ICRISAT
Science with a human face

SASA
State-of-the-Art on Semi-Arid Agriculture

# Freezing for the Future

***Conserving crop germplasm for the generations ahead***

December 2012 (Issue No.13)

## Preamble

*"Deep inside the ICRISAT campus just outside Hyderabad, there are two sub-zero rooms that house the seeds of 120,000 plants from over 100 countries and 120,000 chances to change poor farmers' lives. The rows of plastic containers and freeze-dried metallic packages resemble a huge and very cold medicine cabinet."* said Rachel Kyte, Vice President for Sustainable Development,World Bank, talking about germplasm accessions in her blog post, dated 28 October 2012, www.worldbank.org/sustainabledevelopment .

A Greek proverb says, "A society grows great when men plant trees in whose shade they know they will never sit", which concurs with the definition of success, ie, to leave the world a little better than when you came into it. Now, how much better is it than to unselfishly ensure food for generations that come after us? Crop genebanks (banks that store genetic material of crops, usually seeds), first developed over 50 years ago, provide a means for doing this.

Ms Rachel Kyte at the ICRISAT genebank. Among the scientists with her are (far right) Dr William Dar, Director General, ICRISAT and (left) Dr HD Upadhyaya, Principal Scientist and Head, Genebank.

back to top

## The Genebank

The genebank at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) first acquired 8,961 sorghum accessions (or varieties) from the Indian Agricultural Program of the Rockefeller Foundation collection in 1974 through the All India Coordinated Sorghum Improvement Project (AICSIP), and another 3,000 sorghum accessions from the duplicate sets maintained in the USA (Purdue and Fort Collins) and Puerto Rico (Mayaguez).

Initially, ICRISAT also acquired over 2,000 pearl millet accessions assembled by the Rockefeller Foundation in collaboration with the Indian Council of Agricultural Research (ICAR) in New Delhi, and another 2,000 accessions collected by the Institut Francais de Recherche Scientifique pour le Développement en Coopération (ORSTOM) in Francophone West Africa.

Dr LJG van der Maesen (third from left) informs a visitor about the genebank activities. Dr MH Mengesha is on the far left.

ICRISAT also acquired a few thousand of germplasm accessions of chickpea, pigeonpea and groundnut from various organizations located in different countries.

"We started with temporary storage buildings with room air-conditioners", recalls Dr LJG van der Maesen, ICRISAT's first Botanist, who also pioneered the collection missions and characterization of the early accessions. Later, in 1979, Dr Melak H Mengesha established a full-fledged state-of-the-art genebank. Over 30 years later, the same genebank (named "The RS Paroda Genebank" in 2002) is a world repository for germplasm of ICRISAT's mandate crops – sorghum, pearl millet, chickpea, pigeonpea, groundnut, and six small millets (finger millet, foxtail millet, little millet, kodo millet, proso millet and barnyard millet).

back to top

## What purpose does a genebank serve?

To meet the food-security needs of a rapidly growing global population, genetic diversity, created through natural and human selection over millennia and complemented by the diversity present in wild relatives of crop plants, provides the raw material that can be employed to improve crop productivity. But genetic variation, once considered unlimited, is fast eroding as modern varieties replace traditional cultivars over large areas, and natural habitats are destroyed. Genetic diversity must be conserved, both, to combat new pests and diseases that emerge from time to time, and to produce varieties better-adapted to changing climatic and environmental conditions.

To this end, genebank personnel engage in the assembly, conservation, maintenance characterization, evaluation, documentation, and distribution of germplasm for research and development.

## Building the collection

With over 120,000 germplasm accessions assembled from 144 countries, through donations and by launching collection missions, the ICRISAT genebank is one of the largest international genebanks for the germplasm of crops mentioned earlier. Major donors to the collection are the national programs in Ethiopia, France, India, Italy, Iran, Lebanon, Niger, Nigeria, Sudan, the United States of America; organizations; individual research workers; and generous farmers of many nations. Also, ICRISAT scientists conducted over 200 collection expeditions in 62 countries to collect several landraces on the verge of extinction, braving difficult terrain, hostile environments, and harsh conditions.

