

Exploration and Collection of Plant Genetic Resources

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Abstract

Investigations were carried out on the exploration and collection of small millet genetic resources in the Indian Subcontinent in 1985, 1987 and 1989. The major objectives of the present research were (1) observation and collection of small millet species such as *Echinochloa frumentacea*, *Eleusine coracana*, *Panicum miliaceum*, *P. sumatrense*, *Paspalum scrobiculatum*, *Setaria italica* and other minor millet species (2) analysis of the millet-weed complex through field observation and collection of weed species associated with millet cultivation, and (3) studies on the traditional utilization and food technology of millet species. The present paper summarizes some of those results from research in the three states of India, Karnataka, Tamil Nadu and Andhra Pradesh, in 1985, in the Maharashtra and Orissa states of India, and northern Pakistan in 1987, and in the Bihar and Madhya Pradesh states of India, and northern Pakistan in 1989.

Introduction

Exploration and collection of plant genetic resources have been carried out for the following four different research topics: (1) phylogenetic relationships among plant species and their speciation, (2) origin and dispersal of cultivated plants, (3) ethnobotanical studies on the relationship between plants and man, and (4) breeding of new cultivars and systematic introduction of exotic cultivars. These four different research subjects, however, are closely interrelated to each other. For example, the plant genetic resources collected for genetic studies of a given plant species group have been used for studies on the origin of cultivated plants belonging to the same group, and furthermore, some of them have been used as materials for the breeding of new cultivars.

The Indian Subcontinent and surrounding areas form the most important center of millet domestication in Eurasia. The millet species domesticated in Eurasia and those originating from Africa have been cultivated as important cereal crops in this area. The former includes *Coix lacryma-jobi* L. var. *ma-yuen* (Roman.) Stapf (Job's tears), *Panicum miliaceum* L. (common millet) and *Setaria italica* (L.) P. Beauv. (foxtail millet), while the latter consists of *Eleusine coracana* Gaertn. (finger millet), *Pennisetum americanum* (L.) Schum. (pearl millet) and *Sorghum bicolor* Moench (sorghum). Furthermore, there are several endemic millet species domesticated in the Indian Subcontinent, such as *Echinochloa frumentacea* Link (Indian barnyard millet), *Panicum sumatrense* Roth. (little millet), *Paspalum scrobiculatum* L. (kodo millet), and *Setaria glauca* (L.) P. Beauv.

In the present studies, observation and collection of small millet species were made in southern India in 1985 in Karnataka, Tamil Nadu and Andhra Pradesh states; in Maharashtra and Orissa states in India and in northern Pakistan in 1987; in the Bihar and Madhya Pradesh states of India and in northeastern Pakistan in 1989. The major objectives of the present studies were the (1) observation and collection of small millet species, such as *Ec. frumentacea*, *El. coracana*, *Pn. miliaceum*, *Pn. sumatrense*, *Ps. scrobiculatum*, *St. italica* and other minor millet species, (2) analysis of the millet-weed complex through field obser-

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variations and collection of weed species associated with millet cultivation, and (3) studies on the traditional utilization and food technology of millets.

The present paper summarizes some results of our field studies. Millet species collected in seven states of India and northern Pakistan in 1985, 1987 and 1989 are listed in Table 1.

These field studies were carried out with the cooperation of the National Bureau of Plant Genetic Resources, India, the All-India Coordinated Small Millet Improvement Project, Indian Agricultural Research Council, and Plant Genetic Resources Laboratory, National Agricultural Research Centre, Pakistan Agricultural Research Council.

Observation and collection of millet species in South India

Our field observations and collection of millet species in southern India in 1985 and 1987 are briefly summarized below.

1 Millet species in Karnataka

As listed in Table 1, six *Brachiaria* sp. (probably the cultivated form of *Br. ramosa* (L.) Stapf), seven *Ec. frumentacea*, 49 *El. coracana*, two *Pn. miliaceum*, 75 *Pn. sumatrense*, 14 *Ps. scrobiculatum*, one *Pt. americanum*, 62 *St. italica* and five *Sr. bricolor* samples were collected along the travel route.

