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Plant Genetic Resources and Germplasm Use in India

Curan A. Bonham*
Ehsan Dulloo **
Prem Mathur ***
Pratibha Brahmi ****
Vandana Tyagi *****
R. K. Tyagi******
Hari Upadhyaya*******

Abstract: Plant genetic resource (PGR) scientists now recognize the importance of shifting from a singular focus on conservation to a focus on both conservation and utilization of germplasm in order to meet future challenges. This paper analyzes the patterns of distribution of pearl millet, six small millets, chickpea and pigeonpea germplasm over the last 10 years at the two major genebanks functioning in India: the National Genebank at the National Bureau of Plant Genetic Resources (NBPGR) and a Consultative Group for International Agricultural Research (CGIAR) Genebank at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), as well as the patterns of use of germplasm by millet breeders in India. Between the years of 1999-2009, ICRISAT distributed approximately 48 per cent of all its collections to breeders in India whereas NBPGR distributed 36 per cent of their collection. A total of 20 responses (30 per cent of surveys sent) were collected through this study. Sixty-five percent of respondents said that they rarely (<50 per cent of the time) use germplasm from genebanks in their breeding programs. It is important that both genebanks look into several issues in order to improve levels of distribution and utilization, collection, duplication, engagement of the private sector, access to information, and pre-breeding.

Keywords: Germplasm, traits, plant genetic resources, breeding, ICRISAT, NBPGR.

* Bioversity International, via dei tre Denari 472/a, 00057 Maccarese, Rome, Italy
Email: c.bonham@cgiar.org

** Bioversity International, via dei tre Denari 472/a, 00057 Maccarese, Rome, Italy
Email: e.dulloo@cgiar.org

*** Bioversity International, Pusa, New Delhi, India - 110012 Email: p.mathur@cgiar.org

**** National Bureau of Plant Genetic Resources, Pusa, New Delhi, – 110012, India
Email: pratibha@nbpgr.ernet.in

***** National Bureau of Plant Genetic Resources, Pusa, New Delhi, – 110012, India
Email: vtyagi@nbpgr.ernet.in

****** National Bureau of Plant Genetic Resources, Pusa, New Delhi, – 110012, India
Email: rktyagi@nbpgr.ernet.in

******* International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh– 502 324, India. Email: h.upadhyaya@cgiar.org

Introduction

Germplasm collection in India began in earnest in the 1950s due to threats to the disappearance of landrace varieties. Since then thousands of landraces and crop wild relatives, which have provided the source of genes for breeding improved cultivars, have been collected and conserved in genebanks. However, little information is available about the extent to which their genetic diversity has been used to increase crop production (Pardey *et al.*, 1999). Plant genetic resource (PGR) scientists now recognize the importance of shifting from a singular focus on collection and conservation to a focus on both collection/conservation and access and utilization of germplasm in order to meet the challenges of feeding a burgeoning population in the face of a changing climate (Frankel, 1986; Jie Wang *et al.*, 1998). It is thought that through the incorporation of the valuable genes held in genebanks into new crop varieties, these challenges may be overcome.

FAO (2010, 1998) reported that only a few national genebanks had distributed more than 10 per cent of their germplasm, and most of this went to breeders and researchers. Nevertheless, some larger national programmes, such as the US National Plant Germplasm System, has distributed a significant portion of germplasm both domestically and internationally (Smale and Day-Rubenstein *et al.*, 2002). A 15-year Chinese study showed that a much larger number of cultivars and advanced lines were distributed than landraces, wild relatives or genetic stocks (Weidong, 2000). This implies the existence of a considerable unrealized potential for use of plant genetic diversity for increasing food security.

Plant genetic resources were, up until about 20 years ago, held in an open access regime, as global public goods, and were considered as the "common heritage of mankind" (Raustiala and Victor, 2004; Hammer, 2003). New international treaties, such as Trade Related Aspects of Intellectual Property Rights (TRIPS) and International Union for the Protection of New Varieties of Plants (UPOV), established an intellectual property rights regime on plant variety development; and the Convention of Biological Diversity (CBD), granted sovereign rights to nations over biodiversity including genetic resources. These developments have had a large impact on the flows and rules for the access and use of germplasm. The policy and legal regimes along with *sui generis* laws in signatory countries have raised uncertainty with regards to access and benefit sharing and may be responsible for decline in flow of PGR (Gotor and Caracciolo, 2008).

