Managing and accessing genetic stocks in genebanks

Genetic Stocks Management Workshop
Bologna, Italy 28-29 April 2010

Report prepared by **Nicolas Roux, Mathieu Rouard** and **Dave Ellis**
for the Global Public Goods Programme Phase 2
of the System-wide Genetic Resources Programme

The CGIAR System-wide Genetic Resources Programme (SGRP) joins the genetic resources activities of the CGIAR centres in a partnership whose goal is to maximise collaboration, particularly in five thematic areas: policy, public awareness and representation, information, knowledge and technology, and capacity building. These thematic areas relate to issues or fields of work that are critical to the success of genetic resources activities.

SGRP contributes to the global effort to conserve agricultural, forestry and aquatic genetic resources, and promotes their use in ways that are consistent with the Convention on Biological Diversity (CBD). The Inter-Centre Working Group on Genetic Resources (ICWG-GR), which includes representatives from the centres, FAO and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), is the Steering Committee. Bioversity International is the Convening Centre for SGRP and hosts its coordinating Secretariat. See www.sgrp.cgiar.org.

Citation: SGRP 2011. Report prepared by Nicolas Roux, Mathieu Rouard and Dave Ellis for the Global Public Goods Programme Phase 2 of the System-wide Genetic Resources Programme. Genetic Stocks Management Workshop, Bologna, Italy 28-29 April 2010. System-wide Genetic Resources Programme, Rome, Italy.

SGRP

Managing and accessing genetic stocks in genebanks

Report prepared by **Nicolas Roux[1], Mathieu Rouard[1]** and **Dave Ellis[2]** for the Global Public Goods Programme Phase 2 of the System-wide Genetic Resources Programme

Genetic Stocks Management Workshop
Bologna, Italy 28-29 April 2010

Additional contributors to this report: Bioversity International, France (Elizabeth Arnaud); CGIAR, CAS-IP, Italy (Victoria Henson-Apollonio, Francesca Re Manning); Kansas State University, USA (Bikram Gill); GCP, Mexico/CIRAD, France (Jean Christophe Glaszmann); NIAS, Japan (Makoto Kawase); NIG, Japan (Nori Kurata); IAEA, Austria (Pierre Lagoda); University of Nottingham, UK (Sean May); ICARDA, Syria (Francis Ogbonnaya); IRRI, Philippines (Ruaraidh Sackville Hamilton); ICRISAT, India (Shivali Sharma); NBPGR, India (Shyam Sharma); CIAT, Colombia (Joe Tohme); University of Bologna, Italy (Roberto Tuberosa); AfricaRice, Benin; CIMMYT, Mexico; IITA, Nigeria; SGRP; SINGER.

[1] Bioversity International – France, Parc Scientifique Agropolis 2, 34697 Montpellier Cedex 5, France

[2] Plant Genetic Resources Preservation Program, NCGRP, USDA-ARS 1111 South Mason Street, Fort Collins, CO 80526, USA.

SGRP

Contents

Summary

Genetic stocks, broadly defined as plants or populations generated and/or selected for genetic studies, represent a unique and growing class of extremely valuable germplasm which, depending on crop, type of genetic stock and user, community may represent genetic resources of either transient or long-lasting value. Genetic stock collections can broadly be divided into three general groups: cytological stocks (e.g. chromosome addition/substitution, aneuploids, amphiploids), mutants (e.g. induced/insertion mutants, tilling populations) and germplasm sets (e.g. mapping populations, parental lines, reference germplasm). Any one genetic stock collection can represent a few lines to tens of thousands of lines and therefore can potentially offer a challenge, as well as a burden, to genebank managers from the standpoint of storage and maintenance. Another challenge with genetic stock collections is the rapidly changing technology used to development new genetic stocks which may make older collections obsolete. Therefore, the genebank manager is faced with having to predict the long-term value, and hence the need for long-term maintenance, of any given collection. Despite the contrasting options of long-term value for some collections versus short-term value for other collections, there is no question that genetic stock collections should be preserved and that the global system, including CG genebanks, need to play a role in their preservation.

The development of programmes to document and list existing and future genetic stock collections for all major crops is of upmost importance. Such a list would be dynamic, needing continual updating as new stocks are generated. For the major target crops no comprehensive list currently exists, even for wheat, maize and rice.

Results from our initial survey indicated that:

- Genetic stocks exist for all focus crops (rice, wheat, barley, maize, chickpea, cassava, banana);
- Collections vary in size and complexity between crops;
- Current funding for collection maintenance and distribution is mostly from project, and less from core, funds;
- Collections are not uniformly catalogued and usually not available on line;
- There is little coordination of collections between sites or crops;
- A majority of collections are distributed for no charge;
- Institutions generally do not have distribution policies in place.

Genetic stock collections primarily exist in:

1. Individual academic laboratories;
2. University genetic stock centres with multiple faculty sharing responsibility for maintenance and development of collections;
3. Government genetic stock centres;
4. As accessions in conventional genebanks.