Millet cultivation in Karnataka is very extensive. *El. coracana*, locally called *rugi*, is the most common millet species grown in this state (Seetharam, 1989). This species is usually sown in neat parallel rows with a drill pulled by cattle. Direct sowing in dry land and transplanting into irrigated fields are practiced (Fig. 1). *St. italica*, called *nawane*, was usually found as a mixed crop in a field of *El. coracana*, for example, a single row of *St. italica* with eight rows of *El. coracana*. *St. italica* plants usually had a few tillers with relatively small panicles (up to ca. 20 cm) and large grains. Variations were observed for the characters such as anthocyanin pigmentation, bristle length and grain color. Several types were often observed even in a single field. The grain color of *St. italica* was yellow or orange in most cases. Plants with black grains were, however, grown together with those having yellow or orange grains. *Ps. scrobiculatum*, called *harka*, was cultivated in some villages. The plants were usually sown in August and harvested in December. The cultivation of *Pn. miliaceum*, called *baragu*, was observed only in a small field sown in August. Plants with a hairy culm were observed. *Pn. sumatrense* is widely cultivated in Karnataka. Various types of panicle shape were often found even in a single field of this crop. For example, lax panicle, a green dense one, a purple dense one and purple semi-dense one were observed. There was no variation in grain color. All the grains were dark brown. A species belonging to the genus

Table 1 No. of millet species collected in seven states of India and northern Pakistan in 1985, 1987 and 1989

Area	Karna- taka	Tamil Nadu	Andhra Pradesh	Mahara- shtra	Orissa	Bihar	Madhya Pradesh	Subto- tal in India	Northern Pakistan	Total
Year of collection	(1985)	(1985)	(1985)	(1987)	(1987)	(1989)	(1989)		(1987)	
<i>Bracharia ramosa</i>	6	0	0	0	3	0	0	9	0	9
<i>Echinochloa frumentacea</i>	7	13	2	7	4	10	6	49	0	49
<i>Eleusine coracana</i>	49	14	21	5	9	66	7	171	0	171
<i>Panicum miliaceum</i>	2	6	0	0	0	7	0	15	37	52
<i>Panicum sumatrense</i>	75	43	30	68	45	19	64	344	0	344
<i>Paspalum scrobiculatum</i>	14	10	20	0	16	15	91	166	0	166
<i>Pennisetum americanum</i>	1	2	2	0	0	0	0	5	0	5
<i>Setaria glauca</i>	0	0	14	0	8	19	85	126	0	126
<i>Setaria italica</i>	62	22	19	18	9	12	2	144	74	218
<i>Sorghum bicolor</i>	5	5	0	0	0	1	5	16	0	16
Total	221	115	108	98	94	149	260	1,045	111	1,156



Fig. 1 A big field of *EL. coracana* in Karnataka

Brachiaria (probably *Br. ramosa*) was cultivated in a village, 35 km north of Tumkur. There we found two panicle shapes; open and closed. Among the plants with open panicles, two kinds were recognized with respect to the presence of hairs on panicle branches. This species is usually sown in July and harvested by base-cutting in the early morning at the end of October or the beginning of November. Harvesting panicles wet with dew in the early morning probably enables to avoid the disarticulation of mature grains, because this species still retains a considerable degree of shattering habit especially when the plant has dried up. The cultivation of this species was not observed in other localities (Kawase, 1987, 1991).

2 Millets Species in Tamil Nadu

Thirteen samples of *Ec. frumentacea*, 14 of *El. coracana*, six of *Pn. miliaceum*, 43 of *Pn. sumatrense*, ten of *Ps. scrobiculatum*, two of *Pt. americanum*, 22 of *St. italica*, and five of *Sr. bicolor* were collected in this state (Table 1).

Pn. sumatrense, locally called *samai*, is one of the most widely cultivated millet species in the lowlands of Tamil Nadu. Variation was found in panicle shape, ranging from open to closed. The grain color of this species was always dark brown. The grain color of *St. italica* was classified into four types; yellow, orange, brown and black. This species with yellow grains was the most common, and plants with orange grains were also common. *Ec. frumentacea* is sown at the end of June and transplanted 20 days after sowing as in the case of *El. coracana*. The plants are usually harvested by base-cutting in November while panicle plucking is also practiced in some cases. This species is threshed by cattle treading, soon after being harvested. *Pn. miliaceum* was found only sporadically mixed in a few fields of other crops.

