachis (3.6 mm) with a very large involucre pedicel. A majority produced scabrous to ciliate bristles that are below the grain surface but some with long bristles and different colors were also found (Fig. 3). Dumont (1966) reported the occurrence of pearl millet from Niger that produce very long spikes—Zongo (100–150 cm), Dan Zagaro (150–200 cm), Maiwa (80–90 cm), while in Ghana, short spikes (6–50 cm) are found. In Nigeria also the *gero* and *maiwa* kinds produce very long spikes with incomplete grain filling (Bhardwaj, 1970a, b). Marchais (1982) reported that the spikes from Senegal are different from those of Mali, except in western Mali where intermediate forms were found.

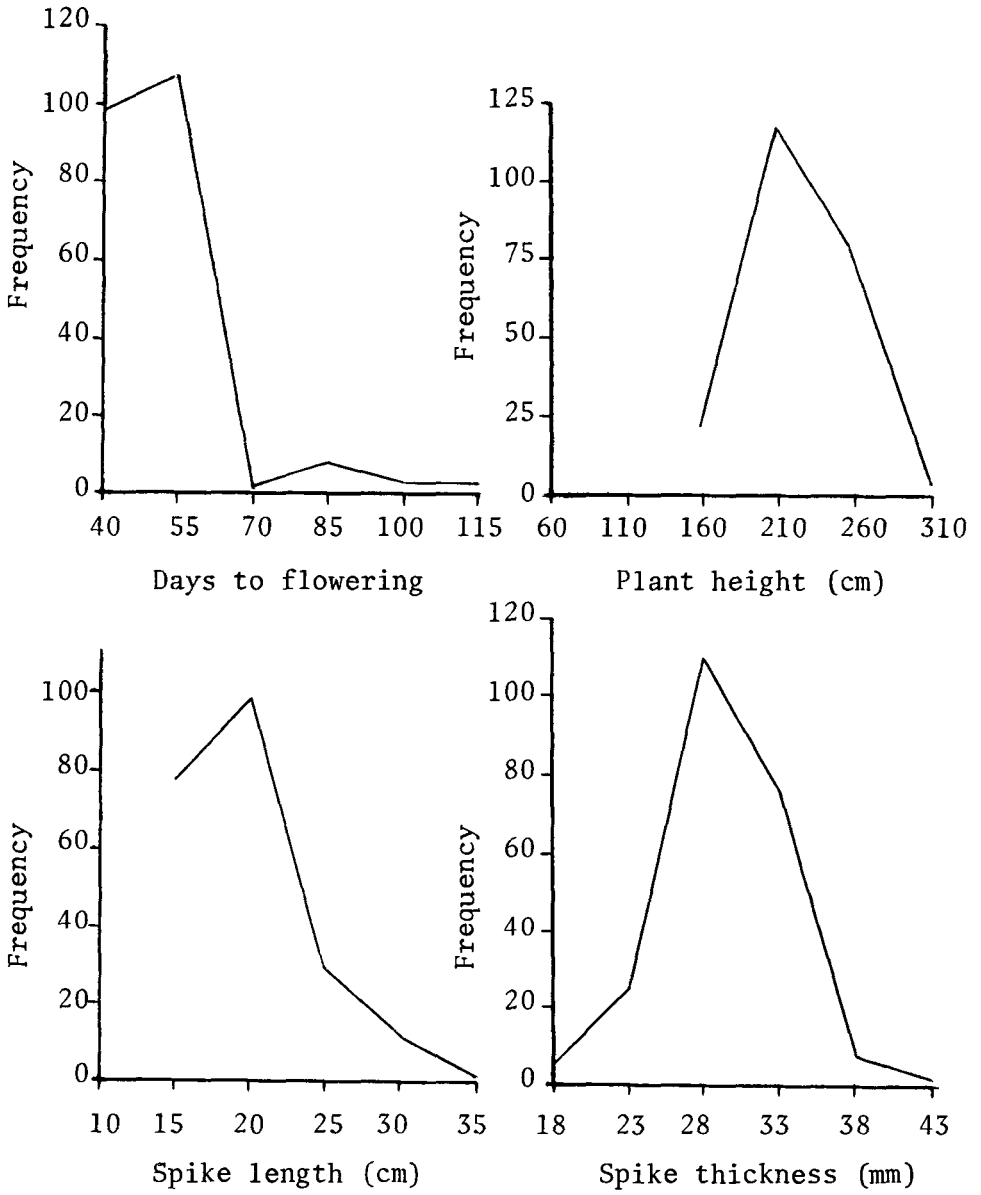

Fig. 4. Days to flowering, plant height, spike length and spike thickness of pearl millet collection from Ghana when evaluated at ICRISAT Center, Patancheru.

Plant height (PHT) and spike length (SPL) in some of the accessions like IP 9476 and IP 9482 that were growing in moisture-stress conditions in the farmers' fields were drastically reduced (Table 1). However, when grown in a uniform nursery at Patancheru, near Hyderabad (17°27′), they grew very tall and produced larger spikes (Table 2). Most of the accessions flowered early, grew tall and produced short and stout spikes (Fig. 4). In general, plants grew 2 m tall both in the farmers' fields and at Patancheru, except a few that were taller in Ghana. Spike length and spike thickness (SPT) were reduced at Patancheru compared to farmers'