The collection provides insurance against genetic erosion and is a source of tolerance to diseases and pests, climatic and other environmental stresses, improved grain quality and yield traits for crop improvement. Several landraces now conserved in the ICRISAT genebank have disappeared from their natural habitats in Africa and Asia. Examples are the Hegari, Zera-zera, and Kurgis landraces of sorghum once present in the Gezira, Kasala and Blue Nile provinces of Sudan.

Collecting germplasm also provides rich opportunities for cooperation between ICRISAT and national programs in different countries. Collection is always done jointly with national /international organizations. The samples are initially characterized and regenerated in the source country and germplasm is acquired under Material Acquisition Agreements. All exotic germplasm that finds its way into the ICRISAT genebank at

Patancheru, India, is examined by the Indian national plant quarantine system before it is released (Upadhyaya and Gowda, 2009).

back to top

## Characterizing new germplasm

Containers of germplasm accessions in one of the medium-term storage rooms.

All germplasm is first characterized for a set of recognized descriptors. These include stable botanical characters and a few agronomic and grain quality traits such as early seedling vigor, number of days needed to flower and mature, plant height, stem thickness, tillering, leaf size, plant color, flower color, panicle length and width, panicle shape, number of seeds per pod, seed size and color, and grain yield (referred to as " characterization data").


Scientists recording characterization data in the field

After the initial characterization, germplasm accessions are evaluated and screened by multidisciplinary teams at ICRISAT and national program scientists. These teams assess the potential and usefulness of germplasm lines for specific situations and constraints. Typically, these include abiotic stress tolerance such as drought and salinity tolerance, biotic stresses resistance, to pests and disease, and quality characteristics. After several years of detailed scientific evaluation and screening, new genetic stocks are identified for use in crop improvement as new sources of breeding material for desirable characteristics.

Germplasm sets are also evaluated for agronomic performance over locations jointly with national agricultural research system (NARS) scientists in Burkina Faso, Canada, China, Ethiopia, India, Indonesia, Japan, Kenya, Namibia, Nepal, Thailand, Ukraine, USA and Vietnam. The joint evaluations have led to better understanding of the germplasm conserved in the genebank.

Hundreds of genetic stocks have already been identified and are being used by ICRISAT and NARS scientists throughout the world. Through participation in such evaluation-identification exercises, many national program scientists have been trained in germplasm characterization. This gives them the skill to identify new genetic stocks and enhances their ability to manage germplasm and its efficient utilization in their national crop improvement programs.

The passport and characterization data of germplasm accessions are made globally accessible as international public goods through the ICRISAT website (http://www.icrisat.org).

back to top

## Maintaining the collection

Managers of the genebank ensure continued germplasm availability for crop improvement. Seed storage under controlled environmental conditions – low temperature and low relative humidity – prolongs seed viability and eliminates the need for frequent regeneration of germplasm, which is expensive and involves risk to genetic integrity. Conserved germplasm is monitored for seed viability and quantity at regular intervals (Upadhyaya and Gowda 2009).

DVSSR Sastry, Manager, Genebank Seed Laboratory, conducts a germination test.

Scientists making observations of wild arachis (related to groundnut) regeneration in a glasshouse.

The conservation of germplasm in genebanks in the form of seeds requires that the integrity of the material conserved be maintained to the highest standard over prolonged periods of time. A short-term storage, maintained at 18-20ºC and 30-40% relative humidity, is used to hold seeds while they are dried and prepared for medium- and long-term storage. Five medium-term storage rooms maintained at 4ºC and 20-30% relative humidity help conserve seed samples for about 20 years. Four long-term storage units at -20ºC conserve the seeds, dried to 5-7% moisture content and hermetically sealed in aluminum foil packets, for more than 50 years.

Germplasm accessions that do not set or produce adequate seed for conservation (such as wild species of groundnut and pearl millet) are maintained as live plants in a botanical garden and in green houses.

Germplasm accessions are multiplied mainly during the postrainy season to get better quality seed. To minimize genetic drift, an adequate number of plants are grown and sampled equally in constituting new seed stocks. While regenerating cross-pollinating crops such as sorghum, pearl millet and pigeonpea, genetic integrity is maintained by pollination control. Pre-storage deterioration in seed quality is minimized by harvesting promptly when maturity is reached.