Some of the most nutritious and valuable crops for small scale farmers in South Asia, the millets and pulses, have not been included in systematic analyses of the extent of use and distribution among genetic resources users (i.e. breeders and researchers). This gap in understanding and the general one-sided focus of agricultural research on major crops of global economic importance (e.g. rice, wheat, and maize) limits our ability to meet the needs of the over 1 billion small scale farmers which rely on neglected crops like the millets and pulses (Mazoyer, 2001).

There is global concern over whether genebanks are achieving the far reaching goals for which they were created such as the conservation and use of the world's PGR. Principle among those goals is the exchange of germplasm between genebanks and users of germplasm which includes researchers, breeders and farmers. The aim of this paper is to analyze the patterns of distribution and use of millet and pulse germplasm over the last 10 years at the two major genebanks functioning in India: the National Genebank at the National Bureau of Plant Genetic Resources (NBPGR) and a CGIAR Genebank at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

NBPGR conserves over 3000 crops of India with a total number of accessions of 395,168, while ICRISAT only conserves the five mandate crops (pearl millet, sorghum, pigeonpea, chickpea, and ground nut) as well as six small millets of the Semi-Arid Tropics with a total of 119,739 accessions. With regard to the four target crops of this study (i.e. pearl millet, minor millets, chickpea, and pigeonpea), ICRISAT holds 66,345 accessions while NBPGR has 57,596 accessions. NBPGR distributes germplasm maintained in network mode from its regional stations and other National Active Germplasm Sites (NAGS), where the active collections are held, while ICRISAT distributes samples from the genebank maintained at its headquarter near Patancheru in India.

This paper examines germplasm sources and flows for these valuable and often neglected crops in India. The data provide the basis for identifying ways to conserve and make available this local germplasm for crop improvement and direct use. In doing so, we also look at the constraints breeders and researchers face in accessing genebank materials and discuss how best to address them.

Methods

To assess the exchange and use of germplasm in India, we collected

information about germplasm distribution and use based on surveys from two distinct stakeholder groups: genebanks and breeders/researchers. We focused our analysis on four major crops namely, pearl millet, minor millets, chickpea, and pigeonpea. These crops were deliberately chosen for several reasons: comparative purposes, as pairs (cereals and legumes), based on their economic and food security importance in India, and because these genebanks hold major collections of these crops in India.

NBPGR and ICRISAT provided germplasm distribution information regarding the quantity of samples, type of recipient, and total collections conserved for the last 10 years for all four target crops. Additionally, a short questionnaire was completed by genebank staff, which explored the mechanisms that link genebanks to users as well as the constraints that impede access to germplasm. This survey also sought to answer the following questions: What percentage of the genebank collections are being accessed by users? Which crops have been accessed most frequently by whom? How can genebank management be improved to facilitate increased germplasm distribution?

We also collected information directly from germplasm requestors or "indenters", as they are called in India, through a survey which was sent to 60 millet indenters, breeders, and researchers, both public and private, registered in India. The breeder survey was designed to elicit responses to better understand the following questions: What are the constraints to germplasm exchange? What mechanisms can be developed to overcome those constraints? Who is requesting germplasm? How much germplasm is used by the average indenter?

This survey was delivered both electronically and by post with instructions and a letter of support from associated institutions. The respondents were given 3 months to complete the 15 questions included therein. All surveys were mailed by 30 July 2010 and received by 30 October 2010.

The Active Germplasm Distribution Index (AGDI) was calculated for the target crops in order to provide indicators of the degree of distribution of these particular crop groups. The AGDI is an indicator of the relative utilization of a germplasm collection in comparison to the overall holdings of a specific crop. It has been used in the past by others (Iwanga, 1993; Hodgkin *et al.*, 2003), which makes it apt for cross genebank comparisons. It is calculated as:

AGDI = [n/(a/100)]/b

where n= total number of accessions distributed, a= total accessions conserved, and b= number of years)