TABLE 1. COMPARISON OF SELECTED PEARL MILLET ACCESSIONS IN THE FARMERS' FIELDS (ORIGINAL PLACE OF COLLECTION) IN GHANA (G) AND WHEN EVALUATED AT ICRISAT CENTER, PATANCHERU (P) 17°27'[a]

Identity	Origin	Plant height (cm)		Spike length (cm)		Spike thickness (mm)		Spike shape[c]		Grain color		Overall plant aspect[d]	
IP no.[b]	Lat. (° ')	G	P	G	P	G	P	G	P	G	P	G	P
9346	11 00	200	210	28	25	30	30	Con	Con	Ivory	Ivory	7	6
9363	11 01	215	210	37	17	16	31	Cyl	Con	Grey	Grey	5	6
9378	11 00	210	210	28	20	36	32	Con	Con	Grey	Grey	5	6
9380	11 00	200	240	26	25	35	34	Con	Con	Grey	Grey	5	5
9382	10 45	220	210	21	20	32	35	Con	Spl	Purple	Purple	5	5
9384	10 45	210	235	20	20	30	30	Con	Con	Ivory	Grey	5	5
9408	11 04	230	180	21	15	37	36	Con	Con	Grey	Grey	7	7
9418	11 04	220	240	32	24	22	28	Cyl	Spl	Grey	Grey	6	5
9420	11 04	200	210	26	22	24	30	Cyl	Cyl	Ivory	Grey	5	6
9431	10 53	200	210	21	20	37	33	Con	Con	Grey	Grey	7	7
9436	10 53	220	230	23	17	36	29	Con	Cyl	Purple	Purple	7	6
9442	10 53	250	230	27	24	25	27	Cyl	Spl	Ivory	Cream	6	7
9453	10 53	245	230	34	20	40	19	Con	Con	Grey	Ivory	5	7
9455	10 55	220	250	39	30	24	27	Cyl	Cdl	Ivory	Ivory	6	6
9457	10 55	200	225	29	28	29	35	Con	Con	Grey	Grey	6	8
9459	10 55	225	250	28	22	30	36	Cdl	Con	Grey	Grey	6	7
9464	10 55	260	230	29	25	34	37	Con	Spl	Purple	Purple	6	7
9466	10 55	240	230	38	30	24	23	Cdl	Con	Grey	Cream	6	6
9468	10 55	220	260	30	20	40	30	Con	Con	Ivory	Ivory	8	5
9476	10 55	120	230	13	20	20	32	Con	Con	Grey	Grey	2	7
9482	10 55	095	200	11	17	13	30	Con	Spl	Grey	Grey	2	8
BJ-104	28 35	—	139	—	18	—	20	—	Cyl	—	Grey	—	8

[a] Data are based on a study of 227 landrace populations grown in a uniform nursery at Patancheru, India.

[b] IP = International *Pennisetum*.

