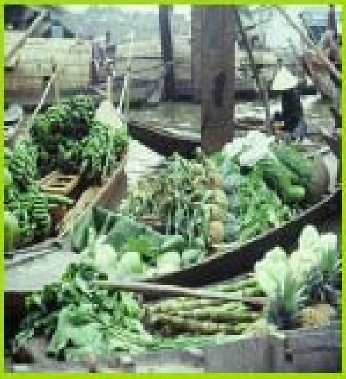
Strengthening Information on Plant Genetic Resources in Asia



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Approaches to enhance the value of genetic resources in crop improvement

S.L. Dwivedi, H.D. Upadhyaya and C.L.L. Gowda
International Crops Research Institute for the Semi Arid Tropics (ICRISAT), Patancheru PO 502324, Andhra Pradesh, India

Introduction

Plant genetic resources are the basic raw materials for future genetic progress and an insurance against unforeseen threats to future agricultural production. Its use in crop improvement is one of the most sustainable ways to conserve valuable genetic resources. Over 6 million *ex situ* germplasm accessions are conserved in 1308 genebanks globally, of which, about 10% ARE held in trust by the CGIAR centers' genebanks. ICRISAT has one of the largest genebanks in the CGIAR system, holding 119,074 accessions of its mandate crops from 144 countries (as of May 09). Of these, 113,830 accessions are designated to the International Treaty on Plant Genetic Resources for Food and Agriculture under the auspices of FAO. The genetic base of improved cultivars of many crops, including ICRISAT mandate crops, is narrow. In spite of large number of germplasm accessions available in the genebanks, there has been very limited use of these accessions in crop improvement programs. The reasons for the underutilization of germplasm include i) lack of accurate and precise large scale multi-location evaluation of germplasm, ii) lack of rational systematic entry points into the vast international collections, and the iii) lack of robust, cost-effective tools to facilitate the efficient utilization of exotic germplasm in plant breeding programs. Clearly, there is a need to increase the use of genetically diverse germplasm with beneficial traits in crop improvement programs to meet the emerging challenges in agricultural production. We discuss below the range of information that we have generated about the germplasm collections and the approaches to use information to identify genetically diverse germplasm. Included in the discussion are also updates on the manual for genebank operations and procedures, information bulletin on mini core, crop germplasm registration, feedback on germplasm utilization, and impact of germplasm in crop improvement.

Assessing diversity in germplasm collection

The pattern of diversity was assessed in the global collection using characterization and evaluation data, recorded following crop-specific descriptors, obtained from the field evaluation of germplasm. Global data base on characterization and evaluation (http://www.icrisat.org) and passport information (http://www.singer.cgiar.org) on 116,148 accessions can be accessed online to extract information about any germplasm in ICRISAT genebank. Analyzing the pattern of diversity revealed that chickpea accessions with no anthocyanin pigmentation (kabuli types) were predominant in East Asia, Mediterranean and Europe. European accessions produced more pods per plant, largest seed and highest grain yield. Accessions from Africa had smallest seed. African germplasm were earliest to flower, while those from East Asia were of late flowering type. A higher proportion of accessions from South Asia, Southeast Asia and West Asia were found resistant to fusarium wilt. Seed color showed maximum diversity (Upadhyaya 2003a).

South African groundnut accessions showed large range variation for most of the descriptors and on average had highest range variation. Primary seed color among morphological traits, and leaflet length among agronomic traits showed highest pooled diversity index (Upadhyaya 2003b).

Diversity pattern in pigeonpea revealed that most of the germplasm were of semi-spreading type, green pigmentation, indeterminate flowering, and yellow flower. Primary seed color had maximum variability, with orange and cream seed coat color being the two most frequent in collection. Accessions from Oceania were conspicuous by early maturity, short height, fewer branches, pods with fewer seeds, smaller seed size, and lower seed yields, while those from Africa were of longer duration, taller, multi-seeded pods, and larger seeds (Upadhyaya et al. 2005a).

The basic and intermediate races in sorghum showed immense diversity in panicles, spikelets and seeds. Large variation has been reported for days to flowering (36 to 199 days), plant height (55 to 655 cm), peduncle exsertion (0 to 55 cm), panicle length (2.5 to 71 cm) and 100-seed weight (0.29 to 8.56 g) (Stenhouse et al. 1997).

Pearl millet germplasm revealed greatest variability for days to flowering (33 to 159 days), plant height (30 to 490 cm), tillers plant^{-1} (1 to 35), panicle length (5 to 135 cm), and 1000-seed weight (1.5 to 21.3 g) (Upadhyaya et al. 2007).

In finger millet, the panicle forms and seeds showed greater diversity. The majority of the accessions had green foliage, with some purple and violet foliage. Erect types were more predominant than those from decumbent and prostrate growth habits. Light brown was the most common seed color followed by reddish brown, dark brown and white. About 3% of the accessions remained fully green until maturity – a valuable fodder trait. The panicle size and shape and seed color among finger millet germplasm accessions revealed maximum diversity, while accessions also differed for plant height, tillering, leaf size and shape, and erect to drooping panicles.