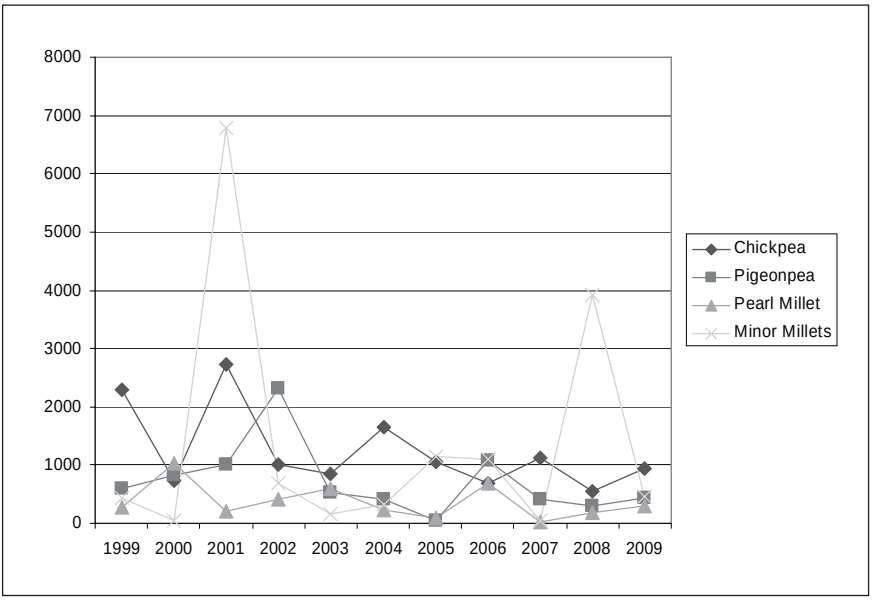
An analysis of the commonalities among breeders was also undertaken in order to understand the needs and focus of millet breeding programmes in India. This analysis serves to inform genebank management decisions in light of the current policy scenario governing exchange of PGR.

Results

Patterns of Distribution - Genebanks

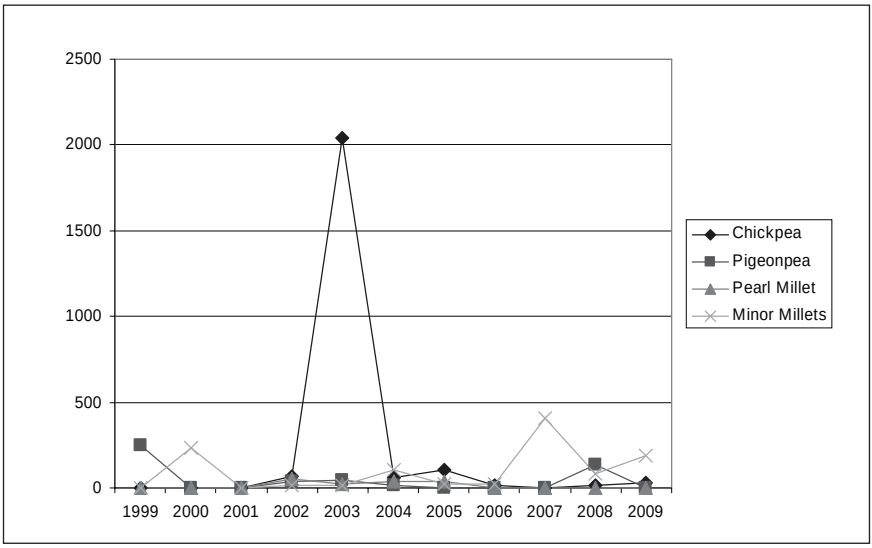
The trend in germplasm distribution over 10 years in each genebank is shown in Figures 1 and 2.

Figure 1: Germplasm Accession Distribution from ICRISAT Genebank during 1999-2009.



Source: Calculated from data provided by ICRISAT update to SINGER/Genesys on Aug 2010. Includes data for germplasm accessions distributed in India from 1999-2009.

Figure 2: Germplasm Accession Distribution from NBPGR Genebank during 1999-2009.



Source: Calculated from data provided by NBPGR on September 2010 encompassing germplasm distributed from 1999-2009.

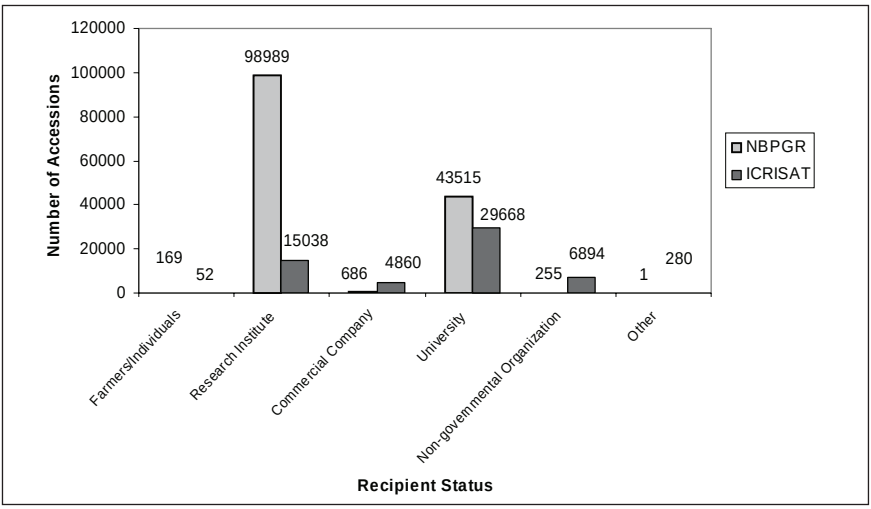
AGDI calculated for four selected crops from the two genebanks data is presented in Table 1 below.