The first category includes large holdings of individual genetic stock collections which are the most vulnerable to lose due to changes in funding, research direction and retirement of the principal scientist who developed and distributed the collections to the user and research communities. The second category, genetic stock centers at Universities, are generally at lesser risk, yet are also vulnerable as they are often supported with short-term funds, such as grants, which are continually subject to uncertainties in ongoing funding. Government or nationally run genetic stock centres and accessions in genebanks are the most stable in terms of funding however these too can suffer from retirements or changes in direction of key personal if not linked to a broader national genetic resources system or supported by long-term funds from user groups. Genebanks in the global system, such as CG genebanks, although subject to funding fluctuations, are viewed as the most stable and are deemed as having a role in the short- and long-term preservation of genetic stocks collections.

Issues for genebanks committing to the storage and/or maintenance of genetic stock collections include:

- Predicting the potentially transient nature of use and value of any one particular genetic stock collection;
- Having the resources for the often difficult regeneration of thousands of genetic stock lines;
- Having dedicated staff and technology for specialized quality control of regenerated genetic stock lines;
- Special challenges, including financial, for genetic stock collections of clonal material.

Thus, unlike conventional plant germplasm collections, where genebanks commit to the long-term storage of all unique germplasm, an initial decision to the level of commitment for long-term versus short-term maintenance may have to be made by the genebank manager/curator prior to acceptance of the genetic stocks collection. A decision tree outlining options for the genebank manager has been developed to aid in this decision. The genebank manager/curator must use the knowledge from the provider, the user community and his/her own personal knowledge of the crop and technology, to make decisions as to the acceptance of genetic stocks on a long-term versus short-term basis.

The acceptance of genetic stock collections by the global system for the long-term would be similar to any other germplasm accession where the genebank manager/curator would make the commitment for distribution and maintenance (including long-term storage, regeneration and quality control) of the collection. In contrast, if the user community, provider or genebank manager/curator feels the genetic stock collection may not have sufficient long-term value to warrant the commitment of resources for long-term maintenance, the collection could be rejected or accepted under conditions for short-term storage and distribution without regeneration. One example of how a genebank might handle a genetic stock collection on a short-term basis could be a mapping population where the donor provides a limited number of seed (100-1,000 seed) for each line in the population and the genebank only makes the commitment to store and distribute the seed until the donated supply is exhausted. No commitment for regeneration of the lines would be made at the time of acceptance, yet based on use (requests for germplasm) and resources, this short-term commitment could be revised at a later date if desired for one or more of the lines. As new technologies and new genetic stocks are developed, the genebank manager/curator must have the flexibility based on potential long-term value of the collection, available resources and the demands for routine germplasm to inactivate existing genetic stock collections when they become obsolete (e.g. after 10 years).

Procedures for managing and accessing genetic stock collections will require a commitment from both the provider and the genebank to adhere to genebank best practices and to continue to meet the needs of the user community. Policies for the maintenance of collections will need to evolve as the technologies advance and change. Genebank functions and funding will need to be tailored to efficiently meet new demands posed from these collections to ensure the global system can sustainably meet their needs and those of crop communities to continue building food security and sustaining productivity.

1. Introduction

Background

The System-wide Genetic Resources Programme (SGRP) starting in 1998 and Global Public Goods Phase 2 (GPG2) have hugely contributed to the integrated operation of the CGIAR genetic resources centres. These programmes, in conjunction with the Phase 1 of GPG, have strengthened the capacity and infrastructure for the secure, long-term *ex situ* conservation and use of plant genetic resources globally. These programmes included 11 of the 15 CGIAR centres covering over 600,000 accessions. With the emphasis of unifying a global system with national and university genetic resources interests, these programmes have been tremendously successful by providing the underpinning for a long-term global system for plant genetic resources. Understandably, the focus has been on the more traditional uses of genebanks, such as plant breeding and plant conservation for improving and securing food and agriculture productivity and safety. However, in recognition of the growing number of collections of plant genetic resources which are not developed as a direct input to breeding programmes, but rather as genetic tools, these programmes wisely included this study to better understand how genebanks might handle these types of "non-traditional" genetic resources collections.

Importance of genetic stocks

Genetic stocks are collections of plants developed specifically for genetic studies. These collections are often by necessity genetically heterogeneous, varying in only one (mutants) to a few to many (mapping populations) loci within the genome of different members of the populations. The collections could vary from less than a hundred lines to tens of thousands of lines and can be highly characterized, characterized only at a single genetic locus or be largely an uncharacterized treasure chest awaiting discovery. Their use could be huge for a matter of years only to be made obsolete by a new technology and new collection of individuals derived from this new technology. Regeneration can be problematic with some genetic stocks (double haploid, gametophytic lethals) as they may produce very small quantities of seed and often require advanced quality control measures which a genebank may not be set up to do (cytogenetics) on a large scale, if at all.