Pattern of use and impact of germplasm in crop improvement

During 1974 to 2008, we supplied 1,354,036 seed samples to researchers in 144 countries including 654,348 samples to those in ICRISAT. The most frequently requested accessions were ICC 4918, ICC 4973, and ICC 5003 in chickpea; ICG 799, ICG 221 and ICG 156 in groundnut; ICP 7035, ICP 26 and ICP 7182 in pigeonpea; IS 18758, IS 1059 and IS 5604 in sorghum; IP 4021, IP 6271and IP 3122 in pearl millet; IE 2333, ISe 376; IPm 1545, IPmr 699, IPs 197 and IEc 51 in small millets. Most of these accessions are either released cultivars or landraces, and originated either in South Asia (India) or in Africa (Burkina Faso, Cameroon, Ethiopia and Mali). The preferred traits in these accessions refer to wider adaptation, early maturity, large seed size and specialty trait (vegetable type pigeonpea). These accessions have been extensively used in crop improvement programs globally.

Several germplasm accessions have been used to develop cultivars and hybrids. In addition, many germplasm lines when evaluated by NARS produced higher grain yield that have been directly released as cultivars. Globally, 85 unique germplasm accessions, distributed to users from ICRISAT genebank, have been directly released as 108 cultivars in 38 countries. In addition, 572 cultivars (as of 2008) in 78 countries have been released by our NARS partners from the breeding materials supplied by ICRISAT that included the germplasm lines. These cultivars have greatly benefited those countries by increasing both production and productivity.

Developing core and mini core collections

Core collections are a cost-effective means of identifying accessions with desirable agronomic traits as well as new sources of resistance to biotic and abiotic stresses. However, in crop species with several thousands of germplasm accessions, even a core collection would be unwieldy for evaluation by the breeders in the multi-location trials. To overcome this, Upadhyaya and Ortiz (2001) postulated mini core collection concept which is a core of core (10% of core or 1% of entire collection) representing the species diversity. Mini core is established after evaluating the core collection for various morphological, agronomic, and seed quality traits, and selecting ~10% accessions from the core collection. Core and mini core collections have been developed in chickpea (Upadhyaya et al. 2001; Upadhyaya and Ortiz 2001), groundnut (Upadhyaya et al. 2002, 2003), pigeonpea (Reddy et al. 2005; Upadhyaya et al. 2006a), sorghum (Grenier et al. 2001; Upadhyaya et al. 2009a), pearl millet (Upadhyaya et al. 2009b), finger millet (Upadhyaya et al. 2006b) and foxtail millet (Upadhyaya et al. 2008). The concept and the process for developing mini core have been recognized as "International Public Good". These core and mini core sets are dynamic in nature and subject to revision once additional dataset become available on new sets of germplasm.

Using core and mini core to identifying new sources of variation

Agronomic traits including yield

The core and mini core collections have provided several new sources of variation for use in crop improvement programs. For example, using days to 50% flowering, pods per plant, seed yield and 100-seed weight as a selection criterion, Upadhyaya et al. (2007a) identified 39 accessions as most promising for early maturity, seed size and grain yield from chickpea core. Several pigeonpea accessions with early maturity, greater harvest index and shelling percentage, and high grain yield were identified (ICRISAT Archival Report 2008). Upadhyaya et al. (2006c) detected rich diversity among groundnut mini core accessions for early maturity, while more diversity for pod yield, shelling percentage and 100-seed weight was observed in Asia region core collection (Upadhyaya et al. 2005a). Pearl millet accessions with high green fodder yield, more productive tillers plant^{-1}, high spikelet density earhead^{-1}, greater grain yield, and large-seed size were identified (Upadhyaya et al. 2007b). Accessions with high grain and/or fodder yield, extra-early flowering, more basal tillers, panicles with variable exertion and head shape, and high soluble sugar content in stalk (for use in biofuel) were identified in sorghum. Likewise, accessions with high grain and/or fodder yield, early maturity, more basal tillers, and long inflorescence types were identified in finger millet and/or foxtail millet (ICRISAT Archival Report 2008).

Drought tolerance

Root length and root mass have been recognized as important traits for improving chickpea productivity under progressively receding soil moisture conditions. Kashiwagi et al. (2005) detected large genetic variation in chickpea mini core for root length density (RLD) and for the ratio of plant dry weight to RLD, and identified nine accessions with largest RLD and the deepest root system in comparison to drought tolerant accession ICC 4958. Moreover, the chickpea landraces from the Mediterranean and the West Asian region showed a significantly larger RLD than those from the South Asian region. Eighteen accessions from groundnut mini core were found tolerant to drought, as measured by SCMR and SLA (Upadhyaya 2005).