Table 1: Sample Distribution Per Crop and its Corresponding AGDI over 10 Years for ICRISAT and NBPGR Genebanks.

Genebank	Crop	Number of Accessions Distributed	Number of Accessions Conserved	Active Germplasm Distribution Index
ICRISAT	Chickpea	13625	20267	6.72
	Pigeonpea	7939	13632	5.82
	Pearl Millet	4001	22211	1.80
	Minor Millets	18882	10235	18.45
	All Crops	56792	119739	4.74
NBPGR	Chickpea	2341	9325	2.51
	Pigeonpea	486	7629	0.64
	Pearl Millet	148	8031	0.18
	Minor Millets	1092	21706	0.50
	All Crops	143615	395168	3.63

It is also important to understand what types of users are accessing germplasm conserved in genebanks. Figure 3 shows the total volume of germplasm distributed to particular user groups by each of the genebanks considered. It shows that research institute and university researchers were among the major recipient of germplasm from both genebanks, especially from the national genebank. ICRISAT on the other hand distributes more germplasm to private and Non governmental organizations.

Figure 3: Germplasm Distribution from ICRISAT and NBPGR Genebanks to different Recipient Groups from 1999-2009

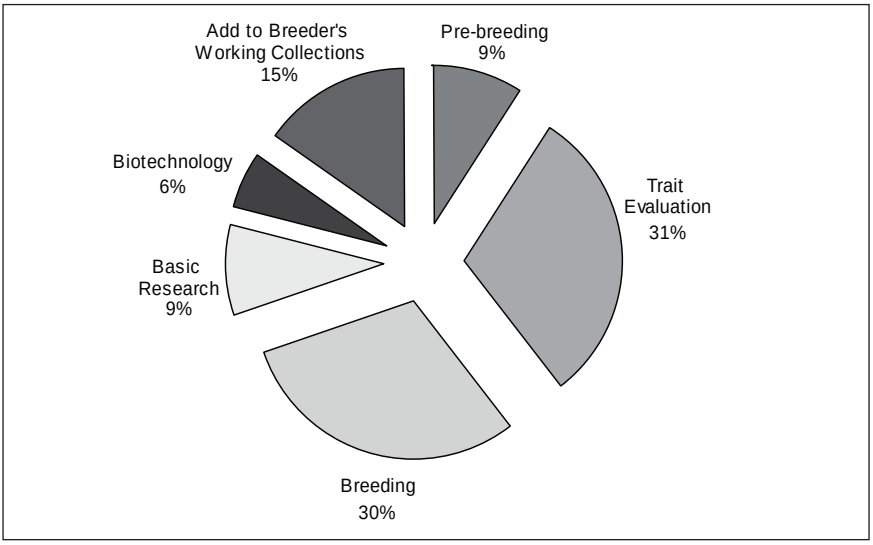


Patterns of Use - Plant Breeders

A total of 20 responses (30 per cent of surveys sent) were collected through this study. Due to the limited sample size, this analysis can only be considered preliminary in nature. Nevertheless, the results highlight some important trends with regards to germplasm use by breeders.

Although, genebanks potentially house a vast repository of novel genes that could be useful in breeding new crop varieties, 65 per cent of respondents said that they rarely (<50 per cent of the time) use germplasm from genebanks in their breeding programs. Of those respondents that accessed germplasm from genebanks, the average number of accessions requested during the 10 year period was 466 accessions, and of those accessions an average of 25 per cent (116 accessions) were being actively utilized in breeding programmes. The various uses of this germplasm by respondents are presented in Figure 4.

Figure 4: Use of Millet Germplasm by Breeders in India



Source: Survey by authors.