Currently, many genetic stock collections are conserved in an assortment of different genebanks, some specializing in a single crop (The Nottingham *Arabidopsis* Stock Center, the Wheat Genetic and Genomic Resources Center, the Maize Genetics Cooperation – Stock Center, the Genetic Stocks – *Oryza* (GSOR) Collection, the C.M. Rick Tomato Genetics Resource Center), while other genetic stock collections are maintained as a subset in traditional genebanks (G.A. Marx *Pisum* Genetic Stock Collection, *Phaseolus* Genetic Stock Collection, G.A. Marx Pea Genetic Stock Center, Barley Genetic Stock Collection, E.R. Sears Wheat Genetic Stock Collection). However, even with these single crop genetic stock centres, there still remains a huge pool of genetic stocks which are maintained by academic labs on grant funds and are therefore at risk for loss when grants no longer fund the work or the investigator retires. Of greater concern is the fact that many of the collections are poorly maintained (stored in bags at room temperature) and their existence may be unknown except to a very few in the field.

Why this report is needed?

Genetic stock collections are a valuable genetic resource in need of attention from the international community to ensure conservation and access to a wider community. Unfortunately, conservation of genetic stock collections requires a different commitment than currently used or available at most genebanks. This report is intended as an early survey of issues with the genebanking of genetic stock collections and includes recommendations to help initiate discussions so that curators, administrators, scientists, breeders, policy makers and funders can increase awareness of conservation needs for these potentially invaluable and at risk genetic resources.

2. What are genetic stocks?

Genetic stocks are plants or populations generated and/or selected for genetic studies. Examples of major classes of genetic stocks are listed in Table 1. No attempt was made to compile an all inclusive list of everything that could be considered genetic stocks but rather to provide examples. It is anticipated that technology will continue to evolve and new and better ways for developing and using genetic stocks will progress. Therefore any list generated today will likely have examples which will be obsolete or have only narrow application in the future.

Table 1. Examples of types of genetic stocks in the three major categories.

Types of genetic stock collections
1 – Cytogenetic stocks
Addition, substitution, inter-specific chromosome introgression
Chromosome Segment Substitution Lines
Aneuploid (monosomic, telosomic, ditelosomic, double-ditelosomic, nulli-tetrasomic)
Synthetics/Amphiploids
2 – Mutant stocks
Deletion/duplication/deficiency/translocation
Induced mutants (pure, stable and characterized)
Tilling populations (M2 derived, M3 and M4)
Insertion mutant populations
3 – Germplasm sets
Parental lines
Mapping and NIL/RIL/DH populations
Reference germplasm (e.g. mini core, sequencing, trait specific)

3. Summary from genetic stocks survey

A survey was conducted to assess genetic stock collections within and outside the CGIAR. The survey was designed as follows:

- Background information: basic contact details, organizations' governance and primary function
- Collection: Scope, size of collection in number of accessions
- Staffing: Number of staff, qualification, change of staffing
- Funding: Core vs. project based funding, future outlook
- Facilities: Adequacy of storage space and facilities, technologies in collection characterization
- Methods used, standards applied in preservation and documentation
- Uses and users: Primary purpose and users of collection, specialist service provided
- Accessibility: Proportion catalogued and web-accessible, policy on management of collections
- Intellectual property rights: Intellectual property rights (IPRs) associated with objects in the collection, policy on IPRs for non-commercial use
- Data were collected from 2008-2010, initially from CG genebanks and subsequently from genebanks outside the CG system.

Survey data analysis

Twenty-one questionnaires were received from various institutions including the Africa Rice Center, Bioversity, CIRAD, CIMMYT, IAEA, ICARDA, Kansas State University, NBPGR, NIAS, National Institute of Genetics, University of Nottingham and USDA-ARS.