Salinity tolerance

Vadez et al. (2007) reported six-fold variation in chickpea mini core for seed yield under salinity, with 16 accessions yielding more than saline tolerant control, CSG 8962. ICC 1431, ICC 5003 and ICC 15610 were highly tolerant to salinity. Likewise, many accessions from groundnut and pigeonpea mini core collections performed well under saline conditions (ICRISAT Archival Report 2008).

Low temperature tolerance

Upadhyaya et al. (2009c) reported several accessions with capacity to germinate at lower temperature (12^{o}C), with many of them maturing and/or yielding similar to or greater than the controls. Some of the best performing low temperature tolerant accessions for pod yield were ICG# 12625, 13284, 2039, 13513, and 1824 in rainy and ICG# 12553, 12625, 7898, 10595, 6148, 6022, 7013, 7884, 7905, and 4992 in post rainy seasons.

Resistance to diseases

Pande et al. (2006) detected high level of resistance to fusarium wilt (FW) in 46 accessions while 3 were resistant to ascochyta blight (AB), 55 to botrytis gray mold (BGM), and 6 to dry root rot (DRR). Accessions with multiple resistance were ICC 11284 (AB, BGM); ICC 11764 and ICC 12328 (BGM, DRR); ICC# 1710, 2242, 2277 and 13441 (DRR, FW); and ICC# 2990, 4533, 6279, 7554, 7819, 9848, 12028, 12155, 13219, 13599 and 13816 (BGM, FW). A few sorghum accessions resistant to grain mold have also been identified.

We have supplied 19 sets of core and 68 sets of mini core collections to researchers in 20 countries and scientists have reported finding useful variation for grain yield, grain quality, and resistance/tolerance to stresses. For example, ICC# 5879, 7255, 8350, 10393, 10885, 12033, 13125, 14203, 14187 and 14199 have been utilized in chickpea breeding in India (Kaul et al. 2005; Johnson et al. 2007). Groundnut accessions with useful traits included ICG 8760 and ICG 3787 (resistant to rust and late leaf spot) in India (Kusuma et al. 2007); 11 to 14 accessions either with high quality oil or resistance to bacterial wilt in China; five large-seeded accessions each in China and Thailand; and five accessions with high shelling percentage each in China, Thailand and Vietnam (Upadhyaya et al. 2006c). Pigeonpea accessions exhibited rich diversity for agronomic traits (Singh et al. 2007), while some of the accessions were better adapted to nutrient-poor soil conditions (Rao and Shahid 2007).

Documenting feedback on germplasm utilization

Germplasm curators would like to have feedback from the researchers about the usefulness of germplasm that they receive from the genebank. This would help curators for better management of genetic resources in genebank. We have supplied 654,348 seed samples to ICRISAT researchers, 392,464 seed samples to researchers in India, and 307,224 seed samples to researchers in 143 countries (as of Dec 2008). We have developed a simple format for obtaining feedback from the users, which is sent along with seed materials. On following up with users, we now receive more feed back than in the past.

Crop germplasm registration

For information dissemination and avoid any claim on ownership, it is essential that germplasm/cultivars with specific attributes are notified for the benefit of researchers globally. ICRISAT has its own mechanism to notify the germplasm with specific attributes for registration. ICRISAT's Plant Material Identification Committee (PMIC) rigorously scrutinizes the proposal for its scientific accuracy. To date, we have notified 257 germplasm for registration. More recently, ICRISAT has opened up its own online journal, Journal of SAT agriculture (http://www.icrisat.org/jornal/about.htm), for researchers including those from NARS to register crops germplasm.

Manual for genebank operations and procedures

More recently, the earlier manual for genebank operation (Technical Manual no. 6) has been updated that will soon be available to users. It contains sections on germplasm assembly, plant quarantine, germplasm registration, seed processing and storage, monitoring seed health and viability, germplasm regeneration, germplasm distribution and utilization, crop specific descriptors, diversity assessment, and taxonomic classification of crops species. We hope that this manual will be helpful to genebank curators and researchers towards safeguarding plant biodiversity in *ex situ* collections and enhancing its use in crop improvement.

Mini core information bulletin

An information bulletin on use of mini core collection for efficient utilization of plant genetic resources in crop improvement will soon be available to germplasm users. Discussed in this bulletin are approaches to establish and validate core and mini core collections that researchers can apply for developing such sets in other crops.

Conclusions

To sum up, the germplasm scientists and allied discipline researchers at ICRISAT have generated huge data sets on characterization and evaluation of crops germplasm, which have been used to develop core and mini core collections. These subsets provided new sources of variation for use in crop improvement. Researchers globally can access the passport and characterization data on these germplasm. A number of germplasm with specific attributes have been registered in scientific journals. An updated version of the genebank manual will be available to those engaged in utilization and maintenance of germplasm. More feedback from researchers will help germplasm curators to serve the scientific community better, and to efficiently manage *ex situ* collections in genebank.

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