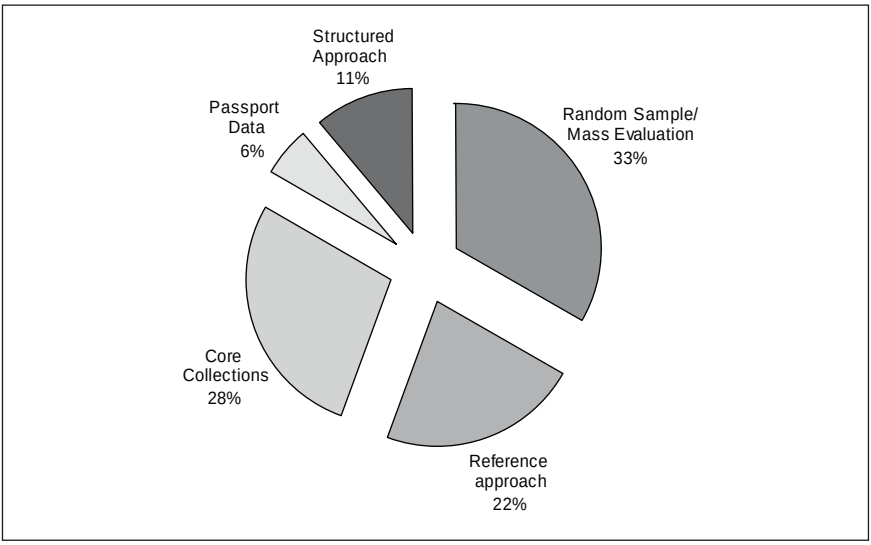
The most important characters that breeders sought to develop in their new varieties were elicited through the survey, and the gaps in the array of traits already available in their breeding collections were also identified. The results of the most common responses are presented in Table 2.

Table 2: Sought-after-traits and Gaps

Traits	**Response Rate)**
Character Sought	
High Yield	85
Drought Tolerance	40
Disease Resistance	75
Early Maturity	55
Gap Found	
High Yield	55
Drought Tolerance	45
Disease Resistance	45
Early Maturity	35

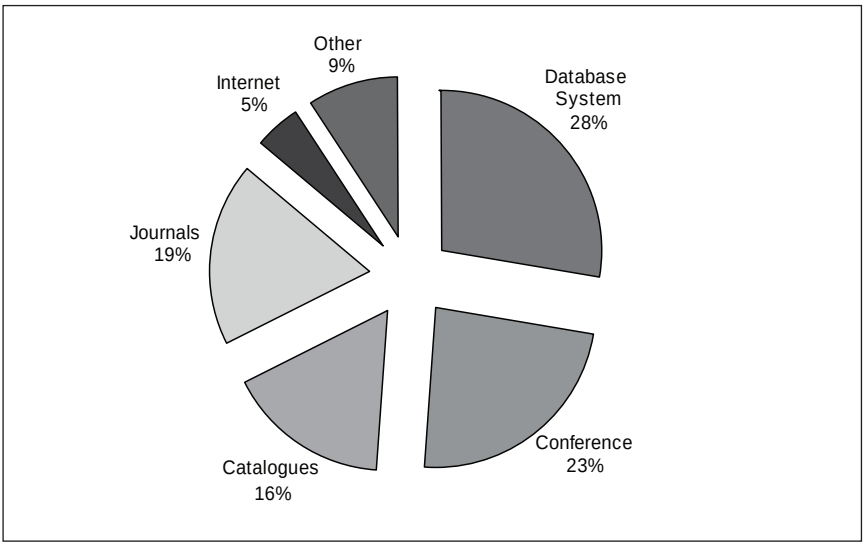
Breeders have a variety of methods and approaches for acquiring and accessing information about germplasm in order to target specific accessions of interest (see Figure 5 and 6). Among the different approaches is Random Sample, which refers to requests for large numbers of germplasm of unknown genotype and origin, the most widely used method with 33 per cent. Core collections, that is the use of a subset of defined genotypes selected through principle component analysis was the next highest strategy adopted by users. Reference approach, the use of some reference to target a particular accession, be it through literature or by personal recommendation, also represented a high percentage (22 per cent). The use of simple passport information associated with accessions to target specific accessions (passport data), and Structured approach which includes an indenter-defined strategy or system for targeting specific accessions were also used to some extent. Figure 6 also shows the different sources by which breeders obtain their information. Breeders are primarily using some form of a database system as well as interactions at conferences or conference proceedings in order to avail themselves of useful accessions held by genebanks. While it appears that the potential for internet dissemination of accession related information is underutilized.

Figure 5: Breeders Approaches to Germplasm Acquisition



Source: Survey by authors.

Figure 6: Breeders Approaches to Accessing Information about Germplasm



Source: Survey by authors.