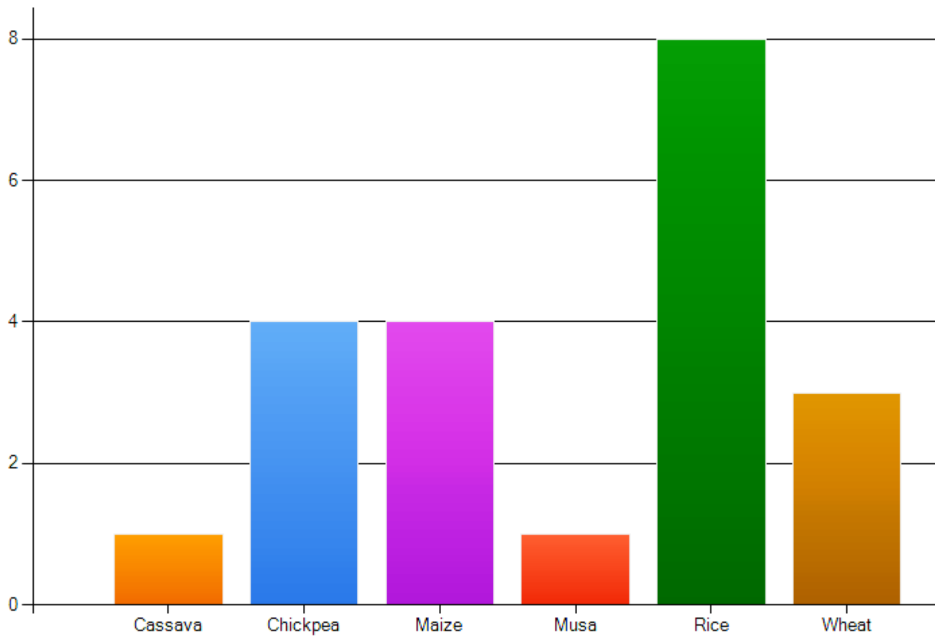

Figure 3.1. List of targeted crops and the number of respondents for each crop for which answers to survey questions were received. The most feedback was on Rice gene resources (38%) and most feedback was from public institutions (95%).

Type of material

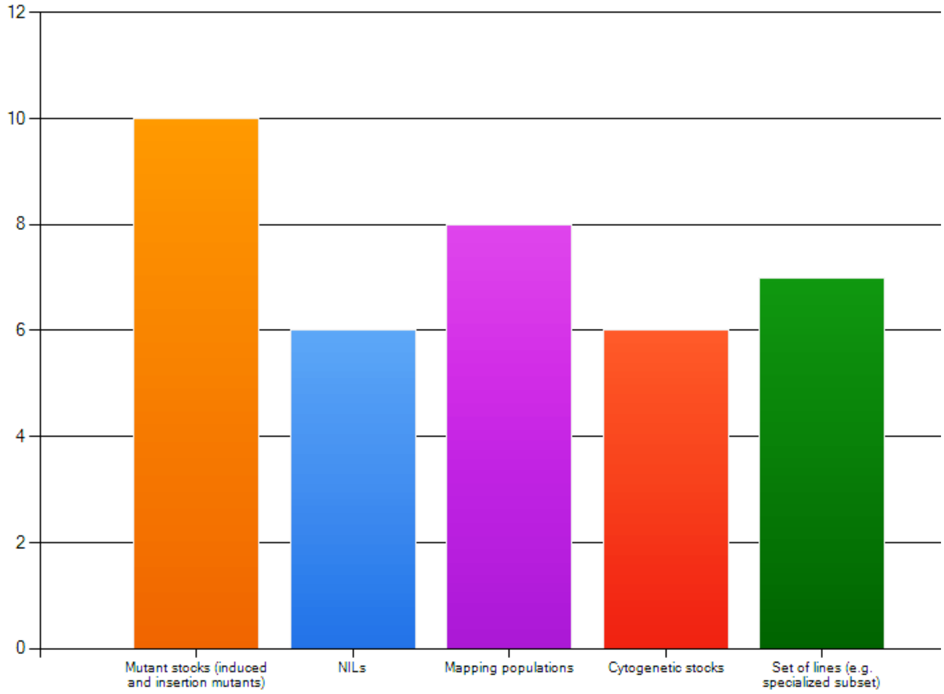

Figure 3.2. Types of resources available in the organizations. These data indicate that genetic stock collections are diverse (e.g. mutants, NILs, mapping populations, cytogenetic stocks and mutant lines) and the relative number of each are distributed rather equally.

Table 3.1. A summary of the size of collections by crop. These numbers are a sampling of existing genetic stock collections indicated by the respondents of the survey.

	Mutants	NILs	Mapping pop. indiv.	Cytogenetic stocks	Set of lines
Rice	130,336	~2000	5,650	288	~1,956 CSSLs 1700 wild species
Wheat	3,140		6,096	2,184	503 (Synthetic Lines)
Maize	~8,350	150	6,100	1,800	100,000 (mutagenized and sequence indexed M2s)
Chickpea	50		500		core collection (1956 accessions); Mini-core (211);Composite collection (3000); Reference set (300) Parental lines (108) ; Biotic and abiotic stress resistance sources (527); Trait specific accessions (313)
Cassava	10				
Musa	750				
Barley	10,000	50	1,000 (5 pop)		GCP reference set (300); BMZ ass. mapping (227); Syrian Jordanian landraces (480)
Arabidopsis	800,000		1,000-9,000 (20 pop.)		10,000-90,000 (clones and amplicons) hundreds of different types

Documentation of genetic stock collections

Genetic stock collections are generally not well catalogued and documented. Only around 50% of genetic stock collections are catalogued and most collections are not available online or in the scientific literature. A major effort in cataloguing collections into databases should be done to preserve, document and make this information available.