[c] Cdl—candle-shaped; Con—conical; Cyl—cylindrical; Spl—spindle-shaped.

[d] Scored on 1–9 scale, where 3 = poor, 5 = average, and 7 = good.

TABLE 2. MORPHOLOGICAL CHARACTERS OF PEARL MILLET GERMPLASM FROM GHANA[a]

Characters	Mean	SD	Range
Days to flowering	47.4	3.0	37–140
Plant height (cm)	224.8	18.5	120–315
Number of tillers	2.0	0.6	1–3
Leaf-blade length (cm)	46.2	7.0	30–60
Leaf-blade width (mm)	31.4	5.5	20–45
Leaf-sheath length (cm)	10.5	1.7	7–18
Internode length (cm)	18.0	3.0	10–23
Stem thickness (mm)	7.2	1.2	5–12
Spike length (cm)	22.1	9.4	6–53
Spike thickness (mm)	26.9	5.6	15–39
Spike density	6.8	1.0	4–8
Rachis diameter (mm)	3.6	0.7	2.7–5.5
Pedicel length (mm)	6.2	2.7	1–12
No. grains/involucre	2.0	0.2	1–3
Grain length (mm)	3.8	0.6	2.4–4.8
Grain width (mm)	2.5	0.3	1.8–3.2
Endosperm texture	4.5	1.3	2–7
1,000 grain weight (g)	13.8	1.2	7.9–18.3

[a] Data based on a study of 227 landrace populations collected from northern Ghana and grown in a uniform nursery at Patancheru, India.

fields, except those collected from drought fields with moisture stress. Spike shape and grain color were very stable except for the occurrence of a few new spike shapes and grain colors and reduction in spike length in some cases. This is probably due to outcrossing in farmers' fields and segregation after one generation of inbreeding in the quarantine grow-out. Some of the accessions that looked agronomically more desirable in the farmers' fields were not that good when grown at Patancheru. Hence, the overall plant aspect scored at the time of collection is useful in utilizing the germplasm.

Variation within populations

Most of the landrace populations grown by the farmers were mixtures of various morphological types. Variation in plant height and maturity existed in almost all fields. Some fields contained a remarkable array of spike and grain types in varying proportions. For instance, sample DSA-40 (Fig. 5) came from a field with a mixture of different spike lengths (21–28 cm), spike thicknesses (32–36 mm), spike shapes (candle-shaped, conical), grain colors (ivory, dark-purple), bristle lengths and bristle colors. Similarly, sample DSA-76 showed mainly variation in grain color and bristle length. Some fields showed variation only for a few characters, for instance, sample DSA-69 varied only in grain color. However, different kinds of pearl millet were observed within a single field and in adjacent fields. Around Bolgatanga, Tumu and Sandema, maximum variation was observed not only among fields but also within fields. In the Bawku region, variation among fields was considerable. Generally, variation was limited where the level of management and production was advanced.

The collecting team met some farmers near Bawku who were selecting for uniformity of head types, just before harvest. Early-maturing, large and uniform