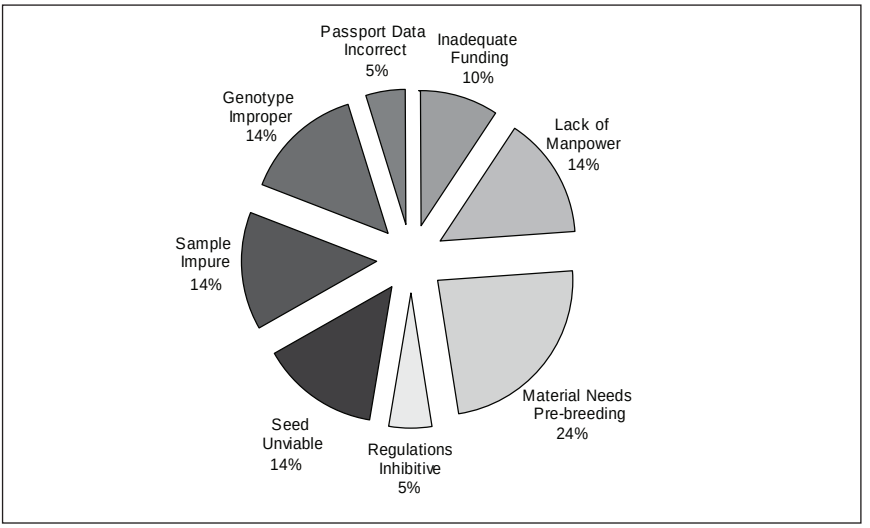
While breeders identified a number of mechanisms of accessing germplasm collections they also recognized several constraints which limit their access to *ex situ* collections. Those constraints are highlighted in Figure 7. The need for pre-breeding is highlighted as the most important problem hindering the usage of germplasm provided to breeders. Additionally, technical issues are also mentioned as constraints to effective germplasm utilization, such as, lack of manpower, impure, unviable samples, and improper genotypes.

It is important to note that 40 per cent of respondents suggested that field days and demonstration trials be conducted more frequently in order for breeders to be able to see the accessions in the field. Additionally, 45 per cent of respondents suggested that access to data be improved through regular publication and wider circulation of germplasm catalogues, publication of information on the internet, or linking passport data with evaluation data on a single database.

The survey also elicited responses about perceived benefits accrued through the use of germplasm which is displayed in Figure 8. The enhancement of breeding lines and cultivar development constitute the major benefits of using germplasm mentioned by breeders, but it's clear

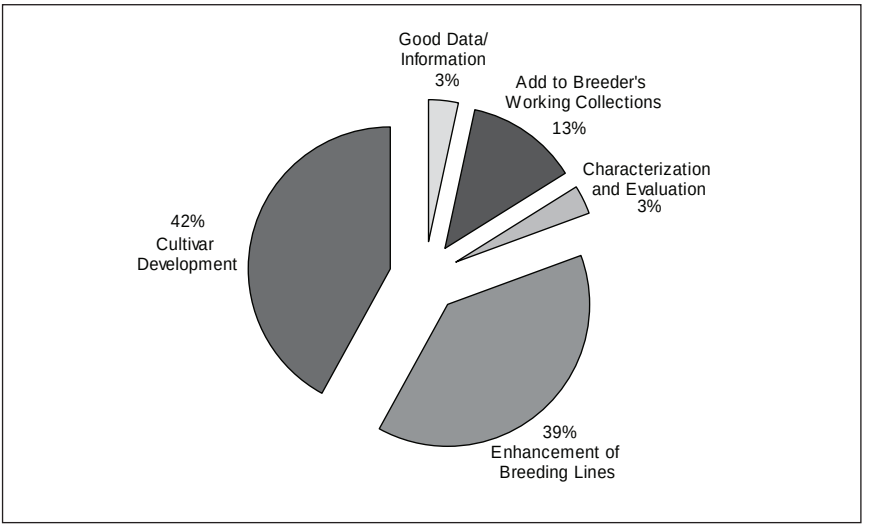
that breeders are also using germplasm from genebanks to establish their own in house PGR collections (13 per cent).

Figure 7: Problems Which Limit the Access to and Utility of Germplasm from Genebanks



Source: Survey by authors.

Figure 8: Benefits Associated with Germplasm Use



Source: Survey by authors.

