Background on the development of the "Global strategy for the *ex situ* conservation of pearl millet"

The development of the strategy involved the following main steps:

- The pearl millet strategy was initiated in December, 2009 and discussions took place with international, regional and national partners through email discussions whereby a survey questionnaire was finalized for circulation.

- Information and data were gathered using databases such as GENESYS (www.genesys-pgr.org), FAO-WIEWS (http://apps3.fao.org/wiews/wiews.jsp?i_l=EN), SINGER (http://singer.cgiar.org/), EURISCO (http://eurisco.ecpgr.org/) and GBIF); reports and other information resources on the holdings of finger millet genepools and additional inventory of collections.

- Identification of major germplasm collections of pearl millet based on information collected above were identified along with Institutes and their respective contact persons to undertake the survey.

- Survey questionnaire was designed in consultation with experts and survey was undertaken to gather information on collections, content and status of conservation in January, 2011 and information was received from 80 countries across Asia, Africa, Europe and Americas.

- After receiving information from the survey, a draft report was finalized and circulated to all the partners for their feedback.

- The consultation meeting was organized on December 22, 2011 to discuss the draft report where participants from India, Kenya, Uganda, Mali, and Senegal participated. Based on their input, the final report was prepared for submission.

**Coordinator:**
Much of the development of the pearl millet strategy was coordinated by Dr. P N Mathur (p.mathur@cgiar.org), South Asia Coordinator at Bioversity International in consultation with Dr. Hari D Upadhyaya, Assistant Research Program Director, Grain Legumes and Principal Scientist and Head of Gene Bank at ICRISAT. The strategy is currently coordinated within the Trust by Luigi Guarino.

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# GLOBAL STRATEGY FOR THE *EX SITU* CONSERVATION OF PEARL MILLET AND ITS WILD RELATIVES

**JANUARY 2012**

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## DISCLAIMER

This document, developed with the input of a large number of experts, aims to provide a framework for the efficient and effective ex situ conservation of globally important collections of finger millet.

The Global Crop Diversity Trust (the Trust) provided support for this initiative and considers this document to be an important framework for guiding the allocation of its resources. However, the Trust does not take responsibility for the relevance, accuracy or completeness of the information in this document and does not commit to funding any of the priorities identified.

This strategy document (dated January 2012) is expected to continue to evolve and be updated as and when circumstances change or new information becomes available.

In case of specific questions and/or comments, please direct them to the strategy coordinator mentioned in the document.

## 1. BACKGROUND

Conserving the rich diversity of crop varieties and related wild species is essential for providing farmers and plant breeders with raw materials to improve and adapt crops to meet future challenges. The urgent need to conserve endangered genetic resources has been discussed in different international fora. Accordingly, programmes for genetic resources collection and conservation of landraces and crop wild relatives have been promoted by the Food and Agriculture Organization of the United Nations (FAO), through its Commission on Plant Genetic Resources, and by Bioversity International, together with other International Agricultural Research Centres (IARCs) of the Consultative Group for International Agricultural Research (CGIAR). A number of national agricultural research systems (NARS) have also been involved in these international activities and undertakings. In addition, some countries have developed strong national plant genetic resources programmes. Initiatives towards this end have included:

1. Adoption of the International Undertaking on Plant Genetic Resources for Food and Agriculture at the FAO Conference in 1983. The undertaking, adhered to by over 100 countries, was the first comprehensive international agreement dealing with plant genetic resources and was an important milestone in ensuring equity of access to plant genetic resources for food and agriculture.

2. Development of agreed technical standards for the storage, regeneration, documentation and distribution of germplasm samples of crop species.

3. Documentation of existing collections, their coverage and status and the publication of periodic reports and updates on the state of the world's plant genetic resources for food and agriculture.

4. The establishment of and support for a range of regional and crop-specific networks to facilitate a more rational and cooperative approach to the conservation, documentation and use of plant genetic resources.

5. In 1992, the Convention on Biological Diversity (CBD) highlighted the importance of conservation, and in 2002 the Parties to the Convention adopted the Global Strategy for Plant Conservation, including specific targets for crop diversity conservation. In 2004 the Conference of the Parties to the Convention passed a resolution welcoming the development of the Global Crop Diversity Trust.

6. In 1996, 150 countries adopted the FAO Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. This Plan calls for action to safeguard "as much existing unique and valuable diversity as possible in *ex situ* collections of plant genetic resources for food and agriculture".

7. The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) entered into force in June 2004, and has been ratified by more than 123 countries. The Treaty, which arose from and replaced the International Undertaking, provides a legally binding framework for access and benefit-sharing in relation to plant genetic resources for a defined range of crops.

As a result of these efforts, in the second half of the 20$^{th}$ century and the early 21st, the number and size of plant genetic resources collections all over the world increased significantly. New long-term conservation facilities were built, in which thousands of seed samples were preserved at relatively low cost. Based on figures in the World Information and Early Warning System (WIEWS) on Plant Genetic Resources for Food and Agriculture and country reports, it is estimated that currently about 7.4 million accessions are maintained globally, 1.4 million more than was reported in the first State of the World (SoW) report (1996). Various analyses suggest that between 25% and 30% of the total holdings (or 1.9 – 2.2 million accessions) are distinct, with the remainder being duplicates held either in the same or, more frequently, different collections. Germplasm of crops listed under Annex 1 of the ITPGRFA is conserved in more than 1240 genebanks worldwide and comprises a total of about 4.6 million samples. Of these, about 51% are conserved in more than 800 genebanks of the Contracting Parties of the ITPGRFA, and 13% are stored in the collections of the CGIAR Centres. Of the total 7.4 million accessions, national government genebanks conserve about 6.6 million, 45% of which are held in only seven countries, as compared to 12 countries in 1996.

However, important collections of crop diversity face urgent and chronic limited/lack of funding. These shortages can lead to loss of diversity, the very building blocks on which adaptive and productive agriculture depends. In order to address these funding constraints and provide support to national and international genebanks on a sustainable funding

support basis, in late 2004 the Global Crop Diversity Trust (Trust) was established. The Trust was founded by the United Nations Food and Agriculture Organisation (FAO) and Bioversity International, as an independent international organization. The Trust is currently hosted in Rome by FAO and is a unique public-private partnership raising funds from individual, corporate and government donors to establish an endowment fund that will provide complete and continuous funding for key crop collections.

In line with the ITPGRFA and the Global Plan of Action for the Conservation and Sustainable Utilization of PGRFA, the Trust's goal is to advance an efficient and sustainable global system of *ex situ* conservation by promoting the rescue, understanding, use and long-term conservation of valuable plant genetic resources. Achieving the Millennium Development Goals, the priorities for development agreed by all members of the United Nations, will require crop diversity to be effectively conserved, and the Trust directly contributes to three of the goals: to eradicate extreme poverty and hunger (Goal 1); to ensure environmental sustainability (Goal 7); and to develop a global partnership for development (Goal 8). The Trust commissioned global strategies for the *ex situ* conservation of pearl millet and its wild relatives to identify major gaps in collections and the challenges faced for their conservation and use in order to support some of these priority activities for agriculture and food and nutrition security.

## 2. OUTLINE OF THE STRATEGY DEVELOPMENT PROCESS

The following procedure was used to develop the strategy:

### 2.1 Focal person for strategy development process

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### 2.2 Strategy development

The project aims to develop, in close consultation with representatives of the relevant institutions and stakeholders, a strategy for the efficient and effective conservation of pearl millet genetic resources and to identify priority collections eligible for long-term support from the Global Crop Diversity Trust and their urgent upgrading and capacity building needs. The strategy will promote the rationalization of conservation efforts at national, regional and global levels, e.g. through encouraging partnerships and sharing of facilities and tasks, and will link with the relevant regional conservation strategies.

### 2.3 Expected outputs

- An assessment, in consultation with representatives of the relevant stakeholders, of worldwide/global collections of pearl millet and their wild relatives;A global ranking of pearl millet collections that are 'most important' in terms of size, extent of diversity, holdings of wild relatives and other standards of assessment, carried out in consultation with relevant regional, national and international partners;
- A conservation strategy and recommendations for the long-term management of pearl millet collections, facilities and tasks.

### 2.4. Major steps in the development of the strategy

Information and data gathered using databases such as (GENESYS (www.genesys-pgr.org), FAO-WIEWS (http://apps3.fao.org/wiews/wiews.jsp?i_l=EN), SINGER (http://singer.cgiar.org/), EURISCO (http://eurisco.ecpgr.org/) and GBIF); reports and other information resources on the holdings of pearl millet genepools and additional inventory of collections.

1. Identification of major germplasm collections of pearl millet based on information collected above. Institutes and their respective contact persons identified to undertake the survey.
2. Simple questionnaire developed for germplasm holdings survey and validated by key partners.

3. Survey information synthesized and gaps identified.

A survey questionnaire (**Appendix 1**) was designed in consultation with experts and sent to curators of the world's 47 largest pearl millet collections in order to gather basic information on the numbers and types of accessions held, the conditions under which they were stored and their accessibility. Survey respondents' contact details are provided in **Appendix 2**.

## 3. GLOBAL CONSERVATION STRATEGY FOR PEARL MILLET

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the fifth most important cereal crop in the world after rice, wheat, maize, and sorghum. It is a widely grown rainfed cereal crop in the arid and semi-arid regions of Africa and Southern Asia, and can be grown in areas where rainfall is not sufficient (200 to 600 mm/year) for the cultivation of maize and sorghum. In other countries it is grown under intensive cultivation as a forage crop. The exact area under cultivation and the production per unit area is not known at global level as most of the information available is combined with other millet crops like finger millet, foxtail millet, etc. However, pearl millet accounts for almost half of global millet production, with 60% of the cultivation areas in Africa, followed by 35% in Asian countries. European countries represent 4% of millet cultivation and North America only 1%, mainly for forage. Today millet is a staple for more than 500 million people. Areas planted with pearl millet are estimated at 15 million hectares annually in Africa and 14 million hectares in Asia. Global production exceeds 10 million tons a year (National Research Council, 1996). In sub-Saharan Africa, pearl millet is the third major crop with the major producing countries being Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania and Senegal in the West and Sudan and Uganda in the East. In Southern Africa, maize has partially or completely displaced millet cultivation because of commercial farming.

India is the largest producer of pearl millet, both in terms of area (9.3m ha) and production (9.3 m t), with an average productivity of 1044 kg/ha during the last five years. The trends in area, production and productivity of pearl millet suggest that area has increased marginally (2%) during last two years and productivity has gone up by 19% (Yadav, 2011 - http://www.aicpmip.res.in/pcr2011.pdf). The major pearl millet growing states in India are: Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, Haryana, Karnataka, Madhya Pradesh, Tamil Nadu and Andhra Pradesh. However, the productivity (kg/ha) is highest in Haryana followed by Gujarat, Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Rajasthan, Maharashtra, and Karnataka. It is mainly cultivated during *Kharif* (rainy) season across the country. However, it is also grown to a lesser extent during *Rabi* (post-rainy) season in Andhra Pradesh, Karnataka and Tamil Nadu. Summer pearl millet cultivation is popular in Gujarat State, producing high yields and excellent grain quality. The productivity imbalance is due to erratic rains and shifting of pearl millet cultivation to marginal soils due to diversification of traditional areas to higher value crops across the country. Outside Africa and India, millets are also grown in Australia, China, Canada, Mexico, Russian Federation and the USA. In most of these countries, pearl millet is grown primarily as a forage crop for livestock production

(National Research Foundation, 1996). Pearl millet is endowed with enormous genetic variability for various morphological traits, yield components, adaptation and quality traits. Pearl millet is also nutritionally superior compared to maize and rice. The protein content of pearl millet is higher than maize and it has a relatively high vitamin A content.

# 4. ORIGIN AND TAXONOMY

## 4.1 Taxonomy

Pearl millet, *Pennisetum glaucum* is an annual, allogamous, cross-pollinated, diploid cereal, belonging to the *Poaceae* family, subfamily *Panicoideae*, tribe *Paniceae*, subtribe *Panicinae*, section *Penicillaria* and genus *Pennisetum*. The genus *Pennisetum* contains about 140 species. The important wild relatives of cultivated pearl millet include the progenitor, *Pennisetum glaucum* subsp. *monodii* Maire, *P. purpureum* K. Schumach*, P. pedicellatum* Trin., *P. orientale* Rich, *P. mezianum* Leeke, and *P. squamulatum* Fresen. Previous names are *P. typhoideum* L.C. Rich and *P. americanum* (L.) Leeke. The four cultivated forms of pearl millet are *typhoides* (found mainly in India and Africa), *nigritarum* (dominant in eastern Sahel), *globosum* (dominant in the western Sahel) and *leonis* (dominant on the West African coast) (Brunken *et al.,* 1977; Rai *et al.,* 1997; Syngenta, 2006).

## 4.2 Taxonomic concepts of the genus *Pennisetum*

Linnaeus (1753) originally placed pearl millet cultigens into two separate species (*P. glaucum* and *P. americanum*) of the genus *Panicum*. Later he moved several of these elements to the genus *Holcus* (Linnaeus, 1759). Rechard (1805) grouped pearl millet along with a number of species previously listed under both *Panicum* L. and *Cenchrus* L. in a new genus, *Pennisetum*. Willdenow (1809), however, established the genus *Penicillaria* to include pearl millet, but Steudel (1855) reduced it to its present status as a section in *Pennisetum.* He merged many variants of pearl millet into a single polymorphic species, recognized as *P. typhoideum* L. Rich. The limits of the section were expanded by Leeke (1907) to include all those wild species of *Pennisetum* having penicillate anther tips and involucral bristles.

The generic name *Pennisetum* has been derived from two Latin words - *Penna* and *Seta*, meaning feather and bristles i.e. feathery bristles. The most extensive treatment of the genus *Pennisetum* was contributed by Stapf and Hubbard (1934), who divided the genus into five sections: *Gymnothrix*, *Brevuvalvula*, *Penicillaria*, *Heterostachya*, and *Eu-pennisetum*. Cultivated pearl millet and its wild and weedy relatives were included in section *Penicillaria*, which included 14 cultivated, 6 wild and 13 intermediate species.

Brunken (1977) further reduced the number of species in section *Penicillaria* to two, on morphological and cytological grounds; *P. purpureum* was maintained as a separate species because of tetraploid chromosome number and perennial life cycle. All the diploid cultivated, weedy and wild taxa that frequently hybridize without genetic barriers are classified under a single species, *P. americanum.* Based on the morphology and adaptive strategies to domestication, *P. americanum* was further divided into three

subspecies: *americanum* including the cultivated forms, subspecies *monodii* including the wild forms, and subspecies *stenostachyum* with the weedy forms.

Clayton and Renvoize (1982) demonstrated that the taxonomically correct name for cultivated pearl millet is *P. glaucum*. They recognized the weedy forms (colloquially called *shibra*) as *P. sieberanum* and their wild progenitor as *P. violaceum. P. violaceum* differs from pearl millet in having involucres that are sessile, deciduous at maturity and always contain a single spikelet.

## 4.3 Common names

Various common names of pearl millet in different countries have been reported as mentioned below (from Wikipedia Pearl millet):

Africa: *GeroHatsii* (Hausa), *mahangu* (Namibia), *sanio, babala, nyoloti, dukkin, souna, haïni* (Zarma), *mexoeira* (Mozambique), *mashela* (Tigrinya), *mhunga* (Shona, Zimbabwe), *lebelebele* (Setswana, Botswana), *zembwe* (Ikalanga, Botswana)
Australia: *Bulrush millet*
Azeri and Turkish: *Dari*
Brazil: *Milheto Kaustubh*
Dutch: *Parelgierst*
English: *Pearl millet, spiked millet, bulrush millet, cattail millet, , candle millet, dark millet*
French: *Millet perlé, Mil penicillaire, Penicillaire, Petit mil, Millet à chandelles*
German: *Perlhirse, Rohrkolbenhirse, Pinselgras, Negerhirse*
India: *Bajri, Sajje* in Kannada; *Kambu* in Tamil; *Bajra* in Hindi, Urdu and Punjabi)
Italian: *Miglio perlato*
Russian: *Proso*
Spanish: *Mijo perla, Mijo negro, Bajra*
USA: *Cattail millet* (*Pennisetum americanum*)

## 4.4 Origin and Domestication

The geographical origin and the centre of domestication of pearl millet are situated in western Africa. The plant was subsequently introduced into India, where the earliest archaeological records date back to 2000 B.C. (Hanna, 1987; Rai *et al.,* 1997; Gari, 2002; Oumar *et al.,* 2008). Records exist for cultivation of pearl millet in the United States in the 1850s, and the crop was introduced into Brazil in the 1960s.

The oldest findings of wild and domesticated pearl millet were recorded at about 3500 B. C. in Dhar Tichitt, a Saharan site in Mauritania (Amblard and Pernes, 1989). Birimi in northern Ghana has laid claim to one of the earliest findings of domesticated pearl millet, dated at about 1459 BC BP (D'Andrea *et al.,* 2001, D'Andrea and Casey, 2002). These archaeobotanical findings in the Sahara and Sahel confirm the hypothesis of original distribution and widespread utilization of wild and cultivated pearl millet across sub-Saharan Africa (Amblard and Pernes, 1989; D'Andrea and Casey, 2002).

However, there is dispute among scholars as to whether pearl millet has a single centre of origin, or more than one place of origin, the so-called "non-centres", which would have resulted from domestication processes occurring independently in several regions. According to this latter hypothesis, the whole Sahel, from Mauritania to western Sudan, was originally covered with these non-centres (Clark, 1962; Portères, 1962; Harlan, 1971; Marchais, 1994; Oumar *et al.,* 2008).

Whether domestication took place as multiple parallel processes in the above mentioned non-centres in several places along the Sahelian distribution belt of the wild progenitors, or at one specific place (Tostain and Marchais, 1993, Oumar *et al.,* 2008), the ultimate centre of origin of the wild progenitors, *P. monodii* and *P. mollissimum*, is most likely to be situated in the Sahara desert (D'Andrea *et al.,* 2001; D'Andrea and Casey, 2002, Khairwal *et al.,* 2007a).

Based on the distribution of pearl millet throughout the continent, the uniform cradle of domestication is likely to be the regions of Mauritania, Senegal and western Mali (Tostain, 1992; Tostain and Marchais, 1993; Rai *et al.,* 1997). Today's cultivated forms developed out of this domestication cradle (Tostain, 1998). Next, these first early-maturing forms of domesticated pearl millet were carried eastwards, facilitated by their efficient adaptation to arid conditions (D'Andrea and Casey, 2002). About 3000 years BC the first translocation carried the crop to eastern Africa (Tostain and Marchais, 1993; Tostain, 1998), and then to India, where 3000-year old carbonized pearl millet was detected at a site on the eastern coast (D'Andrea *et al.,* 2001, Khairwal *et al.,* 2007a).

Another diffusion took place in the region near Lake Chad, more precisely on the Nigerian side (Klee *et al.,* 2004), where a secondary centre of diversity developed at about 2010 years BC (Tostain *et al.,* 1987, Tostain and Marchais, 1993). There, photoperiod-sensitive cultivars were selected which adaptated to the more humid conditions in the southern Sudanian zone (Tostain, 1998; D'Andrea and Casey, 2002). These late-maturing cultivars were transported further towards the Sudanian zone of southwestern Africa, from northern Nigeria to southern Senegal, as evidenced by the above-mentioned findings in northern Ghana (Tostain *et al.,* 1987; Tostain and Marchais, 1993). The third and last major translocation took pearl millet towards the plateaus of southern Africa, across Uganda and towards Namibia, at about 1000 years BC (Tostain and Marchais, 1993; Tostain, 1998).

## 4.5 Pearl millet races

Brunken *et al.,* (1977) scored diverse genepools for a number of floral and grain characteristics and identified grain shape as the most consistent trait, which follows a geographic pattern. Four basic grain shapes were found in the world collection and were used for classification, although not all pearl millet accessions fit neatly in to any of these four basic races.

**Race typhoides**

The race typhoides is characterized by obovate caryopses that are obtuse and terete in the cross-section. Inflorescences are mostly cylindrical in shape. Morphologically it is the

most variable among the four races and is also most widely distributed. It occurs across the entire African continent. It is the only basic race found outside Africa and the predominant race grown in India.

**Race nigritarum**
In this race, caryopsis is angular in cross-section with three and six facets per grain. Inflorescences are candle-like. The apex of the grain is usually truncate and often tinged purple. The mature grain is generally longer and protrudes beyond the floral bracts. This race is generally found in western Sudan to northern Nigeria (Brunken *et al.,* 1977).

**Race globosum**
The caryopsis in this race is spherical with each of its dimensions being approximately equal. Depth of the grain always exceeds 2.4 mm. The grain is otherwise terete and obtuse. Inflorescences are candle shaped and often exceed 1 m in length. It is the most common race in Benin, Ghana, Niger, central Nigeria and Togo (Bono, 1973).

**Race leonis**
The race leonis is characterized by an acute, oblanceolate, terete caryopsis. The most distinct character of the leonis grain is its acute apex, which is terminated by the remnants of the stylar base. At maturity, approximately one-third of the grain protrudes beyond the floral bracts. Inflorescence shape is candle-like. It is specific to Sierra Leone but also grows in Senegal and Mauritania **(**Brunken *et al*., 1977).

# 5. OVERVIEW OF PEARL MILLET COLLECTIONS

## 5.1 Size and composition of pearl millet collections

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has made concerted efforts to obtain the germplasm assembled at different national and international institutes, universities and national agricultural research systems (NARS) and has consolidated the single largest collection of pearl millet in the world. As of now, the global in-trust collections managed by ICRISAT, at Patancheru, India comprise a total of 22211 accessions of which 750 are of wild species (24 species), 19377 are landraces, 132 are improved cultivars, 1943 are breeding/research materials and 25 are others. The geographical origin of pearl millet germplasm assembled at the ICRISAT genebank is provided in Table 1 (Upadhyaya *et al.,* 2007). India contributed a significant number of pearl millet accessions to the global collection maintained at ICRISAT (6,647 accessions). The remaining accessions were collected from about 51 countries. The major donors include: Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM) (2178), Rockefeller Foundation, New Delhi, India (2022) and International Board for Plant Genetic Resources (IBPGR-now Bioversity International), Rome, Italy (974). ICRISAT was also associated with 76 collecting missions in 28 countries and collected 10830 pearl millet accessions. The major diversity centres of pearl millet are considered to be relatively well represented in the collection at ICRISAT.

**Table 1: Geographical distribution of pearl millet germplasm held at the ICRISAT genebank (as of January 2007)**

| Country | No of accessions | | |
|---|---|---|---|
| | Cultivated | Wild | Total |
| **AFRICA** | | | |
| Algeria | 5 | - | 5 |
| Benin | 46 | - | 46 |
| Botswana | 82 | - | 82 |
| Burkina Faso | 862 | 5 | 867 |
| Cameroon | 911 | 85 | 996 |
| Cape Verde Islands | 2 | - | 2 |
| Central African Republic | 142 | 10 | 152 |
| Chad | 98 | 36 | 134 |
| Congo | 8 | - | 8 |
| Ethiopia | 2 | 1 | 3 |
| Gambia | 15 | - | 15 |
| Ghana | 283 | - | 283 |
| Kenya | 98 | 1 | 99 |
| Lesotho | - | 4 | 4 |
| Malawi | 298 | 12 | 310 |
| Maldives | 1 | - | 1 |
| Mali | 1048 | 109 | 1157 |
| Mauritania | 6 | 31 | 37 |
| Morocco | 4 | - | 4 |
| Mozambique | 31 | 2 | 33 |
| Namibia | 1118 | 10 | 1128 |
| Niger | 1130 | 178 | 1308 |
| Nigeria | 2064 | 10 | 2074 |
| Senegal | 393 | 12 | 405 |
| Sierra Leone | 59 | 1 | 60 |
| Somalia | 4 | - | 4 |
| South Africa | 162 | 3 | 165 |
| Sudan | 587 | 27 | 614 |
| Tanzania | 478 | 25 | 503 |
| Togo | 520 | - | 520 |
| Tunisia | 6 | - | 6 |
| Uganda | 118 | 1 | 119 |
| DR Congo | 11 | 3 | 14 |
| Zambia | 155 | 7 | 162 |
| Zimbabwe | 1384 | 13 | 1397 |
| **ASIA** | | | |

| | | | |
|---|---|---|---|
| India | 6502 | 145 | 6647 |
| India-ICRISAT | 1333 | - | 1333 |
| South Korea | 1 | - | 1 |
| Lebanon | 108 | - | 108 |
| Myanmar | 10 | - | 10 |
| Pakistan | 168 | 2 | 170 |
| Russia & CIS | 15 | - | 15 |
| Sri Lanka | - | 2 | 2 |
| Turkey | 2 | - | 2 |
| Yemen | 290 | 3 | 293 |
| **EUROPE** | | | |
| France | 11 | - | 11 |
| Germany | 3 | - | 3 |
| UK | 31 | 1 | 32 |
| **AMERICAS** | | | |
| Brazil | 2 | - | 2 |
| Mexico | 10 | 1 | 11 |
| USA | 219 | 10 | 229 |
| **OCEANIA** | | | |
| Australia | 8 | - | 8 |
| **Grand Total** | **20844** | **750** | **21594** |

In addition to ICRISAT, the Institut de recherche pour le développement (IRD, France) also maintains3968 accessions of pearl millet from 16 countries which include Algeria (11), Benin (221), Burkina Faso (595), Cameroon (149), Central African Republican (62), Côte d'Ivoire (323), Guinea (71), India (40), Kenya (5), Mali (1161), Morocco (4), Mauritania (83), Niger (840), Nigeria (4), Senegal (398) and Zimbabwe (1) (Table 2). These collections were supported by Bioversity International (formally IBPGR) and ORSTOM. These collections are considered duplications of ORSTOM collections which are also maintained at ICRISAT. The Canadian Genetic Resources Programme, Saskatoon, Canada maintains 3821 accessions covering a few species with emphasis on *Pennisetum glaucum* (3390 accessions). Accessions of other species include: *P. violaceum* (221), *P. macrourum* (1), *P. purpureum* (12), *P. orientale* (1), *P. pedicellatum* (11), *P. polystachion* (8), *P. ramosum* (3), *P. unisetum* (1) and other species (14). The collection, all from central African countries, was obtained through an agreement with Bioversity International and Canada that they be conserved as a duplicate collection (with the original at ORSTOM – IDR, France). The number of seeds maintained is moderate for long-term conservation and as safety duplication but not for distribution. The initial viability of these collections was excellent (> 95%). In addition to these global collections, the Agricultural Research Station of the USDA at Griffin, Georgia maintains1314 accessions of which only 1 is a wild relative, 290 are of breeding/research material and 552 are for other purposes. The landrace accessions come from 31 countries which include: Algeria (50), Australia (2), Botswana (1), Brazil (1), Burkina Faso (117),

Cameroon (5), China (3), Egypt (1) Ethiopia (23), Russian Federation (3), Ghana (6), India (321), Kazakhstan (1), Kenya (48), Malawi (1), Mali (3), Morocco (4), Niger (10), Nigeria (183), Oman (3), Pakistan (9), Saudi Arabia (2), Senegal (3), South Africa (22), Sudan (1), Uganda (5), United States of America (70), Yemen (62), Zaire (17), Zambia (1) and Zimbabwe (369).

**Table 2: Total pearl millet accessions and associated information at IRD, France**

| Country | No. of accessions | No. of geo-referenced accessions |
|---|---|---|
| Algeria | 11 | 11 |
| Benin | 221 | 221 |
| Burkina Faso | 595 | 595 |
| Cameroon | 149 | 149 |
| Central African Republic | 62 | 62 |
| Cote-d'Ivoire | 323 | 48 |
| Guinea | 71 | 71 |
| India | 40 | 0 |
| Kenya | 5 | 0 |
| Mali | 1161 | 1147 |
| Morocco | 4 | 0 |
| Mauritania | 83 | 83 |
| Niger | 840 | 840 |
| Nigeria | 4 | 4 |
| Zimbabwe | 1 | 0 |
| Senegal | 398 | 397 |
| **Grand Total** | **3968** | **3628** |

Among the national collections, the largest was recorded from the Indian genebank (National Bureau of Plant Genetic Resources-NBPGR), based at New Delhi, which maintains 8913 accessions of pearl millet under long-term conservation. Most of the accessions are indigenous (8827) with only 168 accessions from other countries. The Indian collection also includes 221 advanced improved varieties and 272 accessions of breeding/research material. About 75% of the Indian accessions are also maintained at ICRISAT (6647 accessions). No other countries in South Asia, except Pakistan (193 accessions), have reported pearl millet collections. Among African countries the collections were reported from genebanks based in Algeria, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Eritrea, Ethiopia, Ghana, Kenya, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Senegal, Sierra Leone, Sudan, DR Congo, Uganda, Zambia and Zimbabwe. Some other countries reported to conserve pearl millet collections are Australia (253), Brazil (52), China (102), Germany (54) and Russian Federation (406) and Lebanon (110). The details of these collections are presented in Table 3 (major collections) and Table 4 (minor collections). In total 56580 pearl millet accessions were recorded from various sources (the grand total of Tables 3 and 4). Landraces represent the largest proportion of pearl millet germplasm

conserved in genebanks worldwide (49973 accessions). Of these only 3% are wild relatives collections (1630), 0.80% are advanced improved varieties (452), 6% are breeding/research materials (3600) and 2% are of unknown description (947). The number of unique samples is lower than the total number of accessions recorded, as many of these are duplicates. For example out of the total ORSTOM collection of 3968, ICRISAT maintains 2178 and Plant Gene Resources of Canada maintains 3390 accessions included in the ORSTOM collections.

### 5.2. Mapping of *Pennisetum* germplasm

Some progress has been made in the recent past in mapping the pearl millet diversity collected worldwide. Global databases show that georeference data have been assigned to 16855 accessions. These collections are being maintained at ICRISAT (13542 accessions), USDA-ARS (472 accessions) and ILRI (13 accessions). With support from Bioversity International 2828 accessions were collected and become part of global collections being maintained by ICRISAT and USDA-ARS. Not much information is available for any of the national collections. It is therefore, important that support and guidelines are provided to assist these countries to georeference their accessions, map their diversity, and identify gaps in their collections. Based on the georeference information from the global database, the distribution pattern of these accessions is shown in Figure 1.

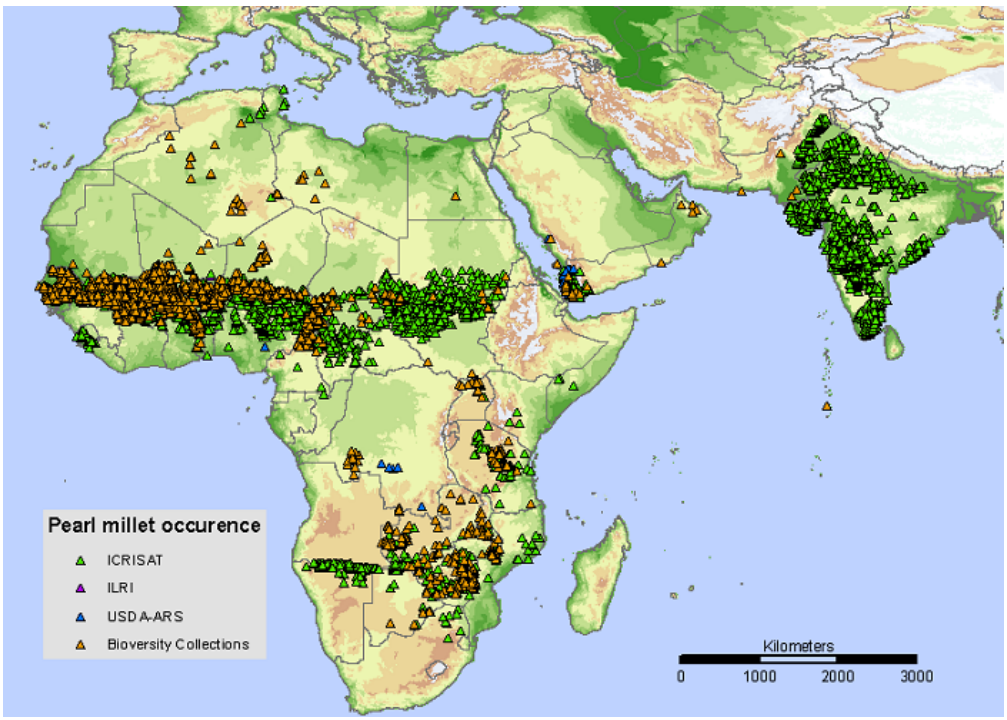


**Figure 1: Mapping of pearl millet accessions based on information available from the global database**

**Table 3: Pearl millet germplasm holdings including accessions originating in the country (indigenous), as well as introduced from other countries (exotic) and their categories (landraces, advanced/improved varieties, breeding and/or research materials)**

| Country | Total No. of accessions | Origin of germplasm | | Landraces | Wild relatives | Advanced/ Improved varieties | Breeding/ Research materials | Others | Source of information |
|---|---|---|---|---|---|---|---|---|---|
| | | Indigenous | Exotic | | | | | | |
| Algeria | 55 | | | 55 | | | | | GENESYS |
| Australia | 253 | 6 | 247 | | | 8 | 142 | 103 | Survey |
| Benin | 221 | | | 221 | | | | | ORSTOM-IRD |
| Botswana | 87 | | | 87 | | | | | GENESYS |
| Brazil | 52 | | | | | | | 52 | Survey |
| Burkina Faso | 993 | | | 993 | | | | | GENESYS |
| Burundi | 21 | | | 21 | | | | | GENESYS |
| Cameroon | 1003 | | | 1003 | | | | | GENESYS |
| Central African Republic | 163 | | | 163 | | | | | GENESYS |
| Chad | 152 | | | 152 | | | | | GENESYS |
| China | 102 | | 102 | 102 | | | | | Survey |
| Cote d'Ivoire | 323 | | | 323 | | | | | ORSTOM-IRD |
| DR Congo | 35 | | | 35 | | | | | GENESYS |
| Eritrea | 200 | 200 | | 200 | | | | | Survey |
| Ethiopia | 82* | | | 82 | | | | | GENESYS |
| Germany | 54 | | | 3 | 25 | | 1 | 25 | SURVEY |
| Ghana | 291 | | | 291 | | | | | GENESYS |
| Guinea | 71 | | | 71 | | | | | ORSTOM-IRD |
| India | 8913 | 8827 | 86 | 8240 | 8 | 221 | 272 | | Survey |
| Kenya | 501 | 455 | 46 | 84 | 392 | | 3 | 22 | Survey |
| Lebanon | 110 | | | 110 | | | | | GENESYS |

| Country | Total No. of accessions | Origin of germplasm | | Landraces | Wild relatives | Advanced/ Improved varieties | Breeding/ Research materials | Others | Source of information |
|---|---|---|---|---|---|---|---|---|---|
| | | Indigenous | Exotic | | | | | | |
| Malawi | 40 | 40 | | 40 | | | | | Survey |
| Mali | 1376 | 293 | - | 1351 | - | 25 | | - | Survey |
| Mauritania | 83 | | | 50 | | | | | ORSTOM-IRD |
| Mozambique | 29 | 29 | | 29 | | | | | Survey |
| Namibia | 1444 | 1441 | | 1441 | 2 | 1 | | | Survey |
| Niger | 2072 | 1408 | 664 | 1148 | | 27 | 897 | | Survey |
| Nigeria | 2138 | | | 2138 | | | | | GENESYS |
| Pakistan | 193 | | | 193 | | | | | GENESYS |
| Russian Federation | 406 | 406 | - | 334 | | 7 | 42 | 23 | Survey |
| Senegal | 336 | | | 500 | 37 | 25 | | | Survey |
| Sierra Leone | 60 | | | 60 | | | | | GENESYS |
| Sudan | 835 | | | 835 | | | | | GENESYS |
| Togo | 42 | 42 | | 42 | | | | | Survey |
| Uganda | 139 | 134 | 5 | 7 | 127 | | 5 | | Survey |
| Zambia | 379 | 379 | | 379 | - | | | | Survey |
| Zimbabwe | 1787 | | | 1787 | | | | | GENESYS |
| **GLOBAL** | | | | | | | | | |
| ICRISAT, India | 22211 | 3953 | 6877 | 19377 | 750 | 132 | 1943 | 9 | Survey |
| IRD, France | 3968 | | 3969 | 3969 | | | | | Survey |
| Plant Gene Resources of Canada | 3821 | | 3821 | 3390 | 272 | 3 | 1 | 155 | Survey |
| USA, Griffin, Georgia | 1314 | | 70 | 471 | 1 | | 290 | 552 | Survey |
| **Total** | **56355** | | | **49777** | **1614** | **449** | **3596** | **941** | |

***: *The figure seems low for Ethiopia. However, despite repeated requests, no information was forthcoming.***

**Table 4: Minor collections of pearl millet germplasm by country, including accessions obtained within the country (indigenous), and those introduced from other countries (exotic) and their categories (landraces, advanced improved varieties, breeding and/ or research materials).**

| Country | Total No. of accessions | Origin of germplasm | | Landraces | Wild relatives | Advanced/ Improved varieties | Breeding/ Research materials | Others | Source of information |
|---|---|---|---|---|---|---|---|---|---|
| | | Indigenous | Exotic | | | | | | |
| Afghanistan | 2 | | | 2 | | | | | GENESYS |
| Bolivia | 2 | | | 2 | | | | | GENESYS |
| Cape Verde | 2 | | | | 2 | | | | GENESYS |
| DR Congo | 8 | | | 8 | | | | | GENESYS |
| Czech Republic | 2 | | | 2 | | | | | GENESYS |
| Democratic Yemen | 10 | | | 10 | | | | | GENESYS |
| Ecuador | 3 | | | 3 | | | | | GENESYS |
| Egypt | 1 | | | 1 | | | | | GENESYS |
| France | 1 | | | 1 | | | | | GENESYS |
| Gambia | 15 | | | 15 | | | | | GENESYS |
| Hungary | 4 | | | 4 | | | | | GENESYS |
| Indonesia | 1 | | | 1 | | | | | GENESYS |
| Islamic Republic of Iran | 2 | | | 2 | | | | | GENESYS |
| Israel | 7 | | | 7 | | | | | GENESYS |
| Italy | 1 | | | 1 | | | | | GENESYS |
| Japan | 15 | | | 15 | | | | | GENESYS |
| Kazakhstan | 1 | | | 1 | | | | | GENESYS |
| Lesotho | 12 | | | 12 | | | | | GENESYS |
| Madagascar | 5 | | | 5 | | | | | GENESYS |
| Maldives | 1 | | | 1 | | | | | GENESYS |
| Mexico | 3 | | | | 3 | | | | Survey |
| Morocco | 17 | | | 17 | | | | | GENESYS |
| Oman | 3 | | | 3 | | | | | GENESYS |
| Peru | 2 | | | 2 | | | | | GENESYS |

| Country | Total No. of accessions | Origin of germplasm | | Landraces | Wild relatives | Advanced/ Improved varieties | Breeding/ Research materials | Others | Source of information |
|---|---|---|---|---|---|---|---|---|---|
| | | Indigenous | Exotic | | | | | | |
| Philippines | 1 | | | 1 | | | | | GENESYS |
| Saudi Arabia | 2 | | | 2 | | | | | GENESYS |
| Slovakia | 2 | | | 2 | | | | | GENESYS |
| Somalia | 4 | | | 4 | | | | | GENESYS |
| South Africa | 11 | 11 | | 11 | | | | | Survey |
| Spain | 4 | | | 4 | | | | | Survey |
| Sri Lanka | 2 | | | | 2 | | | | GENESYS |
| Switzerland | 1 | | | 1 | | | | | GENESYS |
| Tanzania | 20 | 20 | | 15 | 5 | | | | Survey |
| Tunisia | 15 | | | 15 | | | | | GENESYS |
| Ukraine | 4 | | 4 | | 1 | 3 | | | Survey |
| United Arab emirates | 20 | | | 20 | | | | | GENESYS |
| United Kingdom, Aberystwyth | 10 | 10 | | | | | 4 | 6 | Survey |
| United Kingdom, Kew | 3 | 3 | | | 3 | | | | Survey |
| Uruguay | 6 | | | 6 | | | | | Survey |
| **Total** | **225** | | | **196** | **16** | **3** | **4** | **6** | |

**Table 5: *Pennisetum* species accession information as available in GENESYS**

| Sl. No. | Genus/species | Total no. of accessions | Total no. of geo-referenced accessions |
|---|---|---|---|
| 1 | *Pennisetum alopecuroides* | 14 | |
| 2 | *Pennisetum asperifolium* | 1 | |
| 3 | *Pennisetum bambusiforme* | 1 | |
| 4 | *Pennisetum basedowii* | 2 | |
| 5 | *Pennisetum cenchroides* | 5 | 4 |
| 6 | *Pennisetum ciliare* | 867 | 2 |
| 7 | *Pennisetum clandestinum* | 31 | |
| 8 | *Pennisetum compressum* | 1 | |
| 9 | *Pennisetum divisum* | 12 | 6 |
| 10 | *Pennisetum flaccidum* | 11 | 6 |
| 11 | *Pennisetum glaucum* | 22650 | 14044 |
| 12 | *Pennisetum glaucum & stenostachyon* | 1 | |
| 13 | *Pennisetum hohenackeri* | 7 | 5 |
| 14 | *Pennisetum hordeoides* | 2 | 1 |
| 15 | *Pennisetum incomptum* | 1 | |
| 16 | *Pennisetum lanatum* | 2 | |
| 17 | *Pennisetum latifolium* | 1 | |
| 18 | *Pennisetum longissimum* | 1 | |
| 19 | *Pennisetum macrostachys* | 1 | |
| 20 | *Pennisetum macrostachyum* | 1 | |
| 21 | *Pennisetum macrourum* | 8 | 1 |
| 22 | *Pennisetum mezianum* | 11 | 4 |
| 23 | *Pennisetum mollissimum* | 49 | 48 |
| 24 | *Pennisetum orientale* | 49 | 30 |
| 25 | *Pennisetum pedicellatum* | 163 | 136 |
| 26 | *Pennisetum petiolare* | 1 | |
| 27 | *Pennisetum polystachion* | 45 | 16 |
| 28 | *Pennisetum polystachyon* | 88 | 60 |
| 29 | *Pennisetum polystachyum* | 60 | 59 |
| 30 | *Pennisetum purpureum* | 101 | 34 |
| 31 | *Pennisetum purpureum x glauc* | 7 | |
| 32 | *Pennisetum ramosum* | 14 | 12 |
| 33 | *Pennisetum riparium* | 1 | 1 |
| 34 | *Pennisetum schweinfurthii* | 7 | 3 |
| 35 | *Pennisetum setaceum* | 26 | 8 |
| 36 | *Pennisetum setigerum* | 18 | |

| | | | |
|---|---|---|---|
| 37 | *Pennisetum sieberianum* | 7 | 1 |
| 38 | *Pennisetum sieberianum & glaucum* | 1 | |
| 39 | *Pennisetum sp.* | 46 | 32 |
| 40 | *Pennisetum sphacelatum* | 11 | 11 |
| 41 | *Pennisetum spicatum* | 3 | |
| 42 | *Pennisetum squamulatum* | 6 | 3 |
| 43 | *Pennisetum thunbergii* | 5 | 2 |
| 44 | *Pennisetum trachyphyllum* | 9 | 7 |
| 45 | *Pennisetum unisetum* | 6 | 2 |
| 46 | *Pennisetum villosum* | 10 | 1 |
| 47 | *Pennisetum violaceum* | 546 | 341 |
| | **Grand Total** | **24910** | **14880** |

GENESYS is a new global PGR database portal, developed by Bioversity International with financial support from the Trust and ITPGRFA. GENESYS currently provides access to information for 2.5 million germplasm accessions, including information for 24910 accessions belonging to 47 species of the genus *Pennisetum*. Of these accessions, 14880 accessions belonging to 29 *Pennisetum* species have georeference information (Table 5) and hence they can be mapped. Mapping of *Pennisetum* species are shown in Figures from 2 to 4.

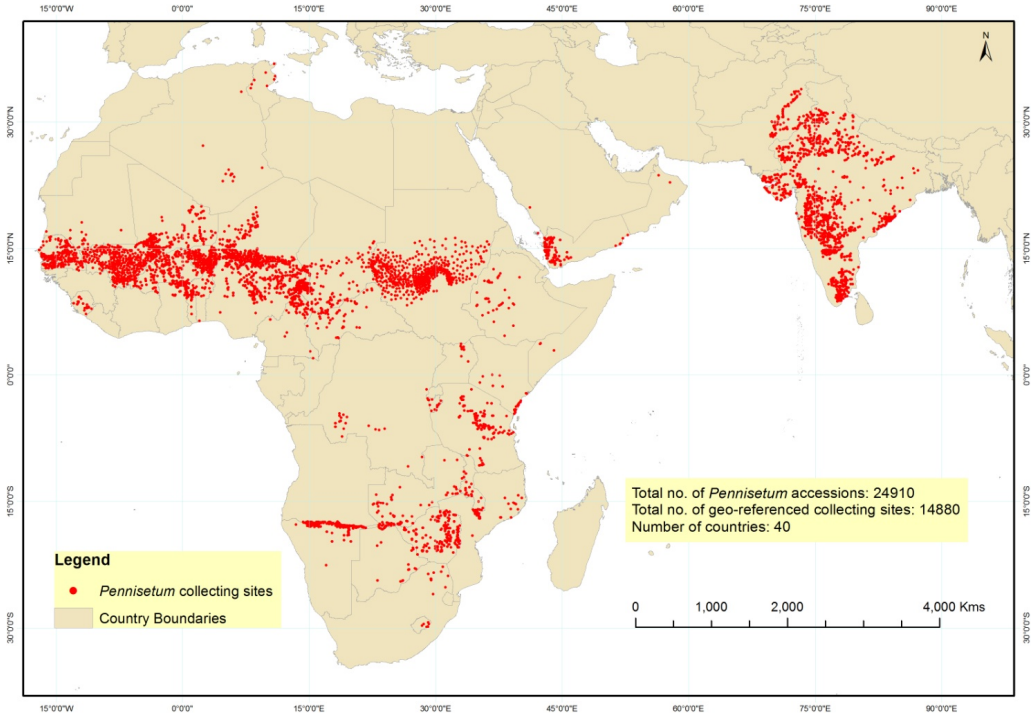


**Figure 2: Mapping of *Pennisetum* accession collecting sites based on information obtained from GENESYS**

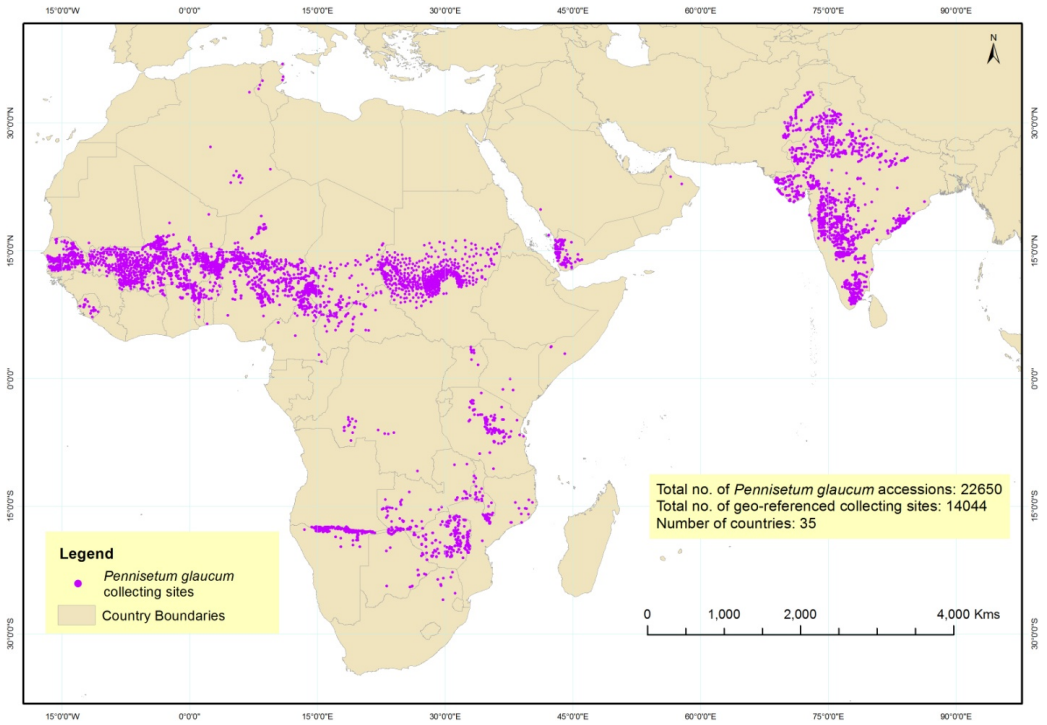


**Figure 3: Mapping of *Pennisetum glaucum* (pearl millet) accession collecting sites based on information obtained from GENESYS**

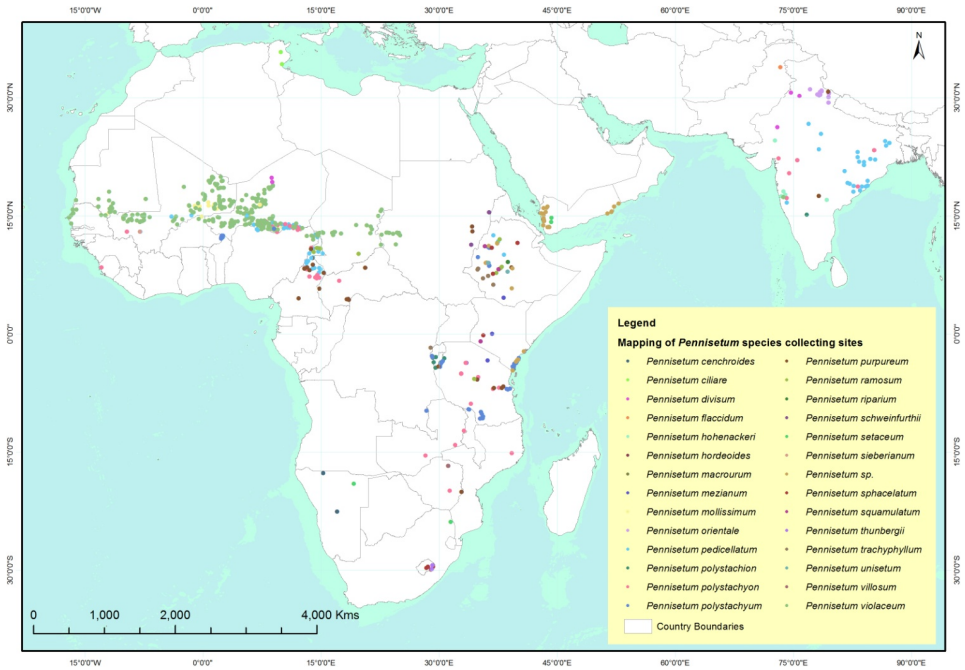


**Figure 4: Mapping of *Pennisetum* species (excluding *Pennisetum glaucum*) accession collecting sites based on information obtained from GENESYS**

The IRD collections also have georeference information for 3628 accessions out of their total collection of 3968 accessions. The details of these data collections by country are listed in Table 2 and mapped in Figure 5.

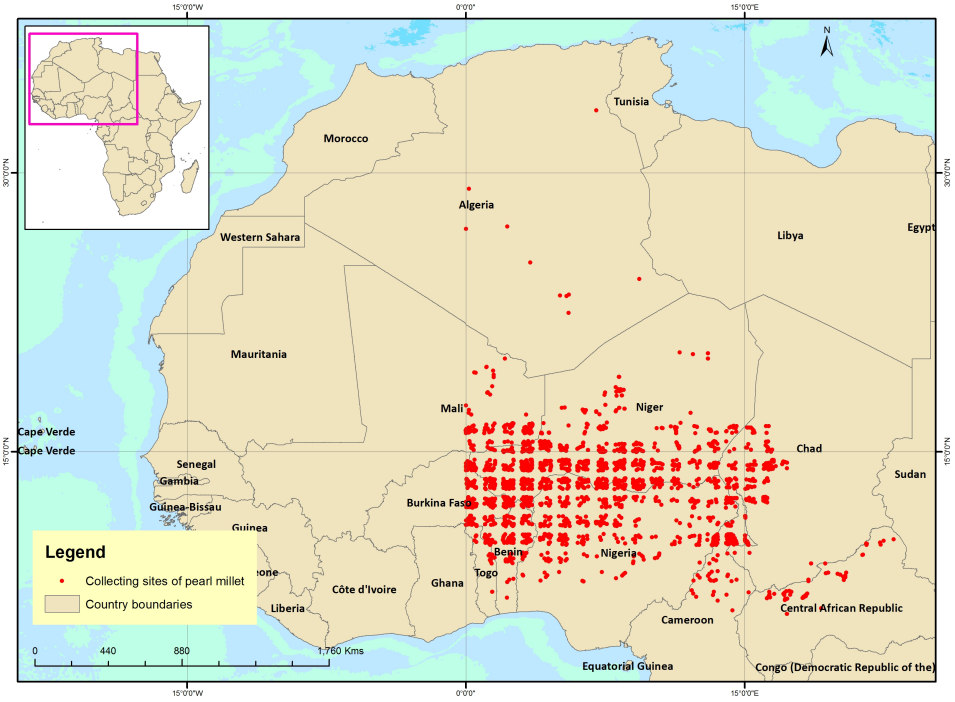


**Figure 5: Mapping of pearl millet germplasm collecting sites based on information available at IRD, France. Georeference information available only for Western and Central Africa (as shown in map inset)**

## 6. STATUS OF CHARACTERIZATION AND EVALUATION

Characterization and evaluation are prerequisites for the efficient utilization of conserved germplasm. From the survey questionnaire it appears that although a modest number of accessions have been assembled and maintained in many countries, systematic characterization and evaluation activities are not sufficient. One reason provided by most genebanks is lack of adequate human and financial resources. Evaluation activities, especially in Africa, have been fewer than hoped.

In the ICRISAT genebank, all cultivated accessions have been characterized and evaluated for 23 morpho-agronomic characters following the descriptors for pearl millet (IBPGR and ICRISAT, 1993). Time to 50% flowering, plant height, panicle length and thickness were recorded during both rainy and post-rainy seasons, whereas number of nodal, productive and total tillers, panicle exsertion, synchrony of panicle maturity, panicle shape, spikelet density, bristle length, grain yield potential, fodder yield potential and overall plant aspect were recorded only during the rainy season. Observations on grain characters such as 1000-seed weight, seed shape, seed colour and endosperm textures were recorded after harvesting during the post-rainy season.

To realize the true potential of the accessions and to facilitate the selection of genotypes by researchers, selected pearl millet germplasm accessions of Indian and African origin were evaluated by the National Bureau of Plant Genetic Resources (NBPGR) for important agronomic characters at different locations (Jhansi and New Delhi) in India in collaboration with ICRISAT and catalogues were published (Mathur *et.al.,* 1993a and 1993b). Considerable phenotypic diversity was observed for almost all the characters. There are accessions in the collection which can flower in as little as 33 days and as much as 159 days in the rainy season. Similarly, plant height ranged from 30 to 490 cm with a mean of 246.2 ± 0 .46 cm. Total tillers varied from 1 to 35 and 1000-seed weight varied from 1.5 to 21.3g. Distribution of qualitative traits indicates occurrence of nine panicle shapes (cylindrical, conical, spindle, club, candle, dumb bell, lanceolate, oblanceolate and globose), five seed shapes (obovate, oblanceolate, elliptical, hexagonal, globular) and ten seed colours (ivory, cream, yellow, grey, dark grey, grey-brown, brown, purple, purplish-black and mixture of white and grey) in the entire collection. Accessions with candle-shaped panicles (11132), short bristled panicles (20004), globular seed shape (5420), grey seed colour (10473) and seeds with partly corneous endosperm texture (13 296) are predominant in the collection maintained at ICRISAT. In the entire collection, only 141 accessions for green fodder yield potential and six accessions for seed yield potential scored 9 (maximum). The phenotypic diversity index (H′) ranged from 0.427 (total tillers in rainy season) to 0.632 (plant height in post rainy season) for quantitative traits. Among qualitative traits, diversity was highest for endosperm texture (H′ = 0.772) and minimum for bristle length (H′ =0.443). Diversity for qualitative traits was higher (H′ = 0.610 ± 0.031) than that for quantitative traits (H′ = 0.573± 0.021). Averaged over all traits, the diversity index was 0.588 ± 0.018 (Upadhyaya *et.al*, 2007). Based on the characterization and evaluation information contained in the database, sources of resistance to biotic and abiotic stresses, adaptation and nutritional qualitative traits have been identified. Status of pearl millet germplasm screening for various biotic and abiotic stresses at ICRISAT is presented in Table 6. IP 4021 and IP 3122 were identified as early maturing accessions, were requested by many countries and were supplied by ICRISAT (>75 times). It was also reported that some of the landraces have wide adaptation, and are therefore very useful in light of the changing climate scenario and for use in crop improvement programmes. The overall range of genetic diversity among cultivated pearl millet varieties and their wild relatives is truly amazing. Extreme types are so different as to appear to be separate species. Much of this diversity is still available in areas of early cultivation in Africa and regions of early introduction in Asia.

**Table 6: Status of pearl millet germplasm screening for various biotic and abiotic stresses at ICRISAT (Upadhyaya *et al.*, 2007)**

| Stress/Trait | No of accessions screened | No of promising accessions identified |
|---|---|---|
| **Cultivated** | | |
| Downy mildew resistance | 3164 | 54 |
| Smut resistance | 1747 | 397 |
| Ergot resistance | 2752 | 283 |
| Rust resistance | 2229 | 332 |
| Drought tolerance | 115 | 7 |
| Salinity resistance | 48 | 32 |
| High seed protein content (>15%) | 1270 | 260 |
| Yellow endosperm | 12 | 2 |
| Sweet stalk | 892 | 16 |
| Male sterility | 17000 | 50 |
| **Wild** | | |
| Downy mildew resistance | 534 | 220 |

Bioversity International, in consultation with various partners, has developed a comprehensive list of descriptors for pearl millet (Bioversity, 2010). This strategic set of descriptors, together with passport data, are an integral part of the information available through the global accession level information portal GENESYS, developed by Bioversity International with the financial support of the Global Crop Diversity Trust. It will facilitate access to and utilization of pearl millet accessions held in genebanks worldwide and does not preclude the addition of further descriptors, should data subsequently become available.

## 7. FORMATION OF CORE SUB-SETS

Developing a core collection that represents the diversity of an entire collection is an efficient approach to enhancing the use of germplasm in crop improvement. Core collections are dynamic and need to be revised when additional germplasm and information become available. The pearl millet [*Pennisetum glaucum* (L.) R. Br.] core collection, consisting of 1600 accessions selected from about 16000 accessions characterized at the ICRISAT genebank up until 1998, was augmented by adding 501 accessions representing 4717 accessions assembled and characterized in the last nine years. The revised core collection consists of 2094 accessions (five duplicate and two sterile male accessions were deleted from the original core collection). A comparison of mean data using the Newman–Keuls test, variance using Levene's test, and distribution using $\chi 2$ test indicated that the variation in the entire collection of 20766 accessions was preserved in the revised core collection. The Shannon-Weaver diversity index for different traits was similar in the revised core and entire collection. The revised core collection was observed to be more valuable than the original core as it has sources of

resistance for important diseases such as downy mildew. Even a core collection of 2094 accessions is large and evaluation and characterization for economic traits can be unfeasible. Hence, a mini-core collection of pearl millet, comprising 238 accessions, was constituted by ICRISAT based on an evaluation of the core collection of 2094 accessions for 18 morpho-agronomic traits. Results indicated that almost the entire genetic variation and a majority of co-adapted gene complexes present in the core-subsets were preserved in the mini-core subsets. Due to its greatly reduced size, the mini-core subset will provide a more economical starting point for proper exploitation of pearl millet genetic resources for crop improvement.

## 8. UTILIZATION

Identification of useful germplasm for crop improvement is the first step in encouraging utilization. From the information obtained through the survey questionnaire it was difficult to obtain a good comparison of utilization activities being carried out in various genebanks, especially in Africa. However, in India, under the National Agriculture System, modest efforts have been undertaken in the last three decades to exploit pearl millet germplasm with useful genes for crop improvement. An evaluation of 2375 germplasm lines, 180 landraces and 504 accessions of core collections of pearl millet for grain and fodder yield and their related traits were carried out and revealed a wide range of diversity for almost all the traits studied (Khairwal *et.al.*, 2007b). Pearl millet germplasm has been widely used in India in developing composites. The *iniadi* germplasm from the Togo-Ghana-Burkina Faso-Benin region of Western Africa is most commonly used in pearl millet breeding programmes worldwide (Andrews and Anand Kumar, 1996).

At ICRISAT, a small seed sample of each accession is available on request to all research workers under the Standard Material Transfer Agreement (SMTA) of the International Treaty. Since 1974, ICRISAT has provided more than 40000 samples to researchers working in different disciplines at ICRISAT, 60000 samples to scientists in India and 30000 samples to 79 other countries (Upadhaya *et.al.*, 2007). Accessions IP 4021 and IP 3122, early maturing accessions, were supplied the most (more than 75 times). To further enhance the utilization of pearl millet germplasm, ICRISAT evaluated sets of selected germplasm accessions at different locations in India and several other countries in Africa, and field days were organized to facilitate the selection of pearl millet germplasm. Trait-specific genepools (early maturing, high tillering, large panicle and large grain) were developed to provide partially conserved genotypes to the breeders. There has been a general lack of interest in using wild species because of the large genetic variability in pearl millet landraces. However, some wild species are very useful in pearl millet improvement programmes, notably *P. glaucum* subsp *monodii* for new source of cytoplasmic-nuclear male sterility (CMS); *P. purpureum* for forage, stiff stalk and restorer genes of the A1 CMS system; *P. orientale* for drought tolerance and forage; *P. schweinfurthii* for large seed; *P. pedicellatum* and *P. polystachion* for downy mildew resistance and *P. squamulatum* for apomictic gene (Rai *et al.,* 1997)..

In general the Indian pearl millet landraces have contributed to earliness, high tillering, high harvest index and local adaptation; whereas African materials have been a good source of high head volume, large seed size and disease resistance. Some examples of germplasm utilization and varieties released are mentioned below (Upadhyaya *et al.,* 1977):

- One of the examples of direct use of landraces is the development of ICTP 8203, a large seeded and high-yielding open-pollinated variety that was bred at ICRISAT by selection within a large seeded *iniadi* landrace from northern Togo. This variety was released as MP 124 in Maharashtra and Andhra Pradesh and as PCB 138 in Punjab states of India. The same variety was released as Okashana 1 in Namibia in 1990 and as Nyankhombo (ICMV 88908) in Malawi in 1996. Direct selection within the same landrace led to the development of a large-seeded and downy mildew resistant male sterile line ICMA 88004, a seed parent of an early maturing hybrid (ICMH 356) released in India in 1993 (Rai *et al.,* 1995).
- Okashana 2, a variety derived from a Zimbabwe local landrace IP 16504 (SDGP 1514) crossed with ICMV 87901 and ICMV 88908 was released in Namibia in 1998 (Obilana *et al.,* 1997).
- IKMP 3, a variety released in Burkina Faso was developed from selection within the landrace IP 11381 (CVP 417) from Burkina Faso.
- IKMP 5, a variety released in Burkina Faso was developed from selection within the landrace IP 11317 (CVP 170) from Burkina Faso.
- An open-pollinated variety CMV-IS 88102, developed from selection within the landrace IP 6426 from Mali, was released in Burkina Faso in 1993 and as Benkadi Nio in Mali in 1994.
- Kangara (SDMV 92040), a variety released in Namibia in 1998, was derived from two landraces IP 17527 and IP 17531 and S2 progenies of SADC white grain composite. The same variety was also released as PMV 3 in Zimbabwe in 1998.
- Donor parents like 863B (IP 22303), P 1449-2 (IP 21168), ICMB 90111 (IP 22319), ICMP 451 (IP 22442), and IP 18293 were identified as sources for the most important gene, i.e., resistance against different pathotypes of downy mildew diseases in India.

## 9. DISTRIBUTION OF *PENNISETUM* SPECIES AND THEIR GAPS IN WORLD COLLECTIONS

A study of the distribution of *Pennisetum* species and of gaps in world collections was undertaken by Bioversity International with support from the Global Crop Diversity Trust and the World Bank, using datasets of herbarium collections, as well as the germplasm collections available from GBIF and SINGER and the climate database available at WorldClim.

Based on the available records, 53 wild species and 2 infra-specific taxa have been identified, accounting for a total of 55 taxa for the genus *Pennisetum*. These different taxa are classified as follows, according to their closeness to the cropped species *P. glaucum,* using the Maxted and Kell (2009) model, as follows:

| Primary wild relatives | Secondary wild relatives | Tertiary wild relatives |
|---|---|---|
| *P. glaucum* cultivars and landraces | *P. purpureum* | All other species in the genus |
| *P. glaucum* subsp. *monodii* | *P. squamulatum* | |
| *P. glaucum* subsp. *stenostachyum* | | |

Species' taxonomy was reviewed using Maxted and Kell (2009) in the first stage, the GRIN taxonomical and the Royal Botanic Gardens, Kew taxonomy database in the second. After crosschecking and correcting both synonyms and orthography of the species' names, a thorough georeferencing process was carried out to obtain a spatially explicit database containing as many records as possible for each species. After this, records outside continental boundaries were deleted and a final dataset was produced for analysis (http://gisweb.ciat.cgiar.org/GapAnalysis/).

The analysis dataset contained 4326 observations, with 3364 (78%) being herbarium specimens and 962 (22%) being genebank accessions. The average number of total samples per taxon was 79 (standard deviation of 163), indicating that available data is not particularly limited, although it is concentrated in certain taxa (i.e. *P. ciliare*, *P. polystachion*, *P. purpureum*, *P. violaceum*, *P. clandestinum, P. villosum*). Other taxa such as *P. domingense*, *P. lanatum* and *P. sieberianum* present a very limited sampling and/or data availability and thus need further characterization and sampling in order to obtain a reliable ecogeographic evaluation.

The gap analysis of the *Pennisetum* genepool showed that there are 47 out of 55 taxa under analysis that are either under-represented or not represented in genebanks and these were therefore flagged as high priority species. Twenty six of these taxa presented only 10 data points (sum of herbarium and germplasm), which indicates that these species in particular need to be further collected. Only species *P. violaceum* was found to be adequately represented in genebanks, while *P. ciliare*, *P. flaccidum*, *P. orientale* and *P. pedicellatum* were found to be relatively under-represented and thus flagged as medium priority species. Based on the analysis, all these species have been identified as high priority for conservation. The outcome of these studies is presented in Figures 6 to 8.

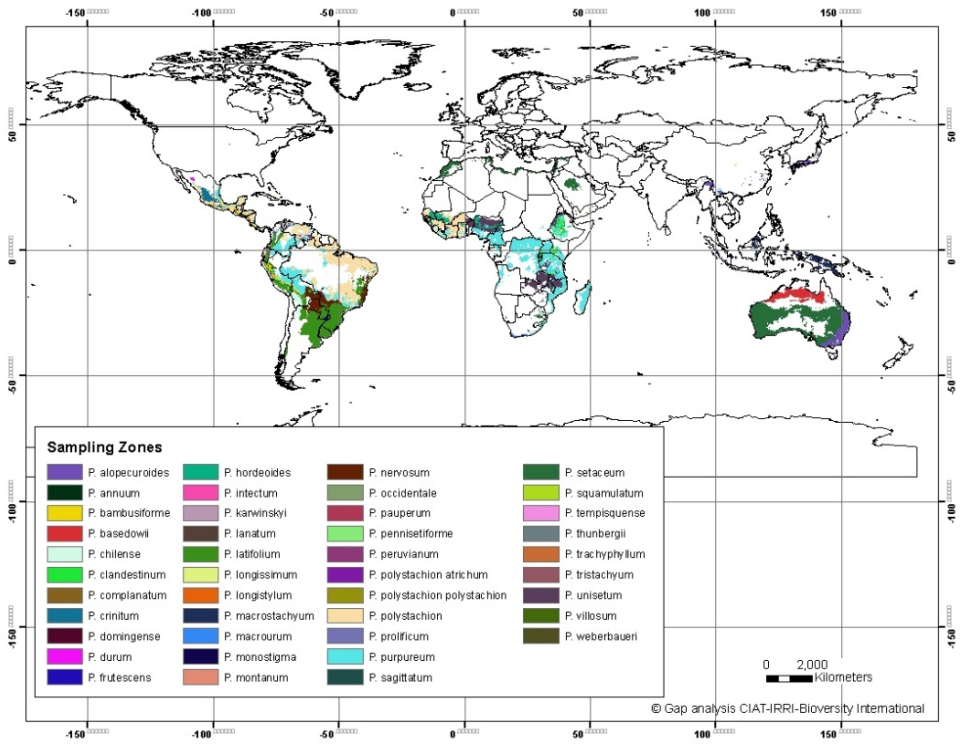


**Figure 6: Potential sampling zones (http://gisweb.ciat.cgiar.org/GapAnalysis/)**

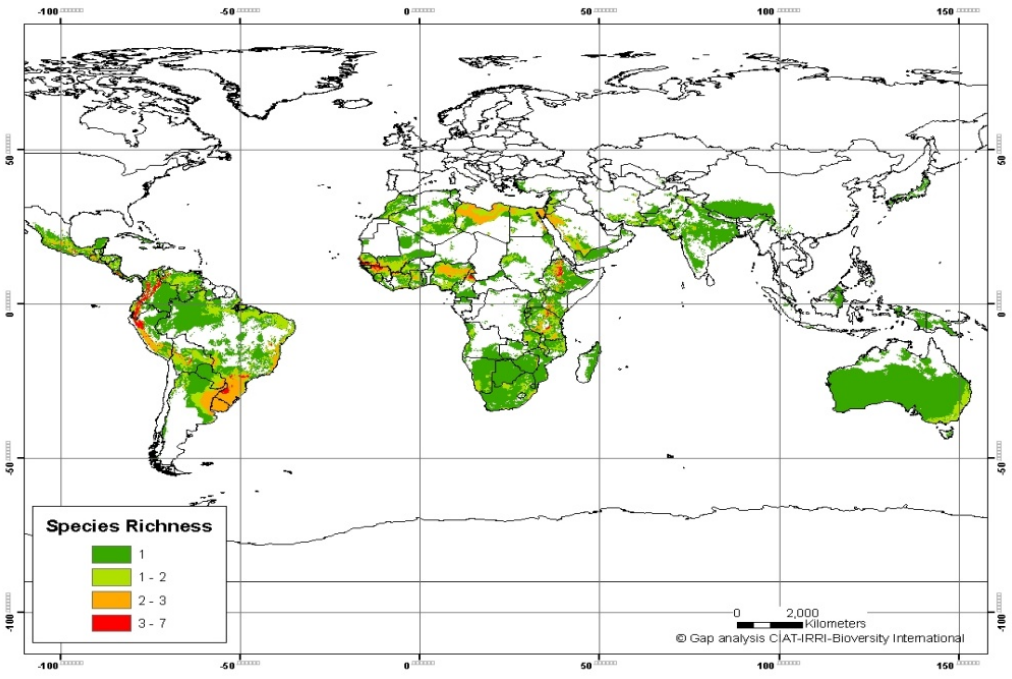


**Figure 7: Potential sampling richness (http://gisweb.ciat.cgiar.org/GapAnalysis/)**

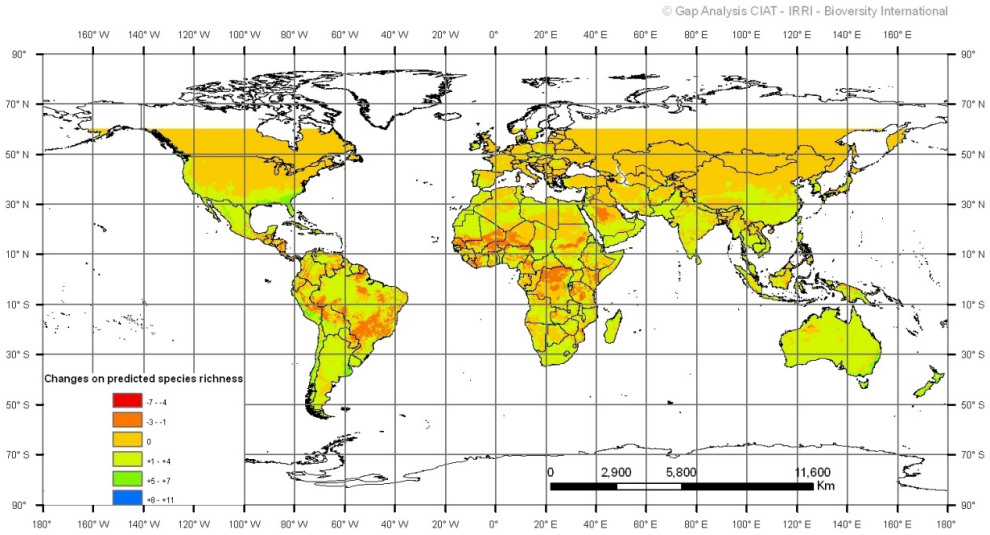


**Figure 8: Predicted species richness under future climatic conditions (http://gisweb.ciat.cgiar.org/GapAnalysis/)**

## 10. SAFETY-DUPLICATION

The situation on safety-duplication varies from collection to collection. Some are safety-duplicated in one or more of the global collections (ICRISAT, IRD-France/ORSTOM, Canadian Genetic Resources Programme and USDA), however, most of the national genebanks are looking into safety-duplicating in different and distinct sites within their own countries. In India, most of the collections are safety-duplicated (medium-term storage) at one of the National Active Germplasm Sites (NAGS) based at Jodhpur, Rajasthan. Most of the Indian collections (about 48 per cent) maintained at NBPGR are also part of the ICRISAT collection as safety-duplicates. In the case of southern African countries, the national collections are safety-duplicated at the Regional South African Development Community (SADC) Plant Genetic Resources Centre (SPGRC) collection in Zambia, and SPGRC is backed up at the Nordic Genebank in Sweden. Most of the ICRISAT collections are also safety-duplicated at their regional genebank at Niamey, Niger (5205 accessions) and also at the Svalbard Global Seed Vault (8050). Many national programmes have indicated that part of their collections are not safety-duplicated. There is an urgent need to support the duplication of these collections before they are lost.

## 11. STORAGE FACILITIES AND CONSERVATION STATUS

The various storage conditions, as well as the purpose of their storage, at various national genebanks, including global collections, are presented in Table 7. From the information obtained from the survey, it has been observed that most of the collections are being maintained as long-term at -18 to -20$^{o}$C. Information for medium-term and short-term conservation has only been received from ICRISAT, Germany, Kenya, Nepal, Switzerland and Russian Federation, Senegal, Uganda and Zambia.

**Table 7: Storage conditions and purpose for conserving pearl millet germplasm**

| Country | Storage conditions | | | Activities |
|---|---|---|---|---|
| | Long-term conservation | | | |
| | Temp ($^{o}$C) | Relative humidity (%) | Packing material | |
| Afghanistan | -20 | 12 | Laminated foil packets | |
| Australia | | | | Acquisition, regeneration, documentation, health of germplasm, distribution, storage and maintenance |
| Canada | -20 | | Aluminium foil envelopes | Acquisition, regeneration, characterization, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication |
| China | -18 | 50 (stored using containers) | Aluminium box | Acquisition, regeneration, characterization, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication |
| Eritrea | -18 to -20 | | Aluminium bags | Acquisition, regeneration, characterization, documentation, distribution, storage and maintenance |
| Germany | -18 | 10 | Aluminium bags, vacuum | Regeneration, characterization, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication |
| India | -18 | | Aluminium foil | Acquisition, regeneration, characterization, documentation, health of germplasm, distribution, storage and maintenance |
| Kenya | -20 | | Aluminium foil | Safe storage, characterization, evaluation, regeneration and utilization in research and production |
| Malawi | -20 | 7.5 | Aluminium foil | Acquisition, regeneration, characterisation, documentation, distribution, storage and maintenance, safety-duplication |
| Mali | -20 | | Aluminium foil | Characterization, storage and maintenance, documentation. The main collections of pearl millet are safety-duplicated at IRD and ICRISAT genebanks |
| Mozambique | -20 | 5 | Aluminium bags | Unknown |
| Namibia | -18 to -20 | | Laminated foil bags and cardboard boxes | Characterization, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication |
| Niger | -18 to -20 | 10 | Laminated foil bags | Characterization, documentation, utilisation, storage and maintenance, safety-duplication |

| | | | | |
|---|---|---|---|---|
| Nigeria | | | | |
| Russian Federation | 4 to 5 | 65 | Laminated aluminium foil bags | Regeneration, characterization, documentation, distribution, safety-duplication |
| Senegal | -18 | 10 | Aluminium bags | Acquisition, regeneration, characterization, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication |
| South Africa | -18 | | Aluminium bags | Safety-duplication |
| Switzerland | | | | |
| Uganda | -20 | | Aluminium foil | Regeneration, characterization, documentation, distribution, safety-duplication, storage and maintenance, utilization in research and development |
| United Kingdom, Aberystwyth | | | | Unknown |
| United Kingdom, Kew | | | | Acquisition, regeneration, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication |
| Uruguay | -20 | | Glass jars | |
| USA, Georgia, Griffin | -18 to 4 | 26 | Glysine lined bags and heat sealed foil bags | Acquisition, regeneration, characterization, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication |
| Zambia | | | | Acquisition, regeneration, characterization, documentation, storage and maintenance |
| Global (ICRISAT) | -20 | | Aluminium foil packets | Regeneration, characterization, documentation, health of germplasm, distribution, storage and maintenance, safety-duplication, strategies to enhance use of conserved germplasm and collaborative evaluation with NARS |

## 12. REGENERATION NEEDS

The regeneration needs for landraces, improved varieties, breeding materials and wild species by individual countries have been presented in Table 8. For landraces, these varied from 1-100% of accessions, whereas the need for regeneration of the wild species samples ranged from 10-100%. While information is not available from most of the national genebanks, it is expected that many collections have high regeneration needs which in some cases may be urgent.

In order to maintain genetic integrity, it is recommended to use seed from the original source, as far as possible. A minimum of 9 g of seeds is required to obtain a plant population of 120 plants for regeneration of a germplasm accession. Because of small seed size, care is required while preparing seed samples. The seed should be treated with a fungicide to control seed-borne fungi. For each accession, prepare one seed packet for planting each row and label the packets with identification number and row number and arrange them according to field layout.

**Table 8: Regeneration status of pearl millet germplasm**

| Country | Total number of accessions | Accessions requiring regeneration (%) | | | |
|---|---|---|---|---|---|
| | | Wild sp. | Landraces | Others (obsolete, advanced/ improved varieties) | Remarks |
| Australia | 253 | | | 13 | |
| Canada | 3662 | 100 | 100 | 100 | |
| China | 102 | | | | No samples need regeneration at the present state of conservation |
| Eritrea | 200 | | 40 | | |
| India | 8190 | | | | No samples need regeneration at the present state of conservation |
| Kenya | 501 | 100 | 80 | 100 | |
| Malawi | 40 | | 30 | | |
| Mali | 538 | | 75 | 75 | |
| Mozambique | 29 | | 100 | | |
| Namibia | 1444 | | | 21 | They are in the process of determining which accessions need to be regenerated |
| Niger | 2072 | | 20 | 100 | |
| Russian Federation | 406 | | 15 | 60 | |
| Senegal | 698 | 100 | 50 | 50 | |

| | | | | | |
|---|---|---|---|---|---|
| South Africa | 11 | | | | No samples need regeneration at the present state of conservation |
| Tanzania | 20 | 100 | 100 | | |
| Togo | 42 | | 42 | | |
| Uganda | 139 | 80 | 80 | 10 | |
| United Kingdom, Kew | 3 | | | | No samples need regeneration at the present state of conservation |
| USA, Griffin, Georgia | 1313 | | 0.5 | 73 | |
| Zambia | 379 | | 50 | | |
| Global (ICRISAT) | 22211 | 10 | 20 | 40 | |

## 13. PEARL MILLET COLLECTIONS: DISTRIBUTION STATUS

The availability of pearl millet accessions from different countries is presented in Table 9. Out of 47 countries responding to the survey only 15 countries indicated their willingness to share their accessions, and the percentage of accessions made available varied from country to country. A small sample of each accession is available on request from ICRISAT genebank to all research workers under the Standard Material Transfer Agreement (SMTA). On an average, ICRISAT supplies approximately 450 samples nationally, 550 regionally and 1780 internationally, per annum.

**Table 9: Pearl millet germplasm available for distribution**

| Country | Total number of accessions | Accessions available for distribution (%) | | |
|---|---|---|---|---|
| | | Wild sp. | Landraces | Others (obsolete, advanced/improved varieties) |
| Australia | 253 | - | - | 100 |
| Canada | 3662 | 100 | 100 | 100 |
| China | 102 | - | 100 | - |
| Germany | 54 | - | 75 | 80 |
| Kenya | 501 | 20 | 80 | 90 |
| Mali | 538 | - | 100 | 100 |
| Namibia | 1444 | - | 100 | - |
| Niger | 2072 | - | 100 | 70 |
| Russian Federation | 406 | - | 0.3 | 90 |
| Senegal | 698 | - | 100 | 95 |
| Tanzania | 20 | 40 | 40 | |
| Uganda | 139 | - | - | 100 |

| | | | | |
|---|---|---|---|---|
| United Kingdom, Kew | 3 | - | 66 | - |
| USA, Georgia, Griffin | 1313 | 100 | 99.5 | 96 |
| Zambia | 379 | - | 50 | - |
| GLOBAL (ICRISAT) | 22211 | 90 | 90 | 90 |

## 14. MAJOR GAPS AND LIMITATION IN THE MANAGEMENT AND USE OF PEARL MILLET GERMPLASM

In order to accurately access the gaps in the genetic diversity held in collections world-wide it is necessary to complete the geo-referencing of all existing accessions and map this against data on the distribution area of pearl millet cultivation and the distribution of its wild species. However, 21 countries (Australia, Canada, China, Eritrea, India, Kenya, Malawi, Mozambique, Namibia, Niger, Senegal, South Africa, Tanzania, Togo, Uganda and Zambia) indicated some gaps in their collections and hence need support for collecting germplasm from identified areas. ICRISAT also indicated gaps in their collections which also require resources and funding support to fill. Major limitations for sustainable *ex situ* conservation have also been identified by many national programmes such as low priority on pearl millet, declining funding for its conservation, lack of trained and experienced staff, lack of facilities for multiplication and regeneration, limited availability of modern technology and tools for germplasm characterization and evaluation. The various factors limiting use of pearl millet germplasm indicated by the partners are: shortage of trained staff on pearl millet breeding, lack of availability of characterisation and evaluation database, low amount of seed availability for distribution, the tendency of breeders to use their own material and lack of interaction with genebank staff. The details of individual country information received for gaps, limitations and factors limiting use are presented in Table 10.

**Table 10: Major gaps in collections, limitations in the management and factors limiting the use of global pearl millet collections**

| Country | Gaps in collection | Major limitation for *ex situ* Conservation | Factors limiting use |
|---|---|---|---|
| Australia | No | Declining funding; low priority on pearl millet as it is not a widely utilized germplasm set | The driver for use is an applied breeding programme, or established industry for new cultivar development. There is a very small pearl millet industry in Australia, but no active breeding programme that is utilizing material from the collection. This limits use of the collection by community gardeners and generally by academic researchers, who do not use a large number of accessions. |
| Canada | No | Regeneration – too little heat and short growing days; crop is not important to Canada – no breeding; no interest to provide funds to support any conservation of crop from government, out crossing is an issue; not as easy to regenerate. | No one knows we have it. Amount to distribute – small amount and increasing concern about viability. |
| China | Yes | Not specified | Scarce number of seeds. |
| Eritrea | Yes | Lack of training; limited experience; lack of facilities for accession multiplication and regeneration; lack of relevant genebank equipment and modern technologies for germplasm characterization. | |
| Germany | No | Inadequate funds | No field cultivation possible under German environmental conditions. |
| India | Yes | Characterization and evaluation; incomplete availability of information in electronic format; trait-specific accessions to be identified; lack of feedback. | Characterization and evaluation; incomplete information in electronic form; trait-specific accessions to be identified. |
| Kenya | Yes | Germination protocols for some wild relatives, staff and funding levels. | Majority of accessions are yet to be characterized and/or evaluated; limited information on the available germplasm; and limited attention given to pearl millet research. |
| Malawi | Yes | Lack financial support to maintain and promote | Limited knowledge on importance of pearl millet (it |

| Country | Gaps in collection | Major limitation for *ex situ* Conservation | Factors limiting use |
|---|---|---|---|
| | | underutilized pearl millet collection; limited knowledge available to users of pearl millet collection; limited capacity in terms of human resources and equipment; pearl millet classed as an underutilized crop in Malawi; not a priority crop. | is an underutilized cereal in Malawi). |
| Mali | Yes | Lack of funds to establish appropriate national genebank and community genebanks closely linked with breeders. Despite the recent contribution of the Trust for collecting and characterization, no funding strategy has been established which could be used periodically for collecting and characterization activities. | Limited knowledge on importance of pearl millet in Mali. The yields of improved varieties are not much higher than those of landraces. Insufficient number of community genebanks. |
| Mozambique | Yes | Low amount of seeds stored at the genebank; most pearl millet germplasm is affected by the birds in the field. | Low amount of seeds stored at the NPGRC<br>Very few collections targeting pearl millet has been covered by the NPGRC so far. |
| Namibia | Yes | Characterization is no up-to-date due to lack of resources; viability testing is behind; possibility that traditional varieties are already contaminated with modern varieties. | Namibian collection perhaps not viewed as valuable by breeders; collection not evaluated; plans need to be made to go to remote villages previously not collected from to fill gaps in collection. |
| Niger | Yes | Genebank activities (characterization, regeneration, documentation and conservation) are not funded by government or by other regional or international agencies; most of the important germplasm has not been collected despite continued biotopes degradation. | Breeding programmes are weak and not funded and still use traditional methods; the most important part of the germplasm has been collected and partly included in former breeding programmes; farmers are not aware of the germplasm availability and in general cannot obtain it due to of lack of knowledge and means. |
| Russian Federation | No | Staff; regeneration; financial support. | Insufficient quantity seeds of some accessions. |
| Senegal | Yes | Lack of funds to buy the necessary equipment; lack of a normal cool room; lack of funds for characterization; lack of funds for collecting missions; lack of funds to equip the cool room | Characterization has not been carried out; documentation is not available online. |

| Country | Gaps in collection | Major limitation for *ex situ* Conservation | Factors limiting use |
|---|---|---|---|
| South Africa | No | Not widely used by farming communities and not a major crop requested by breeders for further development. | |
| Tanzania | Yes | Frequent power cuts. | |
| Togo | Yes | Lack of cold storage room and no plant breeder to keep track of things. | Not many people are aware of our collections; Breeders have a tendency to keep their own materials as source of genes for breeding. |
| Uganda | Yes | Limited knowledge on the germination protocols of wild relatives, inadequate funds to further the characterization and evaluation of the germplasm, No information on the key adaptive traits. | Low awareness among the potential users |
| United Kingdom, Aberystwyth | No | Not specified | There are research lines which are still actively being used and so may not be available for general distribution. |
| United Kingdom, Kew | No | Not specified | Not known yet |
| USA, Georgia, Griffin | Yes | Insufficient land and labour for regeneration; lack of disease control during regeneration. | |
| Zambia | Yes | Inadequate and irregular financial resources for regeneration and characterization of the collection; Inadequate storage space for the collection in the genebank; limited facilities for germination testing and other seed management; inability to retain staff. | Lack of evaluation data; limitation on media for information dissemination about the collection |
| GLOBAL (ICRISAT) | Yes | Inadequate funds; lack of experienced personnel; insufficient manpower. | Lack of knowledge/data on the collection for useful traits; limited agronomic evaluation and molecular characterization to explore traits for utilization. |

## 15. DOCUMENTATION STATUS OF PEARL MILLET COLLECTIONS

Table 11 summarizes information on the status of collections regarding passport, characterization and evaluation data held in electronic format. Passport information is computerized in most of the collections. However, availability of electronic characterization/evaluation data is lower. Many countries have indicated that these data are freely available on request. The countries are maintaining information in different platforms such as MS Access, MS excel, SQL server 2005, Oracle9i, visual basic and front end designing, and GRIN. The collections of SADC member countries are being documented using SADC documentation and information systems and are also available through the SPGRC website.

At ICRISAT, computerization of data started in 1980 using the ICRISAT Data Management and Retrieval System (IDMRS) software developed at ICRISAT. Then, System 1032 was used and now is maintained using MS Access for faster and more efficient data management. Databases include: passport, characterization, inventory and distribution. Passport and some characterization databases can be accessed through GENESYS. Germplasm catalogues were prepared using multi-locational evaluation data in India jointly by NBPGR and ICRISAT (Mathur *et al.,* 1993a and b).

**Table 11: Documentation of pearl millet germplasm**

| Country | Passport data | Characterization data | Evaluation data |
|---|---|---|---|
| Australia | YES | YES | YES |
| Canada | YES | NO | NO |
| China | YES | YES | YES |
| Eritrea | YES | YES | NO |
| Germany | YES | YES | NO |
| India | YES | YES | YES |
| Kenya | YES | Partly | NO |
| Malawi | YES | YES | NO |
| Mali | Yes | Yes | Yes |
| Mozambique | YES | NO | NO |
| Namibia | YES | YES | NO |
| Niger | NO | YES | YES |
| Russian Federation | YES | YES | YES |
| Senegal | YES | NO | NO |
| Tanzania | YES | NO | NO |
| Ukraine | YES | YES | NO |
| United Kingdom | YES | NO | NO |
| USA | YES | YES | YES |
| Zambia | YES | YES | NO |
| GLOBAL (ICRISAT) | YES | YES | YES |

The following databases were also searched to gather information for pearl millet and the respective contact details:

1. **GENESYS (**http://genesys-pgr.org/)
2. **SINGER (**http://singer.cgiar.org/)
3. **EURISCO (**http://eurisco.ecpgr.org/)
4. **FAO-WIEWS (**http://apps3.fao.org/wiews/wiews.jsp?i_l=EN**)**

# 16. BRIEF OVERVIEW OF PEARL MILLET GERMPLASM CONSERVATION BY COUNTRY

## 16.1 Country Collections

**Australia**

Australia is responsible for maintaining a collection of 253 accessions. The safety-duplicates are maintained by ICRISAT for long-term conservation. The importance of pearl millet for use and breeding includes selected breeding programmes which have been evaluated for agronomic productivity across multiple sites and which could be used to potentially establish a pearl millet industry in Australia. Normal regeneration interval to maintain the viability of the pearl millet collection is 10-20 years. Testing for seed germination and viability is most commonly carried out using the International Seed Testing Association (ISTA) seed testing procedures. The health testing is however satisfied when all imported seeds clear quarantine with disease-free status. The software used for maintaining the collection is the SQL Server with Visual Basic Front End. The users are updated through the web based AusPGRIS germplasm information system, mails and web portals.

**China**

China is one of the major East Asian countries to maintain a pearl millet collection. No gaps have been identified so far and no studies are being pursued on the collection as resources are very limited. Seeds are stored under long-term conservation and medium-term storage conditions and are used for breeding programmes. The crop is important for forage use only. Normal regeneration interval to maintain the viability of the pearl millet collection is 30 years. Users are informed about the collection through the internet.

**Ethiopia**

Several requests were made to national PGR programmes; however, no response was received. The Head of Ethiopia's PGR programme was also invited to the global consultation meeting which was organized on 22-23 December 2011 in New Delhi, India but no representative from Ethiopia participated in the meeting. Hence the information provided in this report is based on a literature survey and the information obtained from available databases.

**Eritrea**
The National Agricultural Research Institute maintains a total of 200 accessions of pearl millet for long-term and short-term conservation. The wild species have not yet been conserved, which has been one of the major gaps identified. No accessions from long-term storage are regenerated. The active collection was stored in ambient temperature before 2006 and as a result requires regeneration. ISTA methods are used for germination testing. Viability testing is carried out for accessions maintained under short-term storage conditions and requires regeneration. The software used for maintaining the collection is Microsoft Access with visual basic interface. The potential users are informed about the collections through access to the database, meetings and workshops.

**Germany**
The Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) maintains 54 accessions of pearl millet. No gaps have been identified so far as it is not a priority crop of Western Europe and no breeding potential has so far been discovered. Seeds are maintained for long-term conservation. The safety-duplicates are, however, maintained by the Svalbard Global Seed Vault (SGSV) for long-term conservation under special regulation. Normal regeneration interval to maintain the viability of the pearl millet collection is 20-30 years. Germination tests are carried out regularly. The software used for maintaining the collection is an Oracle programme database. Potential users are informed about the collections through the internet.

**India**
NBPGR maintains a germplasm holding of 8913 accessions. Seeds are maintained under different storage facilities such as long- and medium-term. The importance of pearl millet for use and breeding includes a few breeding lines which have been identified for traits such as early maturity, high grain yield, tolerance to downy mildew, presence of long and large number of spikes. NBPGR maintains six different species in its collection which has also been identified as one of the unique features of the collection. Germination tests are carried out monthly but monitored on a yearly basis. The health testing is, however, processed yearly. The software used for maintaining the collection is the MS Access/Excel.net. The utilization of germplasm is enhanced by SINGER. The users are informed about the collection through field demonstrations and participation in AICRP Workshops.

**Kenya**
Kenya Agricultural Research Institute, National Genebank of Kenya maintains a total of 501 accessions. The indigenous collection includes accessions from Rift Valley (188), eastern Kenya (132), coastal Kenya (93), western Kenya (22), central Kenya (10), Nyanza, Nairobi (4) and the exotic collection includes accessions from India (10), USA (9), Australia (7), Italy (7), Pakistan (6), Zimbabwe (4) and Egypt (3). Incomplete ecological representation of the species is one of the major gaps identified. Seeds are maintained for long-term and medium-term conservation. The germplasm is monitored for viability and possible recommendation for regeneration every ten years. This activity is behind schedule. The materials are yet to be duplicated for safe storage in another

genebank. The software used for maintaining the collection is MS Access. Part of the data (on storage, germination, distribution) is maintained in electronic format.

**Malawi**

There are 40 accessions of pearl millet maintained at the Plant Genetic Resource Centre of Malawi, which ensures the availability of a wide diversity of pearl millet for breeding and other research programmes. Geographical, species and population level gaps in the collection need to be identified and appropriately filled by conducting collection missions, and proposals need to be developed for funding to participate in joint programmes with other major users. Seeds are maintained under long-term storage conditions at the SADC genebank (air tight bottles) and are further duplicated at the Nordic Gene Bank under black-box storage. However, the most interesting aspect of the collection is the ease of productivity; pearl millet is drought resistant, rich in nutrients and many food products could be developed from the crop. The importance of pearl millet for use and breeding includes the availability of broadly diverse germplasm. Normal regeneration interval to maintain the viability of the pearl millet collection is ten years. ISTA rules and procedures are used to test germination and viability could be tested periodically every five years. The health testing is however done by monitoring seed-borne diseases during the growing period, harvesting and germination. The software used for maintaining the collection is the SPGRC Documentation and Information System. The utilization of germplasm is enhanced by SPGRC regional network which ensures the long-term conservation of crop germplasm in the SADC region. The collections are updated through brochures, field days, agricultural fairs and workshops.

**Mali**

There are 1376 pearl millet accessions available in Mali where 1351 landraces and 25 advanced improved varieties are being conserved. Most of these accessions are safety-duplicated at ICRISAT India or IRD France. Local improved varieties, such as Toroniou C1, M9D3, etc. have been developed from the collected accessions. Diversity field and seed fairs undertaken with Bioversity International, FAO and International Fund for Agricultural Development (IFAD) contributed pearl millet landraces and improved varieties for utilization. One of the major constraints has been how to undertake new collecting and characterization of pearl millet. The consultation organized by the Global Crop Diversity Trust in Bamako, Mali in February 2011 with breeders and curators, NGOs etc., provided an excellent opportunity to the country to initiate new projects on pearl millet, sorghum, cowpea and yam. Eighty accessions were collected through the pearl millet project and the characterization activities will soon be completed. Furthermore, the Trust provided funding to support the purchase of sealers, freezers, aluminium foil, computers, in addition to a scanner to conserve and manage a pearl millet database. Through a Trust funded training project established with the Unit of Forestry Seed based in Sikasso, staff from Unité des Ressources Génétiques (URG), Mali received training on some parameters of seed testing (specific purity, moisture content and germination testing) and data management. All these activities supported by the Trust allow URG to correctly implement conservation and sustainable use of pearl millet and other crop accessions. In Mali, the main difficulty is the lack of a proper genebank

building, so the aim is to set up a national genebank and community genebanks in Bamako and in regions where climate change effects are more relevant.

**Mozambique**

The National Plant Genetic Resources Center (NPGRC) maintains 29 accessions of pearl millet. Collecting missions are also conducted in the country where indigenous knowledge has been recorded. So far, very few collecting missions have been conducted specifically targeting pearl millet in Mozambique and the major challenge is to undertake those missions in the target provinces as long as the funds are available. Seeds are maintained under long- and short-term storage conditions for active and safe basic collections. The NPGRC has not yet conducted any multiplication, regeneration and characterization activities on the pearl millet collections held by the genebank and the amount of seed conserved limits its wider distribution outside the country. According to information provided by the farmers, some local varieties have been identified with a few specific traits (e.g. drought tolerant, good taste and bird resistant, etc.); this is, the most interesting aspect of the pearl millet collection. Importance of pearl millet for use and breeding includes the consideration of germplasm as raw material for national breeding programmes and also for basic research projects. Normal regeneration interval to maintain the viability of the pearl millet collection is five years. Germination, viability and health testing is undertaken by the National Seed Services Department. The software used for maintaining the collection is the SDIS Software (SADC Documentation and Information System). The utilization of germplasm is enhanced by the SADC (Southern African Development Community) Plant Genetic resources centre SPGRC regional network which ensures the conservation and utilization of plant germplasm to enhance regional food security and economic security. The potential users are informed about the collections through the website of Instituto de Investigação Agrária de Moçambique IIAM, planning meetings and international conferences.

**Namibia**

The National Plant Genetic Resources Centre, under the National Botanical Research Institute (NBRI), Ministry of Agriculture, Water and Forestry, maintains 1444 accessions of pearl millet, which is a staple crop for 60% of the Namibian population. However, plans need to be made to visit those remote villages which have not been visited previously for the collection of accessions to fill possible gaps in the collection. Seeds are maintained at the SADC Plant Genetic Resources Centre (SPGRC) for long-term base collections and safety-duplicates are maintained at Svalbard for long-term conservation. The main objectives of the pearl millet collection are food security, so that farmers can secure traditional varieties, and ensuring that a comprehensive range of genetic diversity is maintained and conserved for use. Importance of pearl millet for use and breeding includes the presence of multicolored spikes, different seed shapes in each spike, drought tolerance and long bristles, making them bird tolerant. Viability testing has only recently started. The software used for documenting the collection is the SDIS Software (SADC Documentation and Information System). The utilization of germplasm is enhanced by the SPGRC regional network which ensures the conservation and utilization of plant germplasm to enhance regional food security. The potential users are informed about the collections through ITPGRFA letters posted on the website.

**Niger**
Institut National de la Recherche Agronomique du Niger (INRAN) is responsible for maintaining 2072 accessions of pearl millet collections. 1175 accessions are maintained for medium-term conservation and 897 accessions are maintained as breeders' working collection. The safety-duplicates are maintained long-term at ICRISAT Sadore, Niger under black-box storage. The most unique feature of the pearl millet collection is the collection of some 200 accessions of landraces collected during 1990s, which also includes improved varieties, and was used by the farmers and the local seed producers. Normal regeneration interval to maintain the viability of the pearl millet collection is ten years because of energy power irregularity. Germination tests are carried out by replicating 50 seeds twice for a sample of 40-50 accessions of the collections. Germination paper is used instead of sterilized sand. The tests are carried out in the dry season when the use of an incubator is not required. The potential users are informed about the collections through annual reports for INRAN, State of the World PGR reports, national CBD reports and through participation in various conferences.

**Russian Federation**
N.I. Vavilov Research Institute of Plant Industry (VIR), St. Petersburg maintains 406 accessions of pearl millet and no gaps have so far been identified in the collection. Seeds are stored under long-, medium- and short-term storage conditions. Twenty-four accessions were introduced in 1929-1939 and 102 accessions in 1955-1970. The importance of pearl millet for use and breeding includes early maturity, high grain yield, high green matter yield, high crude protein content, drought resistance, tolerance to high salinity. Normal regeneration interval to maintain the viability of the pearl millet collection is 10-15 years. Germination and viability tests are carried out by soaking the seeds in water at $20^0$C for a day, after which the seeds are placed in wet paper for 4-10 days respectively. The software used for maintaining the collection is the Paradox 9. The potential users are informed about the collections through publications in journals.

**Senegal**
Institut Sénégalais de Recherches Agricoles (ISRA) maintains 336 accessions of long-term and working collections. The major gaps identified included the need for further collecting, multiplication, duplication, characterization and documentation, and steps are being taken to fill these gaps, but the main problem is lack of funding. The safety-duplicates of these seeds are maintained by ICRISAT. Due to poor conservation, many wild types have been lost. Normal regeneration interval to maintain the viability of the collection is 5-10 years. Germination tests are carried out by replicating 50 seeds twice for a sample of 40-50 accessions of the collections. Germination paper is used instead of sterilized sand. The tests are carried out in the dry season when the use of incubator is not required. The potential users are informed about the collections through regional, national and international collaboration.

**South Africa**
The National Plant Genetic Resources Centre (NPGRC) maintains a total of 11 accessions. No gaps have been identified yet. Seeds are maintained for long-term conservation. The safety-duplicates are maintained by the SPGRC for back-up collection.

Normal regeneration interval to maintain the viability of the pearl millet collection is 5-10 years. Germination and viability tests are carried out regularly by the Official Seed Testing Station of the Department of Agriculture, Forestry and Fisheries. Purity analysis is performed following ISTA guidelines. The software used for maintaining the collection is SDIS.

**Tanzania**
Pearl millet is one of the traditional, main food crops which is endemic to dry areas of Tanzania. Seeds are maintained for long-, medium- and short-term conservation for future use and breeding purposes. The safety-duplicates are maintained at the SADC Plant Genetic Resource Centre for long-term storage in deep freezers. Germination tests are carried out prior to collection from farmers and before distributing to users. Viability testing is done every five years of storage and if the viability is less than 70% regeneration is carried out. The software used for maintaining the collection is the SDIS Software. The potential users are informed about the collections through workshops and participation in on-farm conservation.

**Togo**
Institut Togolais de Recherche Agronomique (ITRA) maintains a total of 42 accessions. The gaps identified are due to many accessions having been lost from the genebank because the cold room was broken. To fill these gaps a survey needs to be carried out to prospect and collect the lost accessions. Regeneration of accessions is done every year to ensure safety of remaining accessions, because of unavailability of a cold room.

**Uganda**
The Plant Genetic Resources Centre, National Agricultural Research Organisation (NARO) maintains total of 139 accessions of which 86% are of national origin. There are some major gaps in Uganda which need to be filled such as Uganda's diversity not being well represented in the genebank. More germplasm collection has to be undertaken from eastern and northern Uganda. There is an urgent need regenerate and characterize the material in the genebank. Preliminary evaluation, working collaboratively with breeders, needs to be undertaken. The germination protocols for most of the wild species are not yet fully developed. Seeds are maintained for long- and medium-term conservation. Normal regeneration interval to maintain the viability of the pearl millet collection is five years for the active collection and ten-year intervals for the base collection. Seeds are disinfected with 98% ethanol. Top of paper method is used for seed germination. Before registration and processing for storage, seed cleaning is compulsory to eliminate debris, diseased, infected, broken and alien species. During germination, seed observation is undertaken to ensure that it is not mouldy or rotten. If 50% of the seed is mouldy, the sample is identified for regeneration and if completely rotten, it is discarded and comments recorded.

**United Kingdom**
The Institute of Biological, Environmental and Rural Sciences (IBERS), Aberystwyth University, is responsible for holding ten accessions of pearl millet collections which basically comprise research lines which are possibly unique. No gaps have been

identified so far. Seeds are stored under medium-term storage conditions. Normal regeneration activities to maintain the viability of the pearl millet collection are carried out as required. The software used for maintaining the collection is MS Access. Data on the pearl millet collection is also updated in the EURISCO database. The potential users are informed about the collections through the internet.

**Ukraine**
The Institute of Plant Production (IPP) maintains four accessions of a long-term working collection. Steps are being taken to fill the gaps that have been identified that would allow the introduction of pearl millet diversity from a collaborating genebank and other institutions. Seeds are maintained under long- and short-term storage conditions. The safety-duplicates are maintained long-term at the Russian genebank and are fully integrated in the host collection. The collection is too small to be unique however; the samples collected have various morphological traits. Normal regeneration interval to maintain the viability of the collection is 15 years for long-term conservation and three years for non regulated conditions. State Standard Methods are used for germination and viability testing. Health testing is done visually. The software used for maintaining the collection is MS Access. Data on the pearl millet collection is also updated in the EURISCO database. Potential users are informed about the collections through the internet, scientific articles, reports and various conferences.

**Zambia**
The Zambia Agricultural Research Institute is responsible for holding a collection of 379 accessions. Availability of accessions that are drought tolerant would enable the development or improvement of pearl millet varieties for marginal agro-ecological regions. However, there are plans for a detailed eco-geographic survey for the identification of specific gaps and efforts are being made to fill these gaps. Seeds are maintained long-term for the active collections. Safety-duplicates are maintained at the SADC Plant Genetic Resource Centre for long-term conservation and are fully integrated in the host collection. The most unique feature of the pearl millet collection is the wide maturity period including early maturity germplasm accessions, bristle spike accessions for resistance to bird damage and the diversity of grain colour, as it will influence use. Normal regeneration interval to maintain the viability of the pearl millet collection is ten years. A germination threshold of 85% is used as a determining factor for undertaking regeneration of germplasm accessions. The software used for maintaining the collection is the SDIS Software. Potential users are informed about the collections through field and open days, and also through annual and technical reports.

## 16.2 Global Collections

**ICRISAT**
ICRISAT aims to serve as a world repository for germplasm, holding 22211 accessions. However, geographical, eco-regional and diversity gaps need to be identified and further investigation needs to be pursued to fill these gaps. Seeds are maintained under different storage facilities like long-, medium- and short-term conservation, and are also stored at the Svalbard Global Seed Vault, Norway and at the ICRISAT Regional Genebank,

Niamey, Niger. The importance of pearl millet for use and breeding includes sources of resistance for major biotic and abiotic stresses, and for nutritional traits. ICRISAT is responsible for enhancing the use and collection in plant breeding through core and mini-core approach and identification of trait-specific germplasm. Normal regeneration interval to maintain the viability of the pearl millet collection is 8-10 years for active collections and 15-20 years for base collections. Top of paper method is a popular test for the germination and viability testing. The health testing is done by visual examination and blotter test, and agar plate method is used to identify seed-borne fungi. The software used for maintaining the collection is the SQL Server 2005. The utilization of germplasm is enhanced by SINGER. The users are informed about the collection through publications, field days, workshops and databases.

**PGRC, Canada**

Plant Gene Resources of Canada (PGRC), is Canada's national genebank with a mandate to conserve, preserve and enhance utilization of 3821 accessions of pearl millet. The collection came to Canada as part of an agreement between Agriculture and Agri-Food Canada (AAFC) and the International Board of Plant Genetic Resources (now Bioversity International) in 1980. The seeds are maintained under long-term secure storage conditions. Most accessions are duplicated, but the total numbers do not match with those at IRD-France and hence there may be some unique material or they may have lost some useful material which is still maintained in the genebanks. The importance of pearl millet for use and breeding includes considerable geographical diversity, but no characterization or evaluation has been conducted. Regeneration cannot be carried out under most Canadian conditions (attempted at Saskatoon but failed) due to lack of heat units, possible day length sensitivity issues, short growing season and genetic erosion for the collection in-house. As it is not a high priority crop for Canada, not all detailed passport data is computerized, therefore the exact collection data needs to be completed. Users are informed about the availability of pearl millet through the GRIN-CA database.

**USDA, USA**

The United States Department of Agriculture, National Plant Germplasm System maintains 1313 accessions of pearl millet germplasm for long-term conservation and provides the material freely for research purposes. Seeds are maintained under long-term storage facilities at Fort Collins and also at Svalbard Global Seed Vault. The germplasm has been collected from a diverse array of countries which indicates substantial genetic diversity is available from the collection. Normal regeneration interval to maintain the viability of the collection varies depending on the viability testing results, number of seeds in storage and the age of seeds. Regenerated and newly acquired accessions are tested prior to storage. Specific conditions are required for the distribution of pearl millet accession materials protected by Intellectual Property Rights, which are distributed according to specific agreement on an accession by accession basis. Potential users are informed about the pearl millet accessions through the internet, emails, letters and telephone correspondence.

## 17. CONCLUSION AND RECOMMENDATIONS

From the survey carried out and the information gathered from literature and databases, it has been concluded that there are approximately 56580 pearl millet accessions across various genebanks at the global level. Four genebanks, namely (1) ICRISAT, India; (2) IRD, France; (3) Canadian Genetic Resources Programme, Canada; and (4) USDA, USA are responsible for maintaining international collections and also as safety-duplication. The total global collections reported are 31314 accessions which is 55% of the total accessions. At the national level, NBPGR, New Delhi, India has the largest collection, followed by Burkina Faso, Cameroon, Ghana, Kenya, Mali, Namibia, Niger, Nigeria, Senegal, Sudan, Zambia and Zimbabwe. The total number of accessions reported from these 13 countries is 22068, which is 42% of the total collection and 87% of the national collections. India's national collection represents 32% of the total national collections. It appears that most of the national collections are safety-duplicated at one of the four global collections. However, there is a need to validate the status of safety-duplication of all the national collections.

Some countries have indicated gaps in their collections; therefore, systematic efforts are needed to document these gaps and provide support for collecting on a priority basis. The main reason for lack of pearl millet utilization is the poor quantity and quality of the characterization and evaluation data available both for quantitative as well as qualitative traits. Only a fraction of the available germplasm is being used in crop improvement programmes for pearl millet worldwide. Therefore, the economic value and usefulness of the large amounts of conserved germplasm in almost all genebanks is still to be assessed. This activity needs to be strengthened as a priority and should receive attention in all genebanks/countries. Genebanks with a modest number of collections should be encouraged to form core sub-sets and this would lead to more efficient management of the collections, as well as their utilization. Regular monitoring of collections, especially for seed viability and vigour, is of utmost importance to prevent erosion of accessions in the genebank.

Accessions requiring urgent regeneration are a big issue. The collections needing immediate support for regeneration include those of: Eritrea, Kenya, Malawi, Mozambique, Niger, Senegal, Tanzania, Togo, Uganda and Zambia. The Canadian Genetic Resources programme, which is maintaining sets of the global collections, also needs funding support for regeneration of their collections, as the local climate is not suitable for the regeneration of pearl millet. Hence they are seeking a partner who can take up this responsibility.

Since most of the collections have not been evaluated for most of the important biotic and abiotic traits, especially in the context of climate adaptation, there is need for systematic evaluation of most of the national collections for such traits, and such information needs to be made available to national crop improvement scientists for their use. If possible, a regional or global database should be promoted.

In order to discuss the draft strategy prepared, based on the information received through surveys and also from published literature and databases, a consultation workshop was

organised on 22 December 2011, aimed at agreeing upon final recommendations for sustainable management and use of pearl millet germplasm. A total of 20 participants representing India, Mali, Senegal, Uganda and Kenya took part in this consultation workshop. For more details see Appendix 3. The workshop agenda is presented as Appendix 4.

During the morning session of the workshop Dr. P.N. Mathur, South Asia Coordinator, Bioversity International, gave a detailed presentation on the background and details of work for the *ex situ* conservation of pearl millets and their wild relatives. The participants then had a detailed discussion on the general topics of conservation of pearl millets and compared the country-specific strategies and measures that are being followed.

The afternoon session of the workshop was reserved for group discussion and the participants were divided into two groups including an even mix of representatives from both Asia in Africa in each group. After an intensive discussion pertaining to the detailed list of topics, each group made a short presentation of their findings and their proposed strategies. The group participants were composed as follows:

Group 1:

1. Dr. H.D. Upadhyaya, India: Group Chairperson
2. Dr. Chrispus Oduori, Kenya
3. Mr. Ousmane Sy, Senegal
4. Dr. Nelson Wanyera, Uganda
5. Dr. JyotiKumari, India
6. Dr. C.TaraSatyavathi, India
7. Dr. Nidhi Verma, India

Group 2:

1. Dr. A Seetharam, India: Group Chairperson
2. Dr. R. K. Tyagi, India
3. Dr. M Dutta, India
4. Dr. Amadou Sidibe, Mali
5. Dr. Desterio Ondieki Nyamongo, Kenya
6. Dr. M.V.C. Gowda, India
7. Dr. K.C. Bhatt, India
8. Dr. Sushil Pandey, India

Based on the presentations and discussions during the workshop, the groups arrived at the following recommendations:

**1. Review of data on various collections**

The representatives went over the existing records and, based on their knowledge of the current status in their respective countries, they updated the records for their respective countries. They also recommend the following:

- More collections with emphasis on wild relatives should be made from East, West and Central African countries (e.g. DR Congo, Gambia, Morocco and Tanzania);

- Biological status of the material should be defined wherever sizable collections exist and their storage condition should also be mentioned.

**2. Consider the proposed criteria for a reference collection**

Based on the size of collections, diversity and uniqueness, genebanks can be designated as reference collection centres. However, this status should be awarded subject to the condition that they have appropriate and standard storage/conservation facilities.

**3. Identify other significant collections**

The following organizations and countries were identified as having significant collections:

- NBPGR, India
- ICRISAT, India
- IRD/ ORSTOM, France
- Nigeria
- Togo
- Mali
- Cameroon
- Namibia
- Niger
- Zimbabwe
- Kenya

**4. Potential partners for conservation services**

The following organizations and the key persons in those organizations were identified as potential partners for conservation services:

- Dr. Hari Upadhyaya, ICRISAT, India
- Mr. Ousmane Sy, Senegal
- Director, NBPGR, India
- ILRI, India
- CIRA
- All India Coordinated Programme on Pearl Millet and IARI, India
- Dr. Wanyera, NaSARI, Uganda
- Dr. Desterio Nyamongo, Kenya Agriculture Research Institute, Kenya

**5. Gaps in collections**

- Wild relatives (secondary and tertiary genepools) from Asia (regions to be identified) and Central and West Africa have identified gaps in collection;
- Several African countries as identified by Upadhyaya *et.al*. (2010), western Rajasthan, India and areas adjoining in Pakistan have identified gaps in collections.

**6. Current status of Information Systems**

- Adoption of the GRIN-Global and GENESYS databases at the global level will enhance database management and information access;
- Capacity building for database development in African countries is required;
- Germplasm Information System needs to be strengthened in India and with NARS partners;
- Sharing of information on germplasm should be in compliance with a country's National Policy;
- Awareness among the national partners on the importance of Information Management System and their sharing mechanism is necessary.

**7. Safety-duplicates**

- All the unique collections should be kept as safety-duplicates and the countries which have the capability to create safety-duplicate facilities should be encouraged to do so. Countries without this capability, but still possessing significant genebanks, should develop a system for conserving the unique accessions as safety-duplicates where possible, like the regional genebanks, the CGIAR Genebanks and the Svalbard Genebank, as and when feasible;
- Designated ICRISAT accessions should be duplicated at the Svalbard International Seed Vault;
- Senegal germplasm has already been duplicated at ICRISAT;
- To improve the situation, the exchange of passport data must be encouraged and the agreed guidelines adhered to.

**8. Policy and Technical impediments**

- Countries that are not keen to exchange germplasm present significant impediments;
- The cost involved in the regeneration and distribution of the material;
- Lack of infrastructure e.g. cold stores especially in the national systems;
- Uncharacterized material in genebanks;
- Harmonization of national policy in compliance with ITPGRFA for enhanced sharing. Countries should take the initiative to designate and multiply their germplasm in sufficient quantity to share it as per the ITPGRFA provisions;
- The countries lacking well evolved quarantine and phytosanitary facilities should be supported to put a system in place through capacity building and infrastructure development.

**9. Cooperative Programmes**

The following have been identified as significant networks or international organizations that already exist:

- All India Coordinated Programme on Pearl Millet;
- ASARECA - Association for Strengthening Agricultural Research in Eastern and Central Africa;
- SAFGRAD - Semi-Arid Foodgrains Research and Development;

- INTSORMIL - International Sorghum and Millets.

To enhance the cooperative programmes, the following points have also been identified:

- Strengthening networks by encouraging regional collaborative projects and mutual respect;
- South-South collaboration between India and Africa using climate analogues can be a significant programme for future development of conservation;
- Effective networks like NBPGR-AICRP on Pearl Millet and ICRISAT should be further strengthened and replicated in other countries or regions. Civil society organizations are also quite effective for on-farm conservation and participatory research. They can be effectively utilized in PGR programmes;
- Cooperative programmes are also needed for the biochemical evaluation of different quality parameters.

**10. Effectiveness of links to users (breeders/farmers)**

The weaknesses in the path of effective links are:

- Inadequate stocks and lack of evaluation of accessions at genebanks;
- Poor information flow between genebanks and users like trait availability and lack of users' feedback.

The solutions that can be implemented to address the weaknesses are:

- Generation of reliable information on accessions, characterization and evaluation;
- Publication of information;
- Enhanced interaction between genetic resources professionals and users through field days and hosting of demonstration plots;
- Strong linkage between genebanks and crop based institutes. Genebanks should be involved in characterization and detailed/advanced evaluation should be carried out by the breeders;
- Development of core sets and elite germplasm sets (EGS) should be developed for wider scope of use by breeders
- Pre-breeding activity should be strengthened;
- Participatory *in situ – ex situ* genebank management (including characterization) through farmers' participation and creation and strengthening of community genebanks is required.

**11. Training needs (capacity building)**

The capacity building needs have been identified as:

- Conservation and quarantine (including seed technological aspects), bio-systematics, pre-breeding, advanced evaluation;
- Regeneration systems (especially in cross-pollinated crops like pearl millet), genebank management;
- Characterization;
- Evaluation;
- Documentation;
- Database management;

- Socio-economics in conservation;
- Adequate funding at both national and international levels;
- Data analysis;
- Bioversity International should play a proactive role in organizing these capacity building programmes.

## 12. Key steps and strategy

The following key steps and strategies have been proposed for effective conservation:

- Identifying unique collections and accessions;
- Assisting endangered collections and regeneration to preferred international standards;
- Identifying germplasm collection subsets for extensive evaluation to identify trait-specific accessions for traits of economic importance to enhance germplasm utilization;
- Free exchange of germplasm and associated information;
- Capacity building for germplasm management;
- Greater focus placed on the nutritional traits and nutraceutical traits of pearl millet;
- Grain and fodder quality should be evaluated;
- Trait-specific evaluation for drought, salinity, blast, *Striga* and high temperature tolerance;
- Malting, brewing and popping qualities should be noted;
- Development of harmonized policy guidelines on PGR management;
- Structured PGR programmes taking all aspects into account and accordingly identifying the institutional mechanisms;
- Strengthening the institutions through capacity building and infrastructure development for nutritional security and climate change scenario issues.

Once a strategy for conserving the pearl millet genepool has been published and made available, efforts needs to be stepped up to implement it. The strategy outlined here is not seen as static and final, but needs to be kept under regular review and revised as new data and information become available.

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# APPENDIX 1: SURVEY QUESTIONNAIRE

**Survey Questionnaire:**
**Pearl Millet Conservation Strategy Survey – August 2010**

## 1. Background

The Global Crop Diversity Trust is undertaking a series of studies to support the development of international collaborative conservation strategies for different crops. As such strategies evolve; they will provide a basis for the allocation of resources from the Trust to the most important and needy collections with the specific goal of supporting the costs of conserving national and international crop diversity collections over the long time.

This questionnaire has been developed in order to seek the advice and input of representatives of the world's major pearl millet collections in the development of the pearl millet conservation strategy. In particular the questionnaire aims to assess the status of pearl millet conservation throughout the world. As the strategy document is intended to be made available publicly, results of the survey could be included and therefore published.

As curator of a key pearl millet collection, we kindly request you to complete the sections 1-17 of the questionnaire. We estimate that this procedure may take approximately 1 hour of your time. We appreciate your patience. If there are no *ex situ* pearl millet collections in your institute, please can you complete sections 16-17 only. **Please return the questionnaire no later than Friday 27 August 2010 to:**

**The South Asia Coordinator**
**Dr. Prem Narain Mathur**
Bioversity International, Sub-regional Office for
South Asia
NASC Complex
Pusa Campus, New Delhi 110012, India
Tel: +91-11-25849000/01 Fax: +91-11-25849002
Email: p.mathur@cgiar.org

The Global Crop Diversity Trust is keen to have your active participation in the development of the pearl millet conservation strategy and will be pleased to keep your informed on its progress. If you have any questions about this questionnaire or about the proposed strategy in general, please contact Dr. Prem Narain Mathur.

## 2. Information about your organization

| **2.1 Name and address of your organisation holding/maintaining the pearl millet collection** | | | |
|---|---|---|---|
| Name: | | | |
| Address: | | | |
| City: | | Postal code: | |
| Country: | | | |
| Web site: | | | |
| **2.2 Curator in charge of the pearl millet collection** | | | |
| Name: | | | |
| Address: | | | |
| City: | | Postal code: | |
| Telephone: | | Fax: | |
| Email: | | | |
| **2.3 Contact details of respondent to this questionnaire** (only if he/she is not the curator of the pearl millet collection) | | | |
| Name: | | | |
| Address: | | | |
| City: | | Postal code: | |
| Telephone: | | Fax: | |
| Email: | | | |

## 3. Additional key contacts for the pearl millet germplasm collection in your country

| **Name(s)** | **Title(s)/Function(s)** | **Email/Address** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

## 4. Description of your organization

### 4.1 Please describe your own organization

1 Governmental organization
University
1 Private organization
Other (please specify): _____

**4.2 Is the institution in charge of the pearl millet collection the legal owner of the collection?**

1 YES 1 NO

**4.3 Is the pearl millet collection subject to the terms and conditions of the International Treaty on Plant genetic Resources for Food and Agriculture?**

1 YES 1 NO

**4.3.1 If NO, is expected to become under the International Treaty in the near future?**1 YES 1 NO

4.3.1.1 If YES, indicate expected date: _____

**5. Overview of your pearl millet collection**

**5.1 Please describe the main objectives of the pearl millet collection** (long-term conservation, working collection, breeding collection etc.):

| |
|---|
| |
| |
| |
| |

**5.2 Indicate the species and the respective number of accessions from the pearl millet germplasm types that are included in your collection** [Please write the number of accessions in brackets after each species name, e. G. *P.Glaucum* (30), etc.]**:**

| **Type of pearl millet germplasm** | **Species name and number of accessions per species (in brackets)** |
|---|---|
| Wild related species of pearl millet | |
| Landraces | |
| Obsolete improved varieties | |
| Advanced improved varieties | |
| Breeding/research materials | |
| Inter-specific derivatives | |
| Unknown | |
| Other | |

**5.3 Please indicate the share (in %) from each specific type of germplasm that is AVAILABLE for distribution:**

| **Type of pearl millet germplasm** (where known) | **% available for germplasm** |
|---|---|

| | |
|---|---|
| Wild related species of pearl millet | |
| Landraces | |
| Obsolete improved varieties | |
| Advanced improved varieties | |
| Breeding/research materials | |
| Inter-specific derivatives | |
| Unknown | |
| Other | |

**5.4 Origin of the pearl millet collection: please indicate the proportion (%) of accessions on the total amount that were...** *(Note: the sum should be 100 %!)*

| **Origin** | **Proportion %** |
|---|---|
| Collected originally in your own country (national origin) | |
| Collected originally in your own country (regional origin) | |
| Introduced from a collection aboard | |
| From other origin (please define the origin): | |

**5.5 Please indicate the following about storage, moisture content/ and area under cultivation in the pearl millet management:**

| **Type of pearl millet germplasm** | **Duration of storage (years)** | **Moisture content at harvest (%)** | **Moisture content at storage (%)** | **Germination at storage (%)** | **Area under cultivation and average production (kg/hectares)** |
|---|---|---|---|---|---|
| Wild related species of pearl millet | | | | | |
| Landraces | | | | | |
| Obsolete improved varieties | | | | | |
| Advanced improved varieties | | | | | |
| Breeding/research materials | | | | | |
| Inter-specific derivatives | | | | | |
| Unknown | | | | | |
| Other, please specify | | | | | |

**5.6 Are there major gaps in your pearl millet collection?** Please indicate major gaps concerning your pearl millet collection:

Species coverage of the crop: 1 YES 1 NO
Population (sample) representation per species: 1 YES 1 NO

Ecological representation of the species: 1 YES 1 NO
Other, please specify the gap concerning your pearl millet collection:

5.5.1 If there are major gaps, please provide details on the plans to fill these gaps:

| |
|---|
| |
| |
| |
| |

**6. Aspects on the potential of the pearl millet**

**6.1 What would you consider to be the most interesting aspects of your pearl millet collection, making it unique?**

| |
|---|
| |
| |
| |
| |

**6.2 Please describe the main potential/importance of your pearl millet collection for use and breeding:**

| |
|---|
| |
| |
| |
| |

**7. Conservation status (germplasm management)**

| **7.1 Please indicate the proportion (in %) of the pearl millet accessions maintained under different facilities:** *(Note: if the same accessions are maintained under more than one storage condition the sum may exceed 100%)* | **Percentage %** |
|---|---|
| Short-term storage conditions | |
| Medium-term storage conditions | |
| Long-term storage conditions | |
| Other, please specify: | |

| **7.2 Please indicate the proportion (in %) of the Pearl millet accessions conserved as***☹Note: if the same accessions are stored as different types of germplasm the sum may exceed 100%)* | **Percentage %** |
|---|---|
| Seeds | |

| | |
|---|---|
| Field accessions | |
| *In vitro* | |
| Cryopreservation | |
| Pollen | |
| DNA | |
| Other, please specify: | |

**7.3 Please describe the MAIN storage facility available for your pearl millet collection:** *(If you have **more than one** facility, please use the fields for‘ 'additional facilitiees' too)*

| | **Main Facility 1** | **Additional facility 1** | **Additional facility 2** |
|---|---|---|---|
| Type of facility | | | |
| Temperature | | | |
| Relative humidity (%) | | | |
| Packing material | | | |
| Other, please specify: | | | |

| | **Additional Facility 3** | **Additional facility 4** | **Additional facility 5** |
|---|---|---|---|
| Type of facility | | | |
| Temperature | | | |
| Relative humidity (%) | | | |
| Packing material | | | |
| Other, please specify: | | | |

**7.4 Please mark for which activity you have established a genebank management system and/or have written procedures and protocols:**

1 Acquisition (*including collecting, introduction and exchange*)
Regeneration
1 Characterisation
1 Storage and maintenance
Documentation
1 Health of germplasm
Distribution
1 Safety-duplication
1 Other please specify: _____

**7.5 In case you have procedures and protocols, are you able to provide the Global Crop Diversity Trust with this information (i.e. provide a copy)?**

1 YES 1 NO have procedures but not documented

**7.6 Please describe your quality control activities, in terms of frequency, protocols/methods and actions upon results:**

| **Activities** | **Description of quality control** |
|---|---|
| Germination tests: | |
| Viability testing: | |
| Health testing: | |
| True-to-typeness of *in vitro* plantlets: | |
| Other, please specify: | |

**7.7 Is the pearl millet collection affected by diseases that can restrict the distribution of the germplasm?** 1YES 1 NO

7.7.1 If you indicated YES or slightly above, are knowledge and facilities available at your institution for eradication of these diseases?
1 YES 1 NO 1 Limited

**7.8 What is the normal regeneration interval to maintain the viability of the pearl millet collection?**

| |
|---|
| |
| |
| |
| |

**7.9 Indicate the proportion (%) of each germplasm type that requires urgent regeneration.**

| **Type of pearl millet germplasm** | **% available of pearl millet accessions with urgent regeneration need** |
|---|---|
| Wild related species of pearl millet | |
| Landraces | |
| Obsolete improved varieties | |
| Advanced improved varieties | |
| Breeding/research materials | |
| Inter-specific derivatives | |
| Unknown | |

| | |
|---|---|
| Other | |

**7.10 Please indicate the current situation of the pearl millet collection with respect to the following conditions:** (*where: 1 = high/good, 2 = adequate/moderate, 3 = not sufficient/bad, NA = not applicable*)**.**

| **Type of pearl millet germplasm** | **Current situation** | **Expected situation in 2012** |
|---|---|---|
| Funding for routine operations and maintenance | | |
| Retention of trained staff | | |
| Interest for Plant Genetic Resource Conservation by donors | | |
| Genetic variability in the collection as needed by users/breeders | | |
| Access to germplasm information (passport, charact., evaluation) | | |
| Active support/feedback by users | | |
| Level of use by breeders | | |
| Other factors (please specify): | | |

## 8. Safety duplications in other institutions

*(Safety duplication: defined as the storage of a duplicate/copy of an accession in another location for safety back-up in case of loss of the original accession.)*

**8.1 Are pearl millet accessions safety-duplicated in another genebank?**

1 YES 1 NO

8.1.1 If YES, please specify in the table (and add lines as necessary):

| **Name of institute maintaining your safety duplicates:** | **Number of accessions** | **Storage conditions (short, medium, long term)** | **Nature of the storage (e.g. black box, fully integrated in host collection, etc.)** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

## 9. Institutions storing safety duplicates of pearl millet in your genebank

**9.1 Is there any pearl millet germplasm of other collections safety-duplicated at your facilities?**1 YES 1 NO

9.1.1 If YES, please specify in the table (and add lines as necessary):

| **Name of institute maintaining your safety duplicates:** | **Number of accessions** | **Storage conditions (short, medium, long term)** | **Nature of the storage (e.g. black box, fully integrated in host collection, etc.)** |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |

## 10. Further issues on duplication of pearl millet collection

**10.1 To what extent do you consider the pearl millet accessions in your collection to be unique and not duplicated extensively elsewhere (i.e. EXCLUDING safety-duplication)?**

1 Fully unique
Mostly unique
1 Partially unique
1 Fully duplicated elsewhere

**10.2 Are there any constraints to duplicating the pearl millet collection elsewhere outside your country?** 1 YES 1 NO

10.2.1 If YES, please specify:_____

## 11. Information management

**11.1 Do you use an electronic information system for managing the pearl millet collection (data related to storage, germination, distribution, etc.)?**

1 YES 1 Partly 1 NO

11.1.1 If YES, what software is used? _____

**11.2 Please indicate the proportion (%) of the following types of data is: (1) documented and (2) the proportion that is available electronically:**

| Type of pearl millet germplasm | Passport data | | Characterization data | | Evaluation data | |
|---|---|---|---|---|---|---|
| | **Doc.** | **Electr.** | **Doc.** | **Electr.** | **Doc.** | **Electr.** |
| Wild related species | % | % | % | % | % | % |
| Landraces | % | % | % | % | % | % |
| Obsolete improved varieties | % | % | % | % | % | % |
| Advanced improved varieties | % | % | % | % | % | % |
| Breeding/research materials | % | % | % | % | % | % |
| Inter-specific derivatives | % | % | % | % | % | % |
| Unknown | % | % | % | % | % | % |
| Other, specify: | % | % | % | % | % | % |

**11.3 In case the information on the pearl millet collection is not computerised, are there plans to do so in the future?**

1 No plans
1 Computerisation planned within 3 years
1 Other

**11.4 Is information of the pearl millet collection accessible through the Internet?** 1 YES 1 Partly 1 NO
If YES, please indicate the address of the website: http://_____

**11.4.1 If there is NO data available in the internet, is an electronic catalogue distributed on CD or by Email?**1 YES 1 NO

11.4.1.1 If YES, would you be able to provide the Trust with a copy? 1 YES 1 NO

**If YES, please send a copy to Dr Prem Mathur (**p.mathur@cgiar.org**) when returning the completed questionnaire.**

**11.4.2 If there is NO data available electronically do you produce a printed catalogue?** 1 YES 1 NO

**If YES, please send a copy to Dr Prem Mathur (**p.mathur@cgiar.org**) when returning the completed questionnaire.**

**11.5 Are data of the pearl millet collection included in other databases?**
National 1 YES 1 partly 1 NO

Regional 1 YES 1 partly 1 NO

International 1 YES 1 partly 1 NO

**11.5.1 If YES or partly, indicate the database** (e.g. GRIN, SINGER, EURISCO etc.):
_____

**12. Distribution and use of material**

**12.1 What proportion (%) of the total pearl millet collection is AVAILABLE for the following distributions?**

Nationally: _____% Regionally: _____% Internationally: _____%

**12.2 Please fill in the number of pearl millet accessions DISTRIBUTED annually, and indicate the expected change over the next 3-5 years,** where: + = increasing, 0 = no change, - = decrease

| **Name(s)** | **Number of accessions distributed annually (average of last 3 years)** | **Expected change for the next 3-5 years** |
|---|---|---|
| Nationally | | |
| Regionally | | |
| Internationally | | |

**12.3 Do you put specific conditions or requirements for distribution of pearl millet accessions?**1 YES1 NO

12.3.1 If YES, please specify:
_____

**12.4 What is the proportion of pearl millet germplasm sufficiently available in terms of QUANTITY for distribution?**

| **Type of materials** | **% of accessions sufficiently available** |
|---|---|
| Seeds | |
| *In vitro*/Cryopreserved material | |
| Other, please specify | |

**12.5 Is the distribution of pearl millet germplasm limited because of its HEALTH status?**

- Seeds 1 YES 1 Partly 1 NO

- *In vitro* material 1 YES 1 Partly 1 NO
- Cryopreserved material 1 YES 1 Partly 1 NO
- Other, please specify 1 YES 1 Partly 1 NO

**12.6 Do you have adequate procedures in place for:**

- Phytosanitary certification? 1 YES 1 NO
- Packaging? 1 YES 1 NO
- Shipping? 1 YES 1 NO
- Other, please specify: (_____) 1 YES 1 NO

**12.7 Do you keep records of the pearl millet accession distribution?**
1 YES1 NO
*(e.g. who received it, quantity, date of shipment, nature of distributed material etc.)*

**12.8 Please indicate the proportion (in %) of users who received pearl millet germplasm from you in the past 3 years:**

| **Type of users:** | **Proportion of total distribution %** |
|---|---|
| Farmers and Farmers' organisations | |
| Other genebank curators | |
| Academic researchers and students | |
| Domestic users | |
| Foreign users | |
| Plant breeders– - public sector | |
| Plant breeders– - private sector | |
| NGOs | |
| Others, please specify: | |

**12.9 Describe briefly how you inform potential users about the availability of pearl millet accessions and their respective data in your collection?**

| |
|---|
| |
| |
| |
| |
| |

**12.10 Describe briefly what are the most important factors limiting the use of the pearl millet material maintained in your collection?**

| |
|---|
| |
| |
| |
| |

**12.11 Indicate if users have to pay money or not when they request material from you:**

For accessions: 1 free 1 cost (in US$/accession): _____
For the shipment: 1 free 1 cost (in US$/accession): _____

**12.12 Do you use a <u>Material Transfer Agreement</u> when distributing material?**

1 YES 1 NO

**12.13 Do you have any restrictions on who can receive pearl millet materials?**

**1** YES 1 NO

**12.13.1 If YES, please specify:**

_____

**<u>13. Networks of pearl millet genetic resources</u>**

**13.1 Do you collaborate in (a) network(s) as a pearl millet collection holder?**
1 YES 1 NO

**13.2 If you collaborate in (a) network(s) please provide the following information of them:**
*(A) name, (B) type (national, regional or worldwide), (C) main objectives, and (D) a brief description of the main reasons to participate in the network.*

| **A**<br>**Name of network** | **B**<br>**Type of network**<br>National/Regional/Worldwide | **C**<br>**Main objectives of the network** | **D**<br>**Brief description of the main reasons to participate in the network** |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

**<u>14. Additional crop collections maintained in your institute: please indicate additional crops and number of accessions in the table below:</u>**

| | **Crop or species** | **Number of accessions** | **% of wild relative species** |
|---|---|---|---|
| 1 | | | |

| | | | |
|---|---|---|---|
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |
| 11 | | | |
| 12 | | | |
| 13 | | | |
| 14 | | | |
| 15 | | | |
| 16 | | | |
| 17 | | | |
| 18 | | | |

**15. Major constraints: Please list the 5 major limitations you are facing in the management of the pearl millet collection:**

| |
|---|
| 1) |
| 2) |
| 3) |
| 4) |
| 5) |

**16. Question concerning institutes NOT maintaining pearl millet *ex situ* collections**

**16.1 If your institute does not maintain an *ex situ* collection of pearl millet, please indicate to the best of your knowledge, the following:**

| | |
|---|---|
| **Current pearl millet conservation activities:** | |
| **Institute focal person to contact for further details:** | |
| **Plans for any pearl millet *ex situ* conservation:** | |
| **Any other information:** | |

| **17. Please add any further comments you may have:** |
|---|
| |

| |
|---|
| |
| |

**Thank you for your important contribution!!!**

Please return this questionnaire, no later than Friday 27 August 2010 to:

**The South Asia Coordinator**
**Dr. Prem Narain Mathur**
Bioversity International, Sub-regional Office for
South Asia
NASC Complex
Pusa Campus, New Delhi 110012, India
Tel: +91-11-25849000/01 Fax: +91-11-25849002
Email: p.mathur@cgiar.org

## APPENDIX 2: RESPONDENTS INVITED TO PARTICIPATE IN THE SURVEY QUESTIONNAIRE

**Institutions with pearl millet collections to be invited to respond to the survey**

| Country | Institute name | Contact person | Address | Email address | Response received Yes/No |
|---|---|---|---|---|---|
| Argentina | | Ing. Agr. Beatriz Formica | | bformica@mjuarez.inta.gov.ar | Yes |
| Australia | Australian Tropical Grains Germplasm Centre<br>Crop and Food Science, Agri-Science Queensland | Dr Sally Norton | LMB 1, Biloela QLD 4715 | sally.norton@deedi.qld.gov.au | Yes |
| Austria | Austrian Agency for Health and Food Safety<br>Institute for Potato Plant Material and Plant Genetic Resources | Dipl.-Ing. Paul Freudenthaler | Wieningerstraße 8<br>A-4020 LINZ, Austria | paul.freudenthaler@ages.at | Yes |
| Azerbaijan | National PGR Inventory Focal Point | AfigMammadov | Genetic Resources Institute of ANAS<br>155, Azadligave.,<br>AZ1106, Baku,<br>Azerbaijan | akparov@yahoo.com | Yes |
| Bangladesh | Plant Genetic Resources Center | Dr. Mhd. Khaled Sultan | Bangladesh, Agricultural research institute (BARI), Joydebpur, Gazipur 1701 | sultankbari_2010@yahoo.com | Yes |

| | | | | | |
|---|---|---|---|---|---|
| Brazil | EMBRAPA, Centro de Pesquisa Agroflorestal de Rondônia (CPAF-Rondônia) | Libreros, Dimary | BR 364, Km 5.5, Caixa Postal 406, 78900-970 Porto Velho, Rondônia, Brazil | d.libreros@CGIAR.ORG | Yes |
| Bulgaria | | Dr. SiykaStoyanova | Bulgaria | s_stoyanova@gbg.bg | No |
| Burkina Faso | | Dr. Roger Zangre | Burkina Faso | balma_didier@yahoo.fr | No |
| Canada | Canadian Genetic Resources Program Programme Canadien De RessourcesGénétique Agriculture and Agri-Food Canada/Agriculture et Agroalimentaire Canada | Dr. Ken Richards | Saskatoon Research Centre / Centre de Recherche de Saskatoon<br>107 Science Place<br>Saskatoon, Saskatchewan<br>S7N 0X2<br>Canada | Ken,Richards@agr.gc.ca | Yes |
| China | Lu ping | Mr. Tian Jing | No.12 Zhongguancunnandajie, Haidianqu, Beijing 100081 | zaliang@sina.com | Yes |
| Czech Republic | Crop Research Institute | Iva Faberova | Drnovska 507<br>161 06 Praha – -Ruzyne<br>Czech Republic | faberova@vurv.cz | Yes |
| Eritrea | National Agricultural Research Institute (NARI) | Mr. AmanuelMahdere | Asmara, Postal code: 4627, Eritrea | amanuelmaz@yahoo.com | Yes |
| Ethiopia | | Dr. KassahunEmbaye | Ethiopia | ddg@ibc-et.org, | No |
| Germany | Leibniz Institute of Plant Genetics and | Dr. Ulrike Lohwasser | Gatersleben, D-06466, Germany | lohwasse@ipkgatersleben.de | Yes |

| | | | | | |
|---|---|---|---|---|---|
| | Crop Plant Research (IPK) | | | | |
| Hungary | Research Centre for Agrobiodiversity | Attila Simon | Tápiószele<br>Külsőmező 15.<br>H-2766<br>(Hungary) | jensen@agrobot.rcat.hu | Yes |
| ICRISAT, India | International crops Research Institute for the Semi-Arid Tropics | Dr. Hari D. Upadhaya | Patancheru 502324, Hyderabad | h.upadhyaya@cgiar.org | Yes |
| India, IARI | Indian Agricultural Research Institute | Dr.C.TaraSatyavathi | Pusa Campus, New Delh– - 110 012 | csatyavathi@yahoo.co.in | Yes |
| Indonesia | Indonesia Center Of Agricultural Biotechnology and genetic Research Development | Dr. Azrai | JI. Tentara Pelajar No°3A, Bogor, 16111, Indonesia | azraimuh@yahoo.com | Yes |
| Italy, | | Marisa Scarascia | Italy | marisa.scarascia@igv.cnr.it | Yes |
| Kazakhstan | LP Scientific-Production Center of Grain Growing JSC KazAgroInnovation, Ministry of Agriculture of Kazakhstan | Nilufar Fazilbekova | Village Nauchnyi, Shortandin district, Akmola region, Kazakhstan, 021601 | n.fazilbekova@cgiar.org | Yes |
| Kenya | Kenya Agricultural Research Institute, The National Genebank of Kenya | Dr. Ndungu Kimani | P.O. Box 30148, Nairobi 00100, Kenya | kenya.genebank@gmail.com; ngbk@wananchi.com | Yes |
| Laos PDR | National Agricultural Research Institute (NAFRI), | Bounphanousay Chay | Rice and Cash Crop Research Centre RCRC, Vientiane Lao PDR. | bb_chdd@yahoo.com | Yes |

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| Lesotho | Ministry of Agriculture, Department of Agricultural Research, | Christina Mohloboli Maleoa | PO. Box 829, MASERU 100, Lesotho | maleoacm@yahoo.co.uk | Yes |
| Madagascar | | Dr. Alain Ramanantsoanirina | Madagascar | ntsoaniri@yahoo.com | No |
| Malawi | Malawi Plant Genetic Resources Centre | Lawrent Pungulani | Chitedze Research Station, P.O. Box 158, Lilongwe | genebank@malawi.net, lawrentp@yahoo.co.uk | Yes |
| Mali | Unité des Ressources Génétiques /URG/IER | Amadou Sidibe | URG /IER Avenue Mohamed V, Bamako | Amadousidibe57@yahoo.fr Amadousidibe57@yahoo.fr | Yes |
| Mozambique | Instituto de Investigação Agrária de Moçambique (IIAM) | Barnabas Kapange | Av. Das F.P.L.M. 2698, , Maputo, 3658 | bkapange@gmail.com | Yes |
| Myanmar | Biotechnology, Plant genetic resources and Plant protection Center | Daw Kin San Wei | Myanmar | ksw.dar@gmail.com | Yes |
| Namibia | National Botanical Research Institute (NBRI) | Ms. Sonja Loots | 8 Orban street, Windhoek, 9000, Namibia | sonjal@nbri.org.na | Yes |
| Nepal | National Agriculture Genetic Resources Centre (NAGRC) | Dr. Madan Bhatta | Khumaltar, Lalitpur, Nepal | madan_bhatta@yahoo.com | Yes |
| Niger | Institut national de la recherche agronomique du Niger (INRAN) | DAN-JIMO Baïna | INRAN, Corniche Yantala, BP 429 Niamey Niger | bdj0709@yahoo.fr | Yes |
| Poland | National Centre for Plant Genetic | Marcin Zaczyński | | m.zaczynski@ihar.edu.pl | Yes |

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| | Resources Radzikow | | | | |
| Portugal | | Humberto Nóbrega | Madeira island | isoplexis@uma.pt | |
| Russian Federation | N.I. Vavilov Research Institute of Plant Industry (VIR) | Sergey Shuvalov | 42-44, B.Morskaya Street, St.Petersburg, 190000, Russian Federation | s.shuvalov@vir.nw.ru | Yes |
| Rwanda | | R. Jean Gapusi | Rwanda | gapusirj@yahoo.fr | Yes |
| Senegal | ISRA (Institut Sénégalais de Recherches Agricoles) | Mr. Ousmane Sy | Sélection mil<br>BP 53 ISRA/Bambey, SENEGAL | oussousyso@yahoo.fr | Yes |
| South Africa | National Plant Genetic Resources centre | Mr. Thabo Tjikana | Department of Agriculture, Forestry and Fisheries, private Bag X 973, Pretoria 0001 | ThaboTj@daff.gov.za | Yes |
| Sri Lanka | Plant Genetic Resources Centre | Dr. Ratnasiri | P.O. Box 59, Gannoruwa, Peradeniya, 20400 | pgrc@slt.lk | Yes |
| Sudan | | Dr. Eltahir Mohamed | Sudan | eltahir@sudanmail.net.sd ; elthahir81@yahoo.com | No |
| Tanzania | National Plant Genetic Resources Centre | Margaret Mollel | P.O Box 3024<br>Arusha, Tanzania | mjk_mollel@yahoo.com | Yes |
| Togo | Institut Togolais de Recherche Agronomique (ITRA) | Koffi Kombate | ITRA Siège Cacaveli, Lome, Togo 1163 | kombate_koffi@yahoo.fr | Yes |
| Uganda | National Agricultural Research Organization (NARO) | Dantsey-Barry Hadatou | Entebbe Botanic gardens, PO Box 40, Plot 2-4 Berkeley Road, Entebbe, | itra@cafe.tg ; hadyabarry@yahoo.fr | Yes |

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| | | | Uganda, Kampala | | |
| Ukraine | Institute of Plant Production nd.a.Yuriev | Grigorashenko Larisa | Moskovskyi pr., 142, Kharkiv, 61060 | ncpgru@gmail.com | Yes |
| Ukraine | National Centre for Plant Genetic Resources of Ukraine | Roman Boguslavskiy | Kharkiv, Ukraine | boguslavr@rambler.ru | Yes |
| United Kingdom, Aberystwyth | Institute of Biological, Environmental and Rural Sciences, Aberystwyth University | Ian D. Thomas | Gogerddan Aberystwyth, SY23 3EB<br><br>Wales, UK | idt@aber.ac.uk | Yes |
| United Kingdom, Kew | Millennium Seed Bank, Seed Conservation Department | Janet Terry | Royal Botanic Gardens, Kew Wakehurst Place, Ardingly, West Sussex, RH17 6TN | j.terry@rbgkew.org.uk | Yes |
| USA | USDA, ARS, Plant Genetic Resources Conservation Unit | Melanie Harrison-Dunn, PhD. | 1109 Experiment St. Griffin, GA 30223, USA | Melanie.HarrisonDunn@ARS.USDA.GOV | Yes |
| Zambia | National Plant Genetic Resources Centre, | Dickson Ng'uni | Zambia Agriculture Research Institute, P/Bag 7, Chilanga, Zambia | Dickson.nguni@gmail.com | Yes |

## APPENDIX 3: LIST OF PARTICIPANTS OF "GLOBAL STRATEGIES FOR THE *EX SITU* CONSERVATION OF PEARL MILLET AND ITS WILD RELATIVES" HELD AT THE NATIONAL BUREAU OF PLANT GENETIC RESOURCES, NEW DELHI ON 22 DECEMBER 2011

| | Country | Participant | Email |
|---|---|---|---|
| 1 | India | Dr. Hari D Upadhyaya<br>Assistant Research Program Director, Grain Legumes and Principal Scientist and Head of Gene Bank,<br>International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India | h.upadhyaya@cgiar.org |
| 2 | India | Dr. MVC Gowda<br>Project Coordinator,<br>All India Coordinated Research Project on Small Millets, University of Agricultural Sciences, Bangalore, India | mvcgowda@sify.com ; smallmillets@gmail.com |
| 3 | India | Dr. A Seetharam<br>ex-Project Coordinator,<br>All India Coordinated Research Project on Small Millets, University of Agricultural Sciences, Bangalore, India | annadanasram@rediffmail.com |
| 4 | India | Dr. C Tara Satyavathi<br>Principal Scientist,<br>Division of Genetics, Indian Agricultural Research Institute, Pusa Campus,<br>New Delhi - 110 012, India | csatyavathi@yahoo.co.in |
| 5 | India | Dr. RK Tyagi<br>Principal Scientist and Head,<br>Germplasm Conservation Division, National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi 110012, India | rktyagi@nbpgr.ernet.in |
| 6 | India | Dr. DC Bhandari<br>Principal Scientist and Head,<br>Germplasm Exploration Division, National Bureau for Plant Genetic Resources,<br>Pusa Campus, New Delhi 110012 | bhandaridc@nbpgr.ernet.in |
| 7 | India | Dr. M Dutta<br>Principal Scientist and Head,<br>Germplasm Evaluation Division, National Bureau of Plant Genetic Resources,<br>Pusa Campus, New Delhi 110012, India | mdutta@nbpgr.ernet.in |
| 8 | Uganda | Dr. Nelson Wanyera<br>Millet Breeder,<br>NARO, Uganda | nwanyera@hotmail.com |

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| 9 | Kenya | Dr. Chrispus Oduori<br>Principal Research Officer,<br>National Co-ordinator, Millets Research, and head Sorghum and Millet Research, KARI-Kakamega, P.O. Box 169, Kakamega, Kenya | chrisoduori@yahoo.com |
| 10 | Mali | Mr. Amadou Sidibe<br>Head of Genetic Resources,<br>Institute of Rural Economy, URG/IER BP. 258 Avenue Mohamed V, Bamako, Mali | Amadou.sidibe19@gmail.com |
| 11 | Senegal | Mr. Ousmane Sy<br>Millet Breeder,<br>BP 53 ISRA/Bambey, SENEGAL | oussousyso@yahoo.fr |
| 12 | Kenya | Dr. Desterio Ondieki Nyamongo<br>National Coordinator, Genetic Resources Conservation<br>Kenya Agricultural Research Institute,<br>National Genebank of Kenya,<br>P.O. Box 30148<br>00100 Nairobi, Kenya | dnyamongo@yahoo.co.uk |
| 13 | India | Dr. Bhuwon Sthapit<br>Regional Project Coordinator,<br>Bioversity International, Office for South Asia,<br>NASC Complex,<br>New Delhi 110012, India | b.sthapit@cgiar.org |
| 14 | India | Dr. Hugo Lamers<br>Associate Scientist,<br>Bioversity International, Office for South Asia,<br>NASC Complex,<br>New Delhi 110012, India | h.lamers@cgiar.org |
| 15 | India | Dr. Prem Narain Mathur<br>South Asia Coordinator,<br>Bioversity International, Office for South Asia,<br>NASC Complex,<br>New Delhi 110012, India | p.mathur@cgiar.org |
| 16 | India | Dr. Sushil Pandey<br>Senior Scientist,<br>Millet Curator, Division of Germplasm Conservation, National Bureau of Plant Genetic Resources,<br>New Delhi-110 012, India | sushil_pandey@nbpgr.ernet.in |
| 17 | India | Dr. KC Bhatt<br>Senior Scientist,<br>Plant Exploration and Collection Division,<br>National Bureau of Plant Genetic Resources,<br>New Delhi-110 012, India | kcbhattps@yahoo.com |
| 18 | India | Dr. Jyoti Kumari<br>Senior Scientist,<br>Germplasm Evaluation Division, National Bureau of Plant Genetic Resources,<br>New Delhi-110 012, India | jyoti@nbpgr.ernet.in |

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| 19 | India | Dr. Nidhi Verma<br>Senior Scientist,<br>Germplasm Exchange Unit, National Bureau of Plant Genetic Resources,<br>New Delhi-110 012,India | nidhipgr@gmail.com |
| 20 | India | Ms. Sarika Mittra<br>Scientific Assistant (GIS Consultant),<br>Bioversity International, Office for South Asia,<br>NASC Complex,<br>New Delhi 110012, India | s.mittra@cgiar.org |

## APPENDIX 4: AGENDA FOR THE WORKSHOP ON "GLOBAL STRATEGIES FOR THE *EX SITU* CONSERVATION OF PEARL MILLET AND THEIR WILD RELATIVES", HELD AT THE NATIONAL BUREAU OF PLANT GENETIC RESOURCES, NEW DELHI ON 22 DECEMBER 2011

**Objective:**

To consult representatives of relevant pearl millet collections on key elements of global strategies for the efficient and effective *ex situ* conservation of the genetic resources.

**Expected outcomes**:

1. Key global, regional and national collections of pearl millet genetic resources identified;
2. Critical overlaps and gaps in existing collections identified;
3. Major needs and opportunities for upgrading key collections and building the capacity managers to maintain and distribute them efficiently and effectively over the long term identified; and
4. Recommendations for increased collaboration and sharing of responsibilities, leading to more effective and efficient conservation and greater utilization finalized.

**Programme:**

09:30 – 10:30: ***Session I: Opening Session***

- Welcome
- Address by Director, NBPGR, Chief guest
- Introduction to participants
- Vote of thanks
- Logistical arrangements
- Group photo

10.30 to 11.00: ***Tea/Coffee break***

11.00 to 13.00: ***Session II: Overview of the draft strategy for pearl millet – Prem Mathur***

- Discussion and approval of agenda
- Outline of the strategy development process and expected outputs
- Origin, domestication and taxonomic history
- Overview of pearl millet collections
- Characterization, evaluation, seed distribution and utilization status
- Conservation status, including safety duplication and regeneration needs
- Distribution and gaps in pearl millet collection
- Distribution of *Pennisetum* species and gap analysis
- Documentation status
- Limitation in the management and use

- Training needs for efficient management and use of pearl millet genetic resources
- Recommendations

13:00 – 14:00 ***Lunch***

14:00 – 16:30 ***Session III: Group discussions***

Working groups meet in parallel sessions to consider items 1-12 in the Appendix 5 to this agenda.

15.15 to 15.30: ***Tea/Coffee break***

16.30 – 17.30. ***Session IV: Plenary session for working groups to report back and raise any issues and concerns***

19.30 to 20.30 ***Dinner*** – Bioversity International

## APPENDIX 5: TOPICS TO BE DISCUSSED IN PARALLEL GROUP SESSIONS FOR PEARL MILLET

1. Review and verify the data presented on the various collections and to identify:
   - Any additional collections to be included
   - Any collections that should be dropped from the table
   - Major items of missing data and how they can be filled

2. Consider the proposed criteria for a reference collection, i.e.:
   - Collections on which the world depends
   - Substantial size and diversity
   - Generally international or regional in coverage
   - Well managed to international standards - and in general adequately funded
   - Readily available on request under terms of International Treaty on PGRFA
   - Identify the main collections that meet these criteria

3. Identify other significant collections, and sets of accessions within collections, taking into account criteria such as:
   - Collection size and diversity (number and origin of accessions)
   - Uniqueness of the material
   - Type of material (landraces, released cvs., wild spp. Genetic stocks, etc)

(Where possible, indicate the major support needs of any such collections identified)

4. Identify potential partners who are able to provide conservation services such as: characterizing or evaluating material for key characters, indexing for diseases, providing specialized assistance with regeneration or storage, providing information or germplasm distribution services, etc.

5. Identify major gaps in the total genetic diversity coverage of existing collections

6. Assess the current status of data and information systems and indicate how they could be strengthened and the data made more accessible

7. To what extent are collections already duplicated for safety and how can the situation be improved? What standards/guidelines should apply (consider both second-country safety duplication and duplication at the Svalbard International Seed Vault

8. What are the major policy and technical impediments to a greater distribution of materials (e.g. with respect to seed quantity, seed quality, quarantine/ phytosanitary arrangements, a clear policy on distribution, agreed MTA etc.), and how can they best be overcome?

9. Identify and assess the effectiveness of any networks and international cooperative programmes that exist for the crop in question. How can collaboration best be strengthened?

10. Assess the effectiveness of links to users (plant breeders and farmers). How can a greater use of the genetic materials best be promoted?

11. What are the most important training needs and how might they best be addressed?

12. Identify key next steps in further development of the strategy and its implementation

## APPENDIX 6: LIST OF ACRONYMS

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| AAFC | Agriculture and Agri-Food Canada |
| AGES | Austrian Agency for Health and Food Safety |
| AICRP | All India Coordinated Research Project |
| AICRP-FC | All India Coordinated Project for Research on Forage Crops |
| AICSMIP | All Indian Coordinated Small Millets Improvement Project |
| AISMIP | All India Small Millets Improvement Programme |
| APAARI | Asia Pacific association of agricultural research institutions |
| ASTA | American Seed Trade Association |
| AusPGRIS | Australian Plant Genetic Resources Information System |
| CBD | Convention on Biological Diversity |
| CGIAR | Consultative Group for International Agricultural Research |
| CLAN | Cereal Legumes Asian Network |
| EURISCO | European Plant Genetic. Resources Search Catalogue |
| FAO | Food and Agriculture Organization of the United Nations |
| GBIF | Global Biodiversity Information Facility |
| GCDT | Global Crop Diversity Trust |
| GRIN | Germplasm Resource Information System |
| IARC | International Agricultural Research Centres |
| ICABIOGRAD | Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development |
| ICAR | Indian Council of Agricultural Research |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| IDMRS | ICRISAT Data Management and Retrieval System |
| IFAD | International Fund for Agricultural Development |
| IIAM | Instituto de Investigação Agrária de Moçambique |
| ILRI | International Livestock Research Institute |
| INRAN | Institut National de Recherche Agronomique du Niger |
| IPK | Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), (Germany) |
| IRD | Institut de recherche pour le développement, France |
| ISPGR | The Indian Society of Plant Genetic Resources |
| ISRA | Institut Sénégalais de Recherches Agricoles |
| ISTA | International Seed Testing Association |
| ITPGRFA | International Treaty on Plant Genetic Resources for Food and Agriculture |
| NAGS | National Active Germplasm Site |
| NARC | Nepal Agricultural Research Council |
| NARO | National Agricultural Research Organisation |
| NARS | National Agricultural Research Systems |
| NBPGR | National Bureau of Plant Genetic Resources (India) |
| NBRI | National Botanical Research Institute (Namibia) |
| NPGRC | National Plant Genetic Resources Center (Mozambique) |
| ORSTOM | Office de la Recherche Scientifique et Technique d'Outre-Mer |

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| PGRC | Plant Gene Resources of Canada |
| SADC | South African Development Community |
| SDIS | SADC Documentation and Information System |
| SGRP | System-wide Genetic Resources Program |
| SGSV | Svalbard Global Seed Vault |
| SINGER | System-wide Information Network for Genetic Resources |
| SMTA | Standard Material Transfer Agreement |
| SoW | First State of the World's Plant Genetic Resources for Food and Agriculture Report |
| SPGRC | South African Development Community (SADC) Plant Genetic Resources Centre |
| SQL | Structured Query language |
| URG | Unité des Ressources Génétiques, Mali |
| USDA-ARS | United States Department of Agriculture, Agricultural Research Service |
| VIR | N.I. Vavilov Research Institute of Plant Industry (Russian Federation) |
| WIEWS | World Information and Early Warning System |