We visited three tribal villages in the mountainous areas in Tamil Nadu: a village in the Kunda Hills, a village in the Nilgiris Hills and a village in the Sheveroy Hills. *El. coracana*, *Pn. sumatrense*, *St. italica* and *Ec. frumentacea* were collected. In the third village there was a wide variation in *St. italica* and *El. coracana* as shown in Fig. 2. In *St. italica* there were long (20–25 cm) panicles with relatively long lobes (branches) without bristles, panicles about 15 cm long with short lobes without bristles, and relatively short (less than 15 cm) panicles with long bristles. In *El. coracana*, there were at least three panicle types, a long straight type, an incurved type and a fist-type (Kawase, 1987, 1991).

3 Millet Species in Andhra Pradesh

Two samples of *Ec. frumentacea*, 21 of *El. coracana*, 30 of *Pn. sumatrense*, 20 of *Ps. scrobiculatum*, two of *Pt. americanum*, 14 of *St. glauca* (cultivated form), and 19 of *St. italica* were collected in this state (Ta-

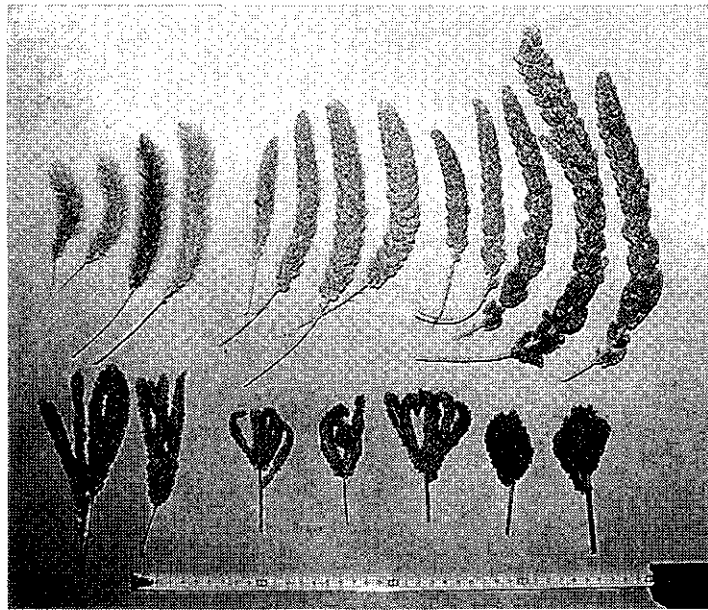


Fig. 2 Variation of panicle shape in *St. italica* (upper) and *El. coracana* collected in a field of a village in the Schveroy Hills, Tamil Nadu (Kawase, 1987)

ble 1). One *Pn. miliaceum* sample was provided by the Andhra Pradesh Agricultural University at Tirupati, and six samples of *Pn. miliaceum* and one of *St. italica* were offered by the Regional Agricultural Research Station, Nandyal.

A cultivated form of *St. glauca* was observed in several areas in the southern part of Andhra Pradesh, especially near the border with Tamil Nadu. *St. glauca* was found almost equally mixed with *Pn. sumatrense*. There were two panicle types in *St. glauca*; one had reddish brown bristles and the other had white ones. Plants with reddish brown bristles were predominantly observed in the fields. The weed form of *St. glauca*, with a shattering habit, occurred outside of the field of the cultivated form.

Several kinds of crops were usually grown mixed in *El. coracana* fields. *St. italica*, *Pn. sumatrense*, and the cultivated form of *St. glauca* were sporadically found in a small field of *El. coracana*. In this field, *Sr. bicolor* was planted in parallel rows one meter apart. According to the information from local farmers, three types of *El. coracana* (*ragi*) were recognized with respect to the growth period; 85-90 days, 120 days and more than 140 days. In the central part of Andhra Pradesh, *St. italica* with yellow grains is widely cultivated under the name of *korra*. *Cajanus cajan* (L.) Millsp. was often found in mixed cropping in *St. italica* fields (Kawase, 1987, 1991).

4 Millet species in Maharashtra

During our trip in this state, seven samples of *Ec. frumentacea*, five of *El. coracana*, 68 of *Pn. sumatrense* and 18 of *St. italica* were collected (Table 1).