Discussion

Patterns of Distribution - Genebanks

Between the years of 1999-2009, ICRISAT distributed approximately 48 per cent of all its collections to breeders in India, whereas NBPGR distributed a relatively smaller proportion of 36 per cent. This level of distribution is considerable in light of the relative size of these collections. NBPGR is the third largest genebank in the world and ICRISAT is the third largest gene bank among the CGIAR genebanks (FAO, 2010). This analysis only encompasses data of germplasm distribution to indenters located in India. Nevertheless, these levels of distribution are comparable to annual levels of germplasm distribution reported by other large genebanks (FAO, 1998; FAO, 2010; Hodgkin *et al.*, 2003).

There is also a great degree of fluctuation between levels of distribution from year to year which highlights the importance of analysis of distribution data over the course of multiple years. It is not clear what is responsible for these large year to year fluctuations, but they may be a response to the initiation of a particular research institute's germplasm evaluation projects which aim to carry out mass evaluation of specific crop germplasm.

ICRISAT has a greater AGDI for all four target crops, but this doesn't mean that NBPGR distributes less germplasm. In fact, NBPGR distributed almost three times the amount of germplasm that ICRISAT did over this 10 year period. When the AGDI of these genebanks' total distributions and holdings is compared, the result is actually quite similar as is evident from the AGDI value for all crops as mentioned in Table 1. These data may allude to the fact that a duplication effect is occurring. Where genebanks that hold similar materials are both accessible, germplasm users have a preference for one genebank at the expense of the other. Since ICRISAT specializes in five mandate crops, it is more sought-after for the four target crops of this study which are among those five mandate crops and are common to both genebanks. For other crops not held in the ICRISAT genebank, germplasm users in India are more likely to use the collections held by NBPGR. By conserving similar accessions these genebanks may be inadvertently duplicating their efforts with regards to these four target crops. The unique accessions held by each genebank should be identified so that breeders can easily access truly distinct accessions and avoid replication in their breeding programmes.

Although there are several categories of germplasm users, there is no doubt that the largest recipients of germplasm samples are from the research

institute and university sectors. In India, from a plant breeding perspective, this distinction is almost not worth making as the line between a research institute and a university is blurry due to the structure and intersection of funding from the central government to the land grant universities and research institutes. Often these two sectors operate on the same campuses and have tight linkages in their research objectives.

However, it is worth noting that ICRISAT distributes a much higher quantity of germplasm to commercial companies and non-governmental organizations (NGOs) than does NBPGR. This may be due to the fact that only few indenters from commercial companies and NGOs send their requests for germplasm of these target crops to NBPGR.

This network of private companies has the capability of developing useful new varieties for the benefit of small farmers. Private sector companies also need to more openly share germplasm collections and information held by them with public sector users. This will further build trust and strengthen the public-private relationship. The National Seed Association (NSA), a consortium of private seed companies in India, has also voiced the need for the harmonization of germplasm exchange so that this untapped potential can be readily accessed by the private sector. ICRISAT has made recent inroads into developing working relationships with the private sector through public-private partnerships, which is reflected in the relatively larger share of germplasm being exchanged with commercial enterprises.

Additionally, farmers/individuals account for a negligible amount of germplasm exchange. Although genebanks were not initially designed with farmer-genebank exchange in mind, the benefits of creating such linkages have been the subject of several analyses (Bramel-Cox, 2000; Ngoc De, 2000; Worede, 2000) and could be a logical and beneficial extension of genebank activities.

Patterns of Use – Plant Breeders

The majority of the millet breeders surveyed used the requested germplasm for trait evaluation and basic breeding. Most breeders are particularly interested in developing high yielding, disease resistant, drought tolerant and early maturing varieties. These traits are also identified as major gaps in the genotypes that they currently have available to them. It is true that the same traits figure in both traits preferred and gap in availability as in Table 2. This is can be considered as more a reflection of the importance placed on the traits than a reflection on their availability.

With respect to the methods breeders use to acquire germplasm from genebanks, it is clear that breeders generally use random selection and simultaneous mass evaluation of many accessions obtained from the genebanks. However, the traditional practice of reviewing the scientific literature for the identification of potentially useful accessions is also a prevalent method used to access germplasm. More recently, the use of core collections has become an important method that breeders use to access the range of diversity conserved in the genebank (van Hintum *et al.*, 2000).

One of the major improvements suggested by breeders to increase utilization of germplasm is to improve the information that is available about accessions. Currently, breeders primarily use some form of a database system, whether managed by genebanks or the breeders themselves, in order to request germplasm, but conferences, journals, and catalogues are also identified as important sources of information about potentially useful germplasm. ICRISAT has made available a catalogue of all its accessions including passport data on-line through their own website and the SINGER portal. However, NBPGR has yet to publish a comprehensive database of its accessions on-line. In neither of these cases is evaluation and characterization data linked to accessions made readily available in a searchable web-based format. Searchable web-based databases that link evaluation data from multi-location trials to passport data about accessions were mentioned as a suitable way to share information. Nevertheless, often breeders are located in remote field stations that have limited access to the internet and publications.