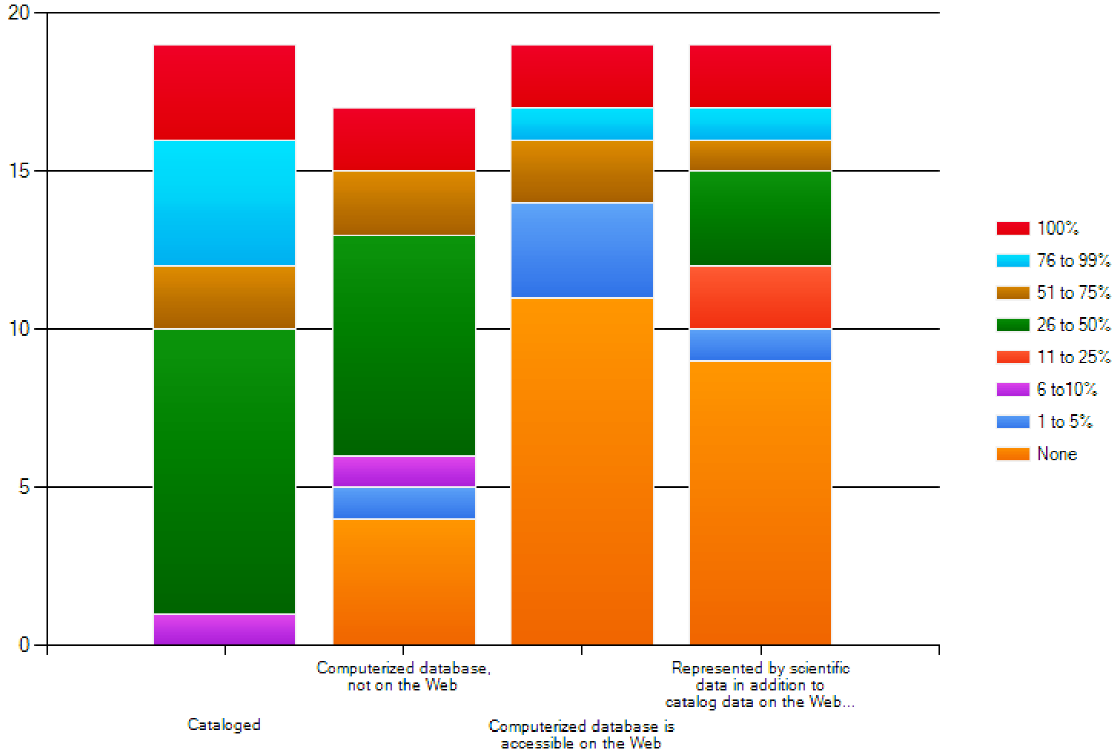

Figure 3.3. The proportion of collections that is catalogued and/or available online.

Staffing

Seventy percent of the respondents indicated that their staffing levels are quite stable and thirty percent mentioned that it is declining. The staffing levels are mainly composed of one or two permanent staff complemented by temporary staff paid on grants. Seventy-one percent of the respondents indicate they are able to fill vacancies as they arise.

Facilities

Some centres indicated that the space allocated to their collections was not adequate. However, the majority of units reported that available building space was barely adequate, although renovation of on-site storage facilities, installation and/or construction of higher-density on-site storage facilities are required (71%)

Uses

The primary users of the genetic stock collections are intramural research staff (95%) but those resources are also widely distributed to staff from other organizations, NARS or crop communities (80%) and also to the private sector (60%).

Policy for distribution and costs

The majority of collections (54%) have a written policy on the management of collections. Seventy-five percent of the respondents declared that the genetic stock collections are distributed for free; however, fees based on cost-recovery are increasing. It is commonly accepted that use of the material must be acknowledged in scientific publications.

4. Examples of current genetic stock collections

Existing genetic stock centres offer a potpourri of examples on how to maintain and distribute genetic stocks. Some centres distribute stocks for free while others use a nominal cost recovery system which relies on small fees for each order or accession. A brief discussion using some of the genetic stock centres as examples aids in understanding the dynamics with running, funding and sustaining such centres and genetic stock collections generally.

The maintenance, distribution, complexity and use of any specific genetic stock collection varies widely based on both the crop or plant and the user community. *Arabidopsis*, with two very well linked and coordinated genetic stock distribution networks, one in the United Kingdom (The Nottingham *Arabidopsis* Stock Center, NASC) and the other in the United States (the *Arabidopsis* Biological Resource Center, ABRC, Ohio), can be viewed as one extreme of the current genetic stock centres. Combined, these centres distribute a total of 50-60K samples annually throughout the world with each centre handling the distribution for their respective regions. Lines originate through donation of a few seed mostly from the US, UK and Germany and consist almost exclusively of genetically modified lines which are distributed freely without MTAs or other agreements. There is no core funding supporting the Nottingham *Arabidopsis* Center, rather funding comes 75% from grant funds and 25% from cost recovery from seed distribution. These centres have huge support from a large international science-based, non-breeder user community group who broadly support freedom to operate.

Rice is another example of a well-coordinated international effort consisting of a few Japanese stock centres, one group, the National Bioresources Project (NBRP) and NIG at Kyushu University and the other group at the National Institute of Agrobiological Sciences (NIAS). The first group maintains ~16,500 genetic stocks including the long-term preservation of 23 wild *Oryza* species. These genetic stocks are distributed for free although plant material is only distributed within Japan. The NIAS collection contains about 243,000 accessions, 50% of which are available. This collection includes ~50,000 Tos17 rice transposon lines and a DNA bank.