El. coracana was cultivated extensively and sometimes found beside rice paddies. Transplanting of this species is usually practiced and broadcasted fields were also frequently encountered. In those fields sometimes *Pn. sumatrense* and *Cajanus cajan* were found sporadically. *Pn. sumatrense* is very sporadically grown in Maharashtra. This species usually had very big panicles and was transplanted in the margins of *El. coracana* or rice paddies, especially inside levees. In some locations, *Pn. sumatrense*, with blackish-colored large panicles, was observed. Cultivation of *St. italica* was very rare. This species had a few tillers with relatively small panicles (up to ca. 20 cm). *Ec. frumentacea* was found at only two locations.

This species is grown with *Pn. sumatrense* but rarely with *El. coracana*. *Ps. scrobiculatum* was also very seldom observed and could not be collected (Kobayashi and Kimata, 1989).

5 Millet species in Orissa

Three samples of *Br. ramosa*, four of *Ec. frumentacea*, nine of *El. coracana*, 45 of *Pn. sumatrense*, 16 of *Ps. scrobiculatum*, eight of *St. glauca* and nine of *St. italica* were collected as shown in Table 1.

El. coracana was usually broadcasted and grown in pure stands or mixed with *Pn. sumatrense*. The grain color of *St. italica* was usually yellow or orange and black in rare cases. On a shifting cultivation slope this species was found to be mixed with *Sr. bicolor*, *Ricinus communis* L. and *Cajanus cajan*. *Pn. sumatrense* with a non-or red-pigmented plant body and panicles was also grown sporadically in *El. coracana* fields. Fields cultivated with *St. glauca* were encountered on the table lands. The plants were, however, grown with *Pn. sumatrense* as crop insurance. In a highly wet field, *Pn. sumatrense* and cultivated *St. glauca* also grew well. Red panicles with red bristles and yellowish white panicles were found in every cultivated field (Kobayashi and Kimata, 1989).

Observation and collection of millet species in northern Pakistan

Recently we have proposed a new theory on the geographical origin of *St. italica* and *Pn. miliaceum*. We consider that these species were first domesticated within the area ranging from Central Asia and Afghanistan to India, and from there they were dispersed both eastward and westward, and became gradually differentiated genetically (Sakamoto, 1987 a,b). Therefore, the northern mountainous region of Pakistan is an interesting area for studies on the domestication and genetic differentiation of those two millet species. Little is known, however, about millet cultivation in this region (Nakao *et al.*, 1965).

In 1987 we made field observations and collections of plant species in three provinces of northern Pakistan, the North-West Frontier Province (NWFP), Gilgit Agency, and Baltistan. A total of 447 samples were collected, of which 243 samples consisted of cultivated plants containing 74 samples of *St. italica*, 37 of *Pn. miliaceum* and 35 of *Oryza sativa* L. The remaining 204 samples consisted of wild and/or weedy plants. Collection sites of *St. italica*, *Pn. miliaceum* and *O. sativa* are plotted in Fig. 3 (Kawase and Sakamoto, 1989). Local names of those two millet species collected at each site along the expedition route are listed in Table 2.

1 Millet species in the NWFP

In the northern part of the NWFP we visited the Abbottabad, Manshera, Swat and Dir Districts. Only a small field of *St. italica* was found in Besham. The individual plants were ca. 70 cm tall and had several tillers with short panicles 10-12 cm long. Most plants had yellow grains but a few had black ones. *St. italica* grains were sold in bazars in and around the vicinity of Timergara and Brolnamhi.

The cultivation of *St. italica* and *Pn. miliaceum* was very popular in many villages throughout the Chitral District in the northern part of the NWFP, at altitudes ranging from 1,500 to 3,000 m. *St. italica* in this area was usually short in stature (20-70 cm) and had many tillers with short, small panicles (ca. 6 cm long) (Fig. 4). The plants were very similar to the landraces occurring in Afghanistan (Sakamoto, 1987 b).

St. italica was grown sometimes along with *Pn. miliaceum*. The plants were sown in June, harvested at the end of September and threshed using animal trampling. Some weedy *St. viridis* (L.) P. Beauv. plants, probable a wild ancestor of *St. italica*, occurring in the *St. italica* field were similar to cultivated *St. italica* except for the small grains with a shattering habit.