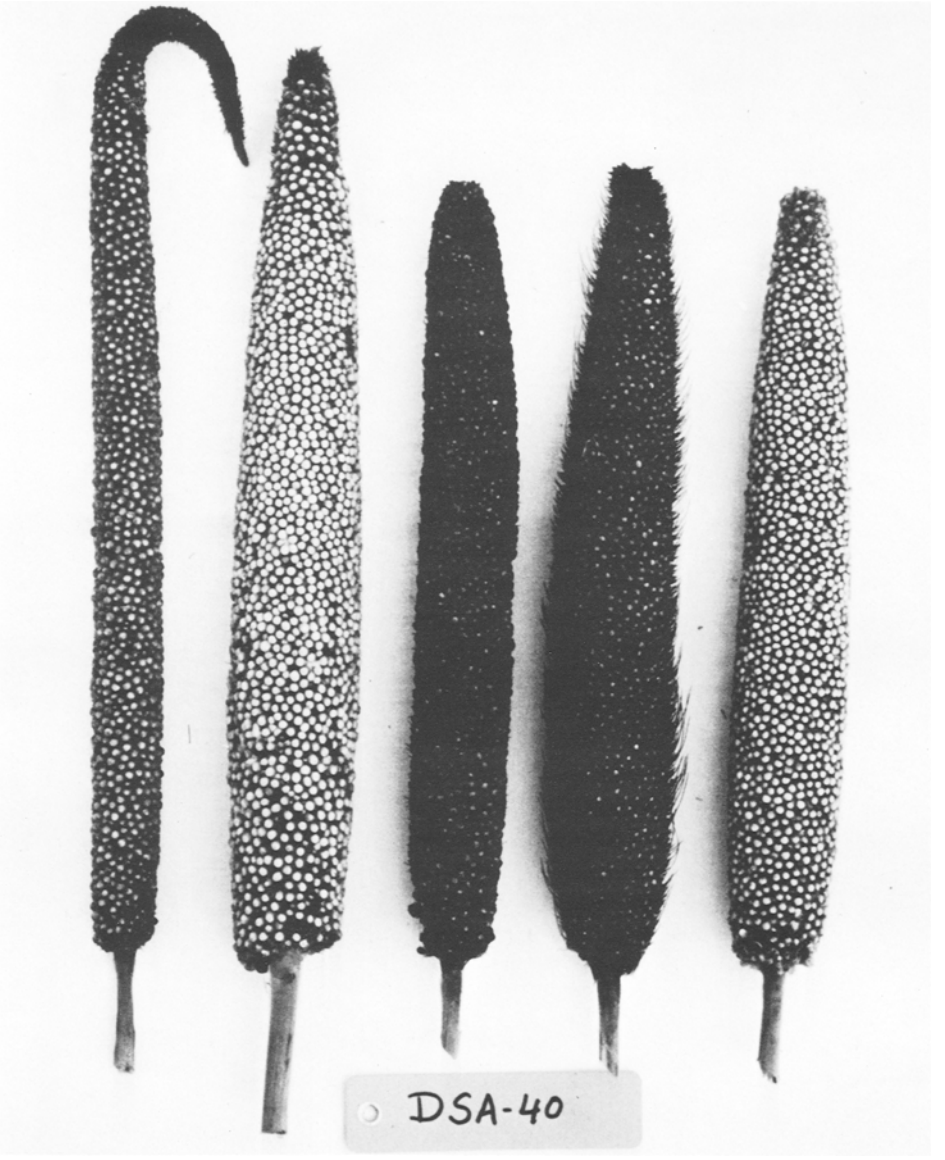

Fig. 5. Variation in head types of pearl millet found in a single field.

spikes with large grain are retained for use as seed stocks for the next planting season. These spikes are bundled (Fig. 6) and stored inside the house above the hearth where the smoke from the kitchen fire provides protection against grain pests. Manipulation of landraces by farmers through selection for a particular type over a long period of time will gradually lead to a loss of variability and evolution of radically different morphologies. The evolution of Ghanaian pearl millet with different colors and very large grain (7.9–18.3 g/1,000 grains) from the wild pearl millet with very small grain (1.45–2.25 g/1,000 grains) is probably