The Wheat Genetic and Genomic Resources Center at Kansas State University is an example of an academic stock centre whose founder, 2-3 years away from retirement, is the main linchpin keeping the Center together. The Center has core funding for salaries from the state and is fortunate to have a very supportive Growers Association which has played a large role in sustaining other funding for the Center. The Center charges a $15/line fee for distribution of ~10g of seed. All seed is distributed with an MTA. Maintenance of the collection requires a grow-out of ~10% of the collection annually followed by cytogenetic examination of the regenerated material for quality control.

Wheat genetic stocks are also an example of many non-related sites maintaining and distributing genetic stocks for a single crop. Within the US, wheat genetic stocks are maintained at the National Small Grains Collection in Aberdeen, Idaho, University of California Riverside and Oregon State University in addition to Kansas State. IPK in Germany also maintains a wheat genetic stock collection and it is likely many other genetic stocks for wheat exist in labs throughout the world. These multiple collections within a single crop are all too common and highlight the difficulty of having a single unified collection for any given crop as has been set up for genetic stocks of the non-crop plant *Arabidopsis*.

The National Bureau of Plant Genetic Resources (NBPGR) of India currently handles many accessions which fall into the category of genetic stocks. At present there is a registration system in India for genetic stocks such as mutants, parental lines and landraces and a separate repository was developed to handle these types of materials in 2009.

The US National Plant Germplasm System is an example of mixed national/academic genebank/stock centres. The Nation System maintains stand-alone stock centres for maize at the Maize Genetic Stock Center in Urbana, Illinois (>100,000 pedigrees) and the Dale Bumpers *Oryza* Genetic Stock Center in Stuttgart, Arkansas (>33,000 accessions) while stock centres associated with the national collection are maintained at traditional genebanks for wheat and barley in Aberdeen, Idaho (>2,300 accessions) and the *Pisum/Phaseolus* Genetic Stock Collections in Pullman, Washington (700 accessions). The Rick Tomato Stock Center at the University of California at Davis (3,685 accessions) is a University-owned genetic stock centre whose distributions are handled through the National Plant Germplasm Systems database GRIN (Germplasm Resources Information Network). All germplasm distributed by these genetic stock centres is distributed freely with only the Rick Tomato Center using an MTA for liability purposes.

The genebanks also handle genetic stocks from their breeding programmes. Examples include:

- **ICARDA** – mapping, tilling and cytogenetic populations estimated at 1700 accessions although this estimate is low as mapping populations alone are this size.
- **IRRI** – 40,000 line IR64 mutant collection in addition to 4000 pure lines. At present mutants are maintained in sub-par conditions as breeder tools and the breeders have not offered them to the genebank.
- **CIAT** – Beans, rice and cassava mapping populations are kept outside the genebank. A 30,000 line collection of t-DNA mutants in rice is a good example of transgenics needing to be maintained separately from other germplasm.
- **Bioversity International** – Banana mutants (IAEA) and mapping populations (CIRAD) in addition to DNA.
- **CIRAD** – 20,000 mutant rice collection.
- **FAO/IAEA** – Mutant Varieties Genetic Stocks (MVGS) database and repository containing induced and somaclonal mutations, tilling populations and mutant crosses with wild-types. The collection contains 1400 characterized lines of potato, *Musa*, rice and cassava, 8000 intermediately characterized lines and over 100,000 less characterized M2 rice lines.

5. Acceptance, maintenance and distribution issues

Incorporation of genetic stock collections into existing genebanks requires careful review and planning. Global genebanks are already suffering from limited resources and genebank curators cannot continue to take more and more material into the genebanks without some impact. While offering unique genetic tools, genetic stocks may offer a very limited amount of new diversity for a crop relative to other types of collections. Further, it may be difficult to pinpoint how specific genetic stock collections contribute to the mission of safeguarding heritage for humanity. Other issues with accessioning genetic stock collections into traditional genebanks include:

- Naming (differences between stocks and conventional germplasm, variety+ names)
- Purpose (why put in the genebank? Is it for long-term conservation or for the active collection?)
- Germplasm management standards (the current standards may be inappropriate for the genetic stocks collections, distribution may require an atypical pattern of seed distribution)
- ICIS Germplasm creation methods (GCP ontology)
- Future (what needs will change or become routine with whole-genome sequencing and other technological advances?)
- Whose responsibility will it be to phenotypically characterize these accessions? Whose responsibility is it to ensure phenotypes and genotypes match? Will there be increased requirements for pure-lining?
- What additional resources will be needed for different types of genetic stocks?

With traditional genebank accessions, the rationalization for incorporation into the genebank collection is relatively straightforward;

- Do they contain unique genetic diversity?
- Do they fill a gap in the collections?
- Are they of use to our user community, now and/or in the future?
- Do we have good passport data to make the accession of value?