In a village (1,590 m alt.) located 28 km NE of Chitral, *St. italica* was cultivated together with *Vigna mungo* (L.) Hepper and *V. radiata* (L.) Wilczek. In another village (2,400 m alt.) *St. italica* with a short plant height (30-70 cm) was grown. A bundle of panicles harvested from a field where *St. italica* and *Pn. miliaceum* were grown together was collected from another village (2,840 m alt.). It contained 158 panicles of the former, 355 of the latter and 34 of weedy *St. viridis*.

2 Millet species in Gilgit Agency

Characteristics of both *St. italica* and *Pn. miliaceum*, that are cultivated in the western part of Gilgit Agency were considered to be basically similar to those found in the Chitral District of the NWFP.

From Gilgit we explored the Hunza Valley in the northern part of Gilgit Agency. *St. italica* in this area, surprisingly, was a tall non-tillering plant with a long panicle. All the strains we observed through-

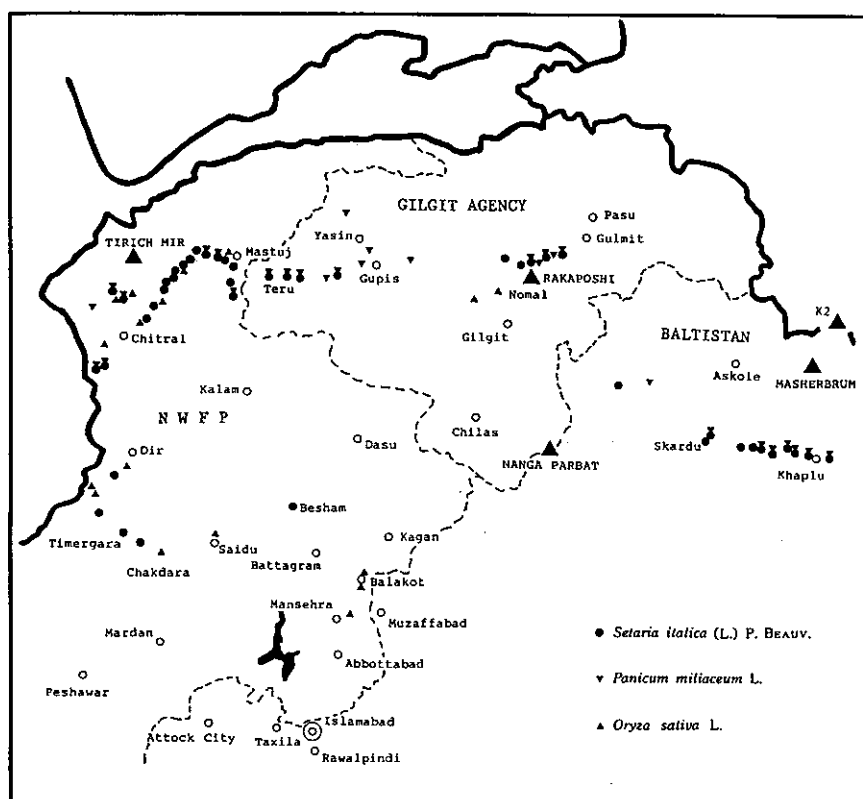


Fig. 3 Collection sites of *St. italica*, *Pn. miliaceum* and *O. sativa* in northern Pakistan (Kawase and Sakamoto, 1989)

out the Hunza Valley were morphologically similar, but they were quite different from those cultivated in the NWFP and in the western part of Gilgit Agency. In one village, for example, the non-tillering type of *St. italica*, ca. 120 or 130 cm tall with a ca. 20 cm long panicle was cultivated.

Pn. miliaceum was grown in many fields. The plant height was ca. 90 cm. Four panicle types were mixed in a field; open panicles with reddish pigmentation, open panicles without pigmentation, non-open type with pigmentation and non-open type without pigmentation. *St. italica* and *Pn. miliaceum* were cultivated in many villages at an altitude ranging between 1,600 and 2,000 m, while they were not found at Gulmit (2,320 m alt.) and northward along the Hunza Valley.

3 Millet species in Baltistan

St. italica of the non-tillering type was predominantly cultivated in many villages in Baltistan (Fig. 5). Morphological variation was observed in plant height (ranging from 80 cm to 180 cm), panicle shape and panicle color. Almost all the fields of the villages (2,200 m alt.), located ca. 50 km from Skardu toward Machulo, were cultivated with *St. italica* plants ca. 170 cm tall. Plants with anthocyanin pigmentation and those without pigmentation were grown in different fields. Several panicle shapes were observed in each field (Fig. 6). A few plants which looked like hybrids of *St. italica* and *St. viridis* were also found. They were very similar to *St. italica*, but they usually had blackish grains and showed a shattering habit.