Additionally, field days were commonly mentioned as solutions to this problem. Breeders maintained that "seeing is believing" and that there is no substitute for seeing the accession in the field. Although NBPGR has been organizing field days for demonstration of promising genetic diversity and germplasm registered with unique traits in the field, there is further scope to invite more breeders/researchers to select germplasm of interest.

As this study shows, one of the main problems associated with the use of germplasm in breeding programmes identified by respondents is the need for pre-breeding (Figure. 7). The major importance of pre-breeding in linking breeders to germplasm collections has also been identified by breeders and scientists elsewhere (FAO, 2010; Tikader and Dandin, 2007; Valkoun, 2001; Nass and Paterniani, 2000). Much of the germplasm available in genebanks is unimproved and has a broad genetic base with many undesirable characteristics. Breeders are looking to develop traits

which are tightly coupled, such as high yield and early maturity, and this requires many successive iterative selections requiring a high investment of time. Therefore, the initial time investment needed for pre-breeding is often a disincentive to the use of unimproved germplasm by breeders, as they are under pressure to produce results as quickly as possible. For this reason, it is common that many breeders turn to advanced breeding materials already maintained in their respective institutes and make crosses with this material instead of exploring the possibility of incorporating new material from genebanks into their breeding programs. Nass and Paterniani (2000) state that pre-breeding is the most promising alternative to linking genetic resources and breeding programmes. Genebanks can increase the value of accessions as well as their use by playing an active role in not only evaluating phenotypic characteristic, but by also making preliminary selections and identifying the desirable traits of a subset of the germplasm conserved.

While the difficulty in finding useful accessions in genebanks is a particularly daunting challenge, a majority of respondents identified both the enhancement of breeding material and the development of new cultivars as the most important benefits accrued through the use of germplasm from genebanks. Ultimately the goal of any breeding programme is to develop new varieties and the fact that these benefits are perceived by breeders is a positive indicator that these genebanks are achieving their goals and that breeders will continue to use the germplasm conserved in genebanks.

Conclusions

The results from this analysis point to a healthy well functioning system of germplasm conservation and use. It is apparent that a large volume of germplasm is being distributed by both of these genebanks and that Indian plant breeders are interested and engaged in germplasm acquisition. Nevertheless, any system that is not continually calibrated can easily fall into disrepair. As such we outline several points which need careful consideration in order to improve the efficiency of this system and ultimately deliver the products needed to address the challenges of food security in India.

- The duplication of collections, although a standard practice from a safety back up perspective, has been viewed as a waste of capacity and inefficiency, when it is done inadvertently (van Hintum and Knupffer, 1995). It appears that there is some overlap between the collections conserved in these genebanks and it is important to

identify where this duplication is occurring. It is also important that NBPGR and ICRISAT work together to find synergies wherein complementary projects can be developed such as linking available data to commonly held accessions.

- Although public sector breeders at universities and national research institutes are accessing large amounts of germplasm, the private sector has not been fully engaged by either of the genebanks. NBPGR may follow ICRISAT's lead by establishing joint projects with private companies, which aim to develop new varieties of not only lucrative crops like hybrid maize, but also for composites and open-pollinated varieties of crops like the millets and pulses, which are important for small scale food insecure farmers.
- A common theme among breeders responding to the survey was the need to develop mechanisms for information exchange between genebanks and breeders. In order to provide these breeders with information regarding available accessions it is necessary that more resources be allocated to the development of information systems and the dissemination of information about germplasm holdings in genebanks.
- In order to make germplasm more valuable and readily usable breeders have emphasized the importance of pre-breeding. Breeders from this study identified the need for pre-breeding as the largest problem associated with the utilization of PGR held in genebanks. Thus, there is a need to give equal emphasis on pre-breeding and germplasm utilization to both important crops at the national level as well as the target crops of this study.
- These challenges and the necessity for timely solutions to them, become all the more relevant in light of the fact that the "green revolution" varieties that have been credited with averting the starvation of millions of people were developed through the use of diverse plant varieties originating in myriad countries at a time when there was essentially free exchange of genetic resources. We are now faced with the dual challenge of meeting the needs of a growing population while also adapting our agricultural systems to climate change. For these reasons, a coherent and efficient system of germplasm exchange is needed which addresses the needs of the small scale farmers in India.

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