Some of these questions also apply to genetic stocks but diversity, our number one criteria, may not. Further, unlike current holdings, a single technological development is not likely to make the accessions obsolete as with genetic stocks. Finally, many of the genetic stock collections consist of genetically modified organisms having differing requirements between countries not only for distribution but also for maintenance.

A driver for most traditional genebanks has been the long-term commitment for genebanking diversity. With only minor differences in diversity between some genetic stock lines (i.e. mutant lines), do we have a similar responsibility to store, save, maintain and distribute these relatively isogenic lines? If we view our user and community groups as predominately plant breeders, the answer is overwhelmingly yes, as these are tools which could aid breeders in the identification of valuable germplasm from our collections and therefore increase use of the traditional collections. The value of genetic stocks is in the identification of valuable genes, alleles, QTLs or other genetic attributes which will in turn benefit those using genebanks in the selection of the germplasm most appropriate for their goal. Without a commitment to the preservation of genetic stocks, these collections would likely be lost along with the tools they provide.

The dilemma is how should the genebank curator/manager allocate already limited resources to the maintenance of these tools? Further, what crystal ball can the genebank curator/manager use to foresee which genetic stocks will be of broad versus narrow or short-term versus long-term value? The answers to these questions do not exclude any options, rather they seek to clarify the decision making process for the curator/manager when deciding which collections are worth accepting and maintaining and which are not. While genetic stock centres may be well in tune with the user community, as the community of genetic stock donors are also likely the initial primary users, this may not be true for traditional genebanks where germplasm users may not be the generators of genetic stock collections and may be years removed from using these latest tools in their improvement programmes. With this said, it is vital that the genebank curator/manager engage all relevant user communities for input when making the decision as to whether, and under what terms, to accept the responsibility for maintenance, distribution or conservation of any specific genetic stock collection.

In addition to the crop user community, the genebank curator/manager must also rely very heavily on the donor/provider/generator of the genetic stocks for trustworthy information on the genetic stocks. Of initial importance will be the willingness to work with the genebank curator/manager to provide information and support to help the curator/manager assess the needs for accepting the genetic stock collection. This information would include identification of key members of the user communities, aid in assessing conditions under which to accept the genetic stocks and understanding the process used to generate the genetic stocks particularly if needed for obtaining permits (i.e. specifics on genetic constructs used to generate GMO lines). Questions regarding Intellectual Property Rights (IPR) used in the generation of the genetic stocks or inherent in the genetic stocks themselves need to be evaluated to ensure freedom to maintain and distribute the material. Data on characteristics of the genetic stocks must be provided as well as information on use of the stocks. Information on special quality control requirements when doing regenerations of the genetic stock collections needs to be provided and assessed to ensure whether the genebank can make such a commitment. Further, quality control measures will vary depending on the type of stocks, the reproduction system of the crop (cross versus self pollinated crops) and whether the crop is seed or clonally propagated. Finally, the provider may need to be willing to provide long-term (i.e. 10-year) support on continued or new uses of the genetic stocks.

Genetic stocks which contain Genetically Modified Organisms (GMOs) may require special requirements not only to distribute but also to accept and maintain. Such special requirements will be site specific with different genebanks requiring different requirements. Reviews by the genebank biosafety committee may be required prior to acceptance and separate facilities will in some cases (CIAT) be needed to store the materials. Special glasshouse or other requirements may be needed for regeneration. In most cases the GMO lines will be regulated events dissimilar to commercial GMO products which may also require country permission for all operations (acceptance, regeneration, shipping, viability testing, etc.). Distributions will require different permits and processes for different countries and may be excluded from others. Information from genetic stock centres which currently handle GMOs will be invaluable to the genebank curator/manager in understanding the commitment and difficulty in handling GMO stock collections.

Most of the discussion to this point has focused on seed crops as these crops constitute most of the current genetic stock collections. However, there are mutant and other genetic stock collections of clonal crops (i.e. banana and cassava) and it can be anticipated that these collections will also continue to grow. These collections will present unique challenges: acceptance and maintenance will depend principally on having the infrastructure for this commitment (i.e. can you have a field bank and if not, they will require either glasshouses or tissue culture labs); there will be a requirement of monthly/yearly care (unlike seeds which can sit for years properly stored without intervention); and distribution will require larger shipments, particularly for users wanting to screen entire collections. Special facilities may be needed for users to come and screen collections at the site of storage to avoid complications with distribution. Finally, user groups may be less in tune with the tools provided by genetic stocks and the time-lines of use and return from the genetic tools could be far greater than with seed crops. Again, case-by-case evaluations of the genetic stock and the crop will need to be the rule.

Acceptance of genetic stock collections may also require unique and/or dedicated staffing needs. A traditional genebank curator/manager may be able to store the genetic stock collections, but a dedicated curator for genetic stock collections, particularly as they evolve to be more complex, may be needed to answer users' inquiries, stay up to date on new and evolving collections, properly manage regenerations and input, and formulate a database. For quality control, a dedicated molecular biologist or cytologist may be needed. Dedicated greenhouse, field and tissue culture/seed technicians may be needed to handle the volume of accessions contained in some of the collections. Finally to ensure use, a dedicated bioinformatician/computer programmer may be needed to develop public usable interfaces for collections as such databases are critical for use of materials in genetic stock centres.