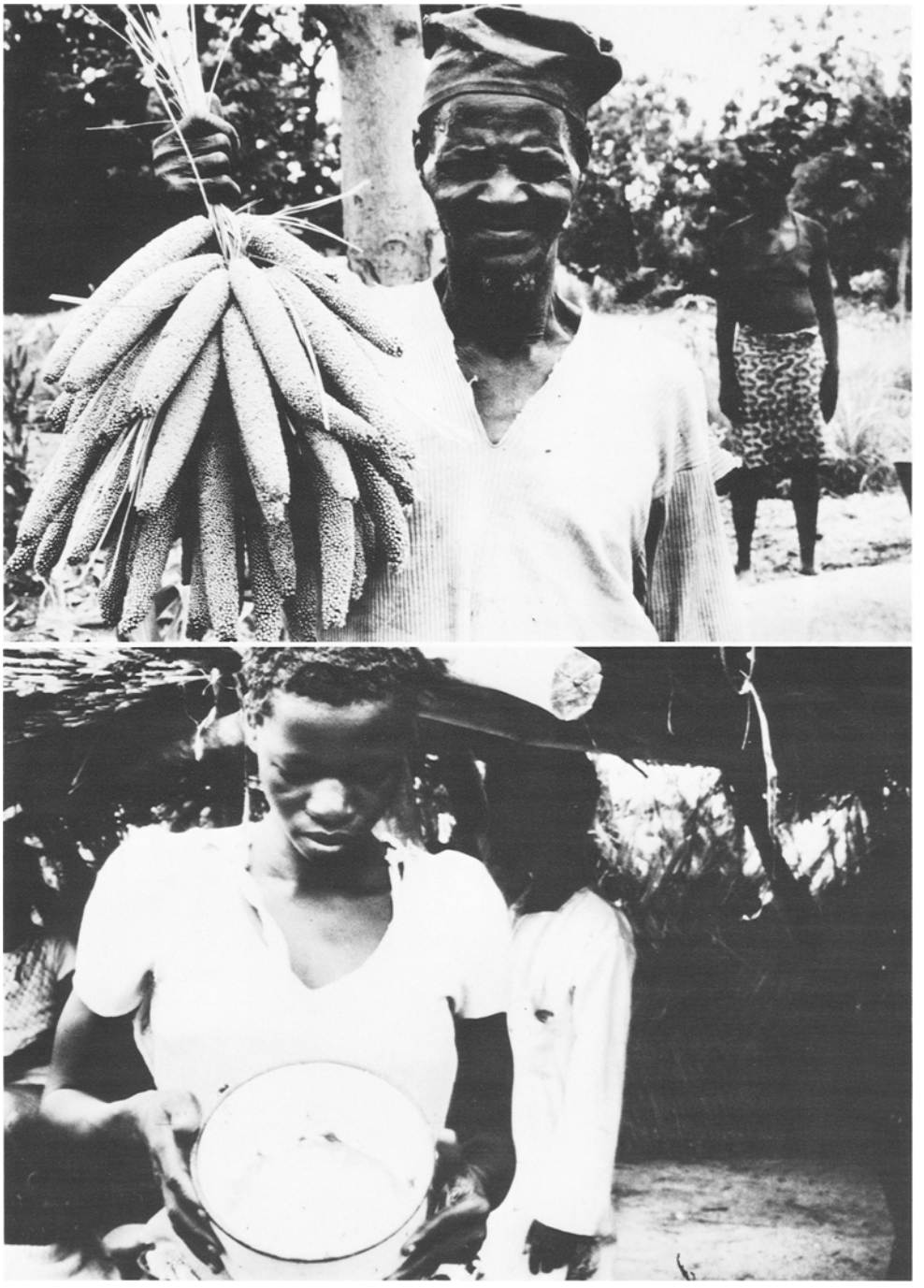

Fig. 6-7. Fig. 6. Uniform head types of millet selected by the farmer for seed. Fig. 7. A thin porridge called *koko* prepared from millet flour.

due to human selection. Harlan (1975) attributed the evolution of advanced cultivars with over 2 m-long spikes from wild pearl millet with 10 cm-long spikes to human selection, while Hawkes (1983) attributes it to aesthetic selection and particular farming practices there. Even though spike selection is practiced, some variation is still maintained in the populations due to allogamy in pearl millet.

As in most parts of West Africa, in Ghana there are 2 distinct kinds—the early maturing type to meet immediate requirements, and the late-maturing kind that matures generally after the cessation of rains. Differences in flowering between early- and late-maturing kinds are determined by 2 genes, L1 and L2 without dominance (Bilquez, 1963). Differences in flowering within the early-maturing kinds are determined by several genes with additive effect (Bilquez and Clement, 1969). Bono (1972) classified pearl millet from West Africa into 2 broad groups: group 1 consisted of millet from Mali, Ivory Coast, Mauritania and Upper Volta, and group 2 from Niger and Senegal. Ghanaian millets are entirely different from those of West Africa in several characters. In Ghana, pearl millet is grown in relatively high rainfall areas compared to several other pearl millet-growing countries in West Africa.