Characteristics of *St. italica* and *Pn. miliaceum* in the Karakoram Range of northern Pakistan

Based on the morphological characteristics observed in *St. italica* collected in this region, our samples could be divided into three groups; (1) the western group that is grown in the area ranging from the Chitral District of the NWFP to the western part of the Gilgit Agency, (2) the eastern group that was col-

Table 2 Local names of *St. italica* and *Pn. miliaceum* in northern Pakistan (Kawase and Sakamoto, 1989)

Accession number	Location	<i>St. italica</i>	<i>Pn. miliaceum</i>
The southern part of the NWFP			
87-9-20-6	Talash Zairat	<i>gogh</i>	
87-9-21-1	Timergara	<i>gogh</i>	
87-9-21-5	Mayar	+	
87-9-22-4	Brolbandhi	<i>ghok</i>	
87-10-26-1	Besham	<i>gokhton</i>	
Chitral District, the NWFP			
87-9-24-2	Bambreet	<i>grashik</i>	<i>olean</i>
87-9-24-3	Karl Kal	+	+
87-9-25-2	Chiwaht	+	+
87-9-25-5		+	+
87-9-25-6	Droshp		<i>olean</i>
87-9-26-2	Kogozhi	<i>grach</i>	
87-9-26-3	Morilasht	<i>grach</i>	
87-9-26-5	Barinis	<i>gras</i>	
87-9-26-6		+	
87-9-26-7		+	
87-9-26-8		<i>gras</i>	
87-9-26-9	Kuragh	+	
87-9-26-10		+	
87-9-26-11		+	
87-9-27-1	Booni	+	+
87-9-27-2	Parwak	+	<i>olean</i>
87-9-27-3		<i>gras</i>	
87-9-27-5	Gasht	+	
87-9-27-6	Harchin	<i>grass</i>	
87-9-27-7	Laspur	<i>gras</i>	<i>olean</i>
The western part of Gilgit Agency			
87-9-28-1	Teru	+	+
87-9-28-2	Gorakmuri	<i>gras</i>	<i>olean</i>
87-9-28-3	Phandar	<i>gras</i>	<i>olean</i>
87-9-28-5	Pengal		<i>olean</i>
87-9-28-6		+	+
87-9-28-8	Jandrot		+
87-9-29-1	Damargand		<i>olean</i>
87-9-29-3	Drach		<i>olean</i>
87-9-30-1	Yangar		<i>chiena</i>
The Hunza valley, Gilgit Agency			
87-10-2-2	Chalat	<i>cha, cheng</i>	
87-10-2-3	Skandarbad	<i>cha</i>	
87-10-2-4	Nagar	<i>cheena</i>	<i>cheena</i>
87-10-2-5	Nasirabad		+
87-10-2-6	Murtazabad	<i>cha</i>	<i>bau</i>
87-10-4-1	Ganish	+	+
87-10-4-2	Aliabad		+
Balitistan			
87-10-6-2	Shut	<i>cha</i>	
87-10-6-4			<i>tzetze</i>
87-10-8-1	Goal	<i>lal cha, sufaid cha</i>	
87-10-8-2	Karis	<i>cha</i>	<i>tzetze</i>
87-10-8-4	Goon	+	+
87-10-8-5	Kunis	<i>cha dang, cha kar, cha mar, golo cha</i>	<i>marpo tzetze kapro tzetze</i>
87-10-9-2	Surmo	+	<i>tzetze</i>
87-10-9-3	Barah	+	+
87-10-9-4	Kharfaq	+	+
87-10-19-1	Skardu	<i>cha</i>	+

+ : collected, but no information.