Examples of the information, commitment and questions which need to be asked/provided from the three major categories of interested parties (providers, genebank curators/managers and recipients) of genetic stock collections are summarised in Table 5.1. Table 5.1 is not intended to be all inclusive but rather to highlight some issues which need to be addressed in the decision making process of whether to accept, maintain or distribute genetic stock collections.

Table 5.1. Examples of commitments needed by involved parties for the storage of genetic stock collections in public (i.e. CGIAR) genebanks.

	Providers (institution or individual)	Genebank	Recipients
Acceptance	Authority to release collection Assurance of collections ownership Provide information of IPR contained in collection	Determine and agree on conditions of acceptance of collection into genebank (i.e. freely distributable)	Obtain all necessary permits to receive material
	Willing and able to provide collection under conditions acceptable to genebank	Determination whether to immediately release for public distribution or keep for period of time prior to release (i.e. for publication)	Biosafety regulations in place if receiving GMOs
	Assurance of identity of lines	Have resources to accept and distribute (also maintain if decided)	Have ability to properly use stocks
	May need to provide distribution quantity of seed or in vitro plantlets	Does user community need some or all of the lines conserved/distributed *	

Table 5.1 (cont'd)	Providers (institution or individual)	Genebank	Recipients
Acceptance	Provide data associated with genetic stocks		
	Provide rationale for putting the collection into a public collection		
Processing incoming samples	Provide additional information (data) as needed	Obtain all necessary permits and have the ability to abide to quarantine conditions if required	
		Increase seed if needed	
		Ensure proper seed (propagule) conditioning for storage	
		Have the ability to test viability as needed	
		Obtain all necessary documentation on lines and IPR	
		Verification of identity of the individual lines	
		Publically disclose non-confidential information and link to other databases	
Maintenance	Regenerate and do QC if required and agreed on	Regenerate and do QC if required and agreed on	
	Provide update on validity/data/ownership as applicable	Periodic review of use and need to maintain/keep/inactivate	
		Monitor health and viability as required	
		Periodically reconsider (e.g. every 10 years) the usefulness and importance of the genetic stocks	
Distribution	Work with genebank, if needed, to allow public distribution	Respond to requests	Send data back on use, traits, etc.
	Responsibility to inform genebank regarding any changes associated with genetic	Obtain necessary permits	
		Comply with agreed conditions	
		Comply with phyto regulations and best health practices	
		Obtain and compile feed-back on use from recipient	
		Comply with IPRs restrictions and requirements	

Notes:

1. Clonal crops may need a different infrastructure and resource considerations at all stages
2. Conditions may be on a case by case basis for different collections or crops
3. GMO considerations may be site and crop specific
4. Strength of the user community may be different for different crops
5. Quarantine/permit requirements will be crop and site specific
6. May not need to always distribute the whole genetic stock collection. e.g. tilling populations may be selected on individual rather than whole collection (first send DNA pool and then select on individual)
7. Aliquot for distribution: depends on crops and type of genetic stock collection: e.g. wheat aneuploids.

6. Curator decision tree for handling genetic stocks

Figure 6.1 is a decision tree to aid genebank curator/managers with making the decision and under what terms to accept or not accept genetic stock collections. Adjustments need to be considered at all stages when using Figure 6.1 to take into account different crops (i.e. acceptance, processing, maintenance and distribution) as well as the relative size of the genetic stock collections.

The decision tree (Figure 6.1) is based on the following questions:

1. Do we maintain and regenerate every genetic stock collection as if they were conventional genetic resources?
2. Is there an immediate need for seeds to distribute the genetic stock collection? Do we need a high quantity of seed?
3. Should we prepare DNA samples?
4. Do we want to commit to long term conservation? (i.e. Svalbard and assigning a plant identification number)
5. Should the collection be conserved as a black box if of low-importance, IPR or other reason? Should this be done directly or after some time (e.g. 10 years) if there is not enough demand or use?
6. To help with the issue of acceptance the following should be considered:
    - Commitments may be different depending on the crop and genetic stock collection;
    - Use of the decision making tree could help determine what material should enter in genebanks;
    - Should individual lines of the collection be given an accession number and therefore become a "burden" to the genebank?
    - Can the material be redistributed and if yes, under which conditions

Acceptance of a genetic stock collection is based on the curator's understanding of the crop and collection in consultation with the donor, the user community and any other crop experts deemed suitable by the curator. Criteria important to the decision of accepting of the collection include:

- The value of the collection to the crop community;
- The level of characterization of the lines making up the collection;
- The genetic uniqueness of the collection;
- The resources available in the genebank to handle the collection;
- The technology used to generate the collection;
- The risk of being lost.

It would be of benefit to the decision making process to define a time limit at which the curator/manager assesses the demand of genetic stock collection that are initially deemed worthy of