Though several wild relatives of pearl millet were reported from Ghana (Stapf and Hubbard, 1934), we did not find either wild or intermediate weedy forms. Since the millet was not flowering, they might have escaped our attention. These weedy forms called *shibras* occur frequently in other parts of West Africa (Catherinet et al., 1963).

In general, pearl millet from Ghana differs from that of other regions in characters such as spike shape, grain size, shape, and color, and earliness. These differences are so conspicuous, that Stapf and Hubbard (1934) classified this complex as *Pennisetum gambiense* Stapf & Hubb. It belongs, however, to race *globosum* (Brunken et al., 1977). Pearl millet from Ghana appears to be a good source of genes for earliness and large grain size.

USES OF PEARL MILLET

Early millet is normally harvested at the peak of the rainy season, and it matures at a time when farmers have exhausted their stocks of food grains from the previous harvest. Harvesting usually starts with the dough stage and is carried out in several stages. Small quantities of heads are harvested each time, usually just enough to feed the family for 3–4 days. Freshly-harvested heads are steamed, threshed and dried. Steaming probably enhances easy threshing and enables the farmer to prepare his food immediately. When it is completely mature, it is harvested on a clear day and dried. The stems are cut at the base with a cutlass. The heads are removed and dried in a corner of the field. Dry heads are threshed by beating them with a stick.

In Ghana, pearl millet grain is used solely for human consumption. Several traditional food preparations are made with pearl millet flour, which is commonly obtained by dry grinding. The grain is ground with a small handstone working on a large, flattened and stationary stone fixed at a convenient slope. As the grain is converted into flour, it moves down the stone and accumulates at the base.

The principal food, served at least once a day in the northern region, is a stiff porridge locally called *tô*. It is prepared by adding pearl millet flour to boiling

Fig. 8-9. Fig. 8. Preparation of a deep-fried pancake called *marsa* from millet flour. Fig. 9. Baskets prepared from the mature fibrous stems of sorghum; probably millet stems can also be used.

water while stirring constantly. The porridge is then placed on a flat plate and the sides are smoothed with a spoon.

A thin, fermented porridge, locally called *koko,* is also prepared by mixing the pearl millet flour with water to make a fine paste. This paste is kept in a warm place for a day or two to ferment naturally. The fermented flour is then added to boiling water with constant stirring to obtain a thin porridge of free-flowing, creamy consistency (Fig. 7). *Koko* is commonly sold in market places.

The favourite snack of Ghanaians is a deep-fried pancake, prepared from the leavened batter of pearl millet flour; locally called *marsa.* The flour is mixed with water in an earthen container to form a paste and is allowed to ferment naturally overnight. The thick, fermented batter is then fried in an earthen pan with 7 cup-like depressions (Fig. 8). It is fried in shea butter (*Butyrospermum paradoxum* [Gaertn. f.] Hepper), palm oil, or groundnut oil. Children often eat the sweet raw grains of pearl millet after threshing.

In Ghana, pearl millet is seldom used for brewing beer, although it is used for this purpose in several other countries (Vogel and Graham, 1979). Dark-colored sorghum is preferred to make the local beer called *pito.*

The green leaves and stems of pearl millet are used by farmers; the former are stripped from the dough-stage onwards to feed goats and sheep, while the stems are used for fencing, roofing material and fuel. In Ghana, stems of cereals are used to make baskets, though sorghum stems are preferred to millet. The soft pith portion is removed from mature dry stems by splitting them and the fibrous portion is then employed to prepare baskets (Fig. 9).

CONCLUDING REMARKS

It is now a well-established fact that the world is gradually losing its irreplaceable landraces for one reason or another. Natural hazards such as drought and floods in different parts of the world are taking their toll of germplasm. Increase in population and other environmental stresses are causing shortage of food in many developing countries. In such stress areas, the first source of food that is available to the farmer and his family are the early-maturing types. These important types are usually harvested first and consumed immediately. These same landraces are also needed by plant breeders to generate new, early-maturing and high-yielding cultivars. That is why a special effort should be made to collect and preserve the early-maturing landraces before they are completely lost.

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