Fig. 4 A short plant of *St. italica* cultivated in the Chitral District of the NWFP showing many tillers with short panicles



Fig. 5 Cultivation of *St. italica* in Baltistan

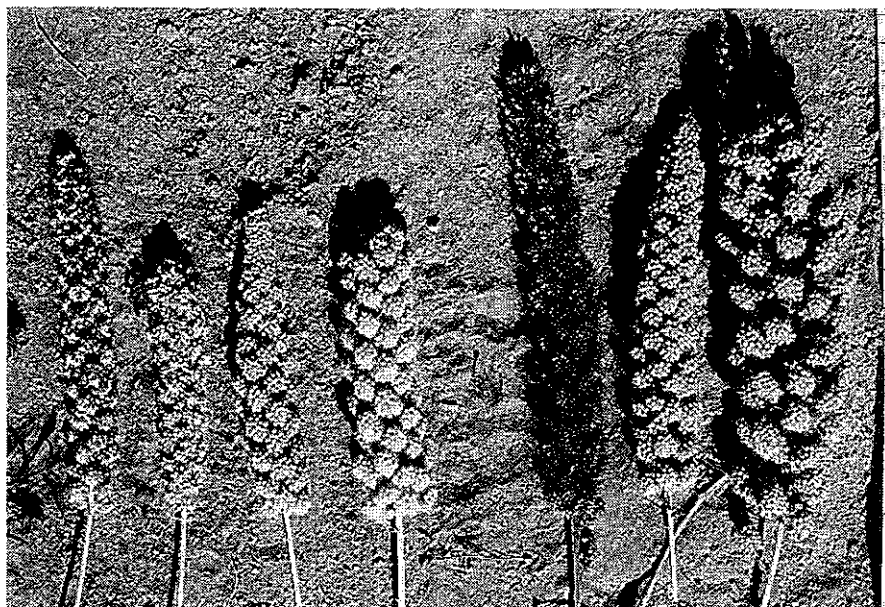


Fig. 6 Panicles of *St. italica* collected from a cultivated field of Baltistan

lected in the Hunza Valley in the Gilgit Agency and the Baltistan Province, and (3) the southern group which was found in the southern part of the NWFP. A clear gap was found among these three groups.

St. italica in the western group is usually shorter (less than 70 cm) and exhibits many tillers with small panicles. The strains belonging to this group closely resemble morphologically the landraces grown in northeastern Afghanistan and described by Sakamoto (1987 b). This group is called *grasshik*, *gras* or *grass* by the local farmers (Table 2). On the other hand, those belonging to the eastern group are tall and non-tillering plants with a large panicle. There was some morphological variation throughout the villages in the Hunza Valley, while wide variations were observed in Baltistan especially in the panicle shape. The plants are called *cha* or *cheng* in the Hunza Valley and *cha* in Baltistan (Table 2). Only few samples of the southern group were collected due to the limited cultivation of *St. italica* in this area.

It appeared that *Pn. miliaceum* collected from the western part of the Karakoram Range was quite different from the plants collected from the eastern part. The plants grown in the Chitral District and in the western Gilgit Agency were of short stature. The local name of this crop was *olean* throughout this area. On the contrary, *Pn. miliaceum* collected in Hunza Valley and Baltistan was much taller than the plants of the western part. This crop is called *tzetze* in Baltistan by the local farmers (Table 2). No *Pn. miliaceum* was collected in the southern part of the NWFP.

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Discussion

Nakagahra, M. (Japan): When you visited the same area at different intervals for collections of small millets, did you observe any changes in the cultivation?

Answer: I have not visited the same collection site at different intervals. Generally speaking, the cultivation of small millets is decreasing year by year due to the modernization of farming techniques and introduction of modern crops.

Iwanaga, M. (IBPGR): Regarding the strategy of the expeditions for collecting genetic resources, one approach is to collect germplasm in areas with a high level of genetic diversity of a target germplasm. An other approach is to organize expeditions according to specific traits for use in plant breeding, for example drought tolerance.

Answer: I have explored areas with a high level of genetic diversity and I have also organized expeditions to collect a specific plant group. In any case, I covered areas displaying diversity as well as marginal areas to study phylogenetic relationships of a given plant group, the origin of crops or for ethnobotanical studies which all require the observation of geographical variation. Even when I focussed on a specific plant group, I have collected other crops and/or related wild plants as much as possible. I have tried to obtain ethnobotanical information on crops because the collected samples are not only plant genetic resources but also plant cultural resources. The method of collection depends on the objectives.

Rana, R. S. (India): Comment: Under joint exploration programs, national and foreign scientists tend to give different identity numbers to the collected samples of germplasm, leading to duplications. This situation has improved since exploration team members give common collector's numbers. It is important that the gene banks also give the original collector's number as the link number to their accession number while supplying samples to indentors.