A quarantine field of pearl millet.

back to top

## Ensuring safety of germplasm

ICRISAT's genebank is designed to withstand natural disasters. For further safety of germplasm, the collection is duplicated in other genebanks. Duplicates of a large portion of chickpea germplasm are conserved at the International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria; and pearl millet, groundnut and small millets at the ICRISAT Regional Genebank, Niamey, Niger.

The Svalbard Global Seed Vault (SGSV), launched in February 2008 and located in the remote Arctic Svalbard Archipelago, Norway, was established to preserve unique duplicate samples of seeds held in genebanks worldwide. The vault provides an insurance against the loss of seeds in genebanks, as well as a refuge for seeds in the case of large-scale regional or global crises. ICRISAT has committed to place 111,000 accessions of the FAO-designated germplasm of its mandate crops and small millets in the vault. To date, there are 97,800 accessions from ICRISAT in Svalbard.

Germplasm accessions, packed and ready for shipment to the Svalbard seed vault.

back to top

## Access to germplasm

Distribution of germplasm and related information is fundamental to ICRISAT's mission of increasing crop productivity and food security. To ensure unrestricted access to the world community, ICRISAT placed its germplasm collections under the auspices of the Food and Agricultural Organization of the United Nations (FAO) in 1994. Under the terms of the agreement with the International Treaty on Plant Genetic Resources for Food and Agriculture

(ITPGRFA), ICRISAT supplies germplasm through standard material transfer agreements (SMTA).

back to top

## Supply of Germplasm

Hundreds of germplasm accessions are evaluated annually by ICRISAT scientists for their suitability for use in developing new varieties and hybrids for the semi-arid tropics. Requests for germplasm – primarily for use in crop improvement research, are processed by selecting for particular qualities against information stored as passport data or the characterization/evaluation databases.

Several thousand germplasm accessions have been restored to their country of origin upon request. Examples are, Botswana (362 sorghum accessions), Cameroon (1827 sorghum and 922 pearl millet), Ethiopia (1723 sorghum and 931 chickpea), India (44,723 accessions of five mandate crops and six small millets), Kenya (838 sorghum and 332 pigeonpea), Nigeria (1436 sorghum), Somalia (445 sorghum), Sri Lanka (71 pigeonpea) and Sudan (977 sorghum and 594 pearl millet).

With the erosion of genetic diversity available on farm, the ICRISAT genebank has become a major source of diversity available to plant breeders for crop improvement. Since 1975 the ICRISAT genebank has distributed more than 1.4 million samples of 100,600 accessions of its mandate crops and small millets to users in 147 countries. NARS partners have released more than 800 varieties in 79

countries from the germplasm and breeding materials supplied by ICRISAT, contributing to food security. Thousands of other samples are being used as raw materials in breeding programs as desirable sources of new agronomic traits for crop improvement.

back to top

## Core and mini core collections

A large gap exists between availability and actual utilization of the germplasm materials. Limited use of germplasm was observed in breeding programs, mainly due to lack of information on economic traits. Representative core collections (10% of the entire collection) following Frankel (1984) and mini core collections (10% of core collection or 1% of the entire collection) following Upadhyaya and Ortiz (2001), have been developed at ICRISAT to enhance use of germplasm in breeding programs globally.

ICRISAT and partners have evaluated 182 sets of mini core collections in 26 countries in Asia, Africa, Europe, Oceania and the Americas, which resulted in the identification of new sources of tolerance to drought, salinity, heat, water logging and disease resistance. They also identified sources for improved agronomic traits (early-maturity, high yield, seed size; Upadhyaya et al, 2006 a,b; 2009, Gowda et al. 2011) and quality (oil, protein, iron, zinc and calcium, Upadhyaya et al 2011, 2012 a,b, ) in the ICRISAT mandate crops. Molecular characterization of mini core collections helped to identify genetically diverse trait-specific accessions for use by the breeders to develop high-yielding cultivars with a broad genetic base.

The revolution in molecular biology, bioinformatics, and information technology has provided the scientific community with tremendous opportunities for solving some of the world's most serious agricultural and food security issues. Molecular characterization of composite sets of germplasm, that include core or mini core collections, have helped in understanding genetic diversity and population structures in each species. The molecular characterization details on ICRISAT germplasm sets are available through www.generationcp.org. Genotype based reference sets of genetically diverse 200-400 accessions have been established at ICRISAT (Upadhyaya et al. 2008). Seeds of mini core collection and reference sets are available for use by the global research community following SMTA.

back to top

## Making a long-term impact

ICRISAT has been highly successful in assembling and conserving germplasm as part of the global effort for the conservation of biodiversity. The greatest impact is in conserving the germplasm and making diverse material readily available for use in crop improvement globally.

Thus we see that through genebanks we fulfill a dual role --not only do we conserve available germplasm for use in breeding programs, we also preserve germplasm, making it possible for future generations to have access to the wealth of crop diversity accumulated today.

Yet, the story does not end with conservation of germplasm alone. Of equal importance is the training imparted by ICRISAT to scientists from several countries in the efficient and sustainable conservation of plant genetic resources and the management of genebanks. This ensures that even the science and practice of germplasm conservation is kept thriving, viable and useful for future generations.

back to top

## Bibliography

**Frankel OH.** 1984. Genetic perspective of germplasm conservation.Pages 161-170 *in* Genetic manipulations: impact on man and society (Arber W, Limensee K, Peacock WJ and Stralinger P, eds.). Cambridge, UK: Cambridge University Press.

**Gowda CLL, Upadhyaya HD, Dronavalli N** and **Singh S.** 2011. Identification of large-seeded high-yielding stable kabuli chickpea germplasm lines for use in crop improvement. Crop Sci. 51:198-209.

**Upadhyaya HD** and **Ortiz R.** 2001. A mini core collection for capturing diversity and promoting of chickpea genetic resources in crop improvement. Theor. Appl. Genet. 102: 1292-1298.

***Upadhyaya HD, Dwivedi SL, Baum M, Varshney RK, Udupa SM, Gowda CLL, Hoisington D*** *and* ***Singh S.****2008.* Genetic structure, diversity and allelic richness in composite collection and reference set in chickpea (*Cicer arietinum* L.). BMC Plant Biology 8: 106http://www.biomedcentral.com/1471-2229/8/106.

**Upadhyaya HD** and **Gowda CLL.** 2009. Managing and Enhancing the Use of Germplasm - Strategies and Methodologies. Technical Manual no. 10. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 236 pp.

**Upadhyaya HD, Gowda CLL, Buhariwalla HK** and **Crouch JH.** 2006a. Efficient use of crop germplasm resources: identifying useful germplasm for crop improvement through core and mini core collections and molecular marker approaches. Plant Genetic Resources 4:25-35.

**Upadhyaya HD, Reddy LJ, Gowda CLL** and **Singh S.** 2006b. Identification of diverse groundnut germplasm: Sources of early-maturity in a core collection. Field Crops Research 97:261-271.

**Upadhyaya HD, Pundir, RPS, Dwivedi SL** and **Gowda CLL.** 2009. Mini Core Collections for Efficient Utilization of Plant Genetic Resources in Crop Improvement Programs. Information Bulletin No. 78. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 52 pp.

**Upadhyaya HD, Ramesh S, Sharma S, Singh SK, Varshney SK, Sharma NDRK, Ravishanker CR, Narasimhudu Y, Reddy VG, Sahrawat KL, Dhanalakshmi TN, Mgonja MA, Parzies HK, Gowda CLL** and **Singh S**. 2011. Genetic diversity for grain nutrients contents in a core collection of finger millet [*Eleusine coracana* (L.) Gaertn.] germplasm. Field Crops Research 121:42-52.

**Upadhyaya HD, Dronavalli N, Singh S** and **Dwivedi SL**. 2012a. Variability and Stability for Kernel Iron and Zinc Contents in ICRISAT Mini Core Collection of Peanut. Crop Sci.: 52:2628–2637.

**Upadhyaya HD, Mukri G, Nadaf HL** and **Singh S.** 2012b. Variability and Stability Analysis for Nutritional Quality Traits in the Mini Core Collection of Peanut. Crop Sci. 52:168-178.

For more information contact H.Upadhyaya@cgiar.org

back to top

International Crops Research Institute for the Semi-Arid Tropics

ICRISAT-Patancheru, 502 324, Andhra Pradesh, India,
Tel +91 40 30713071, Fax +91 40 30713074,
icrisat@cgiar.org, http://www.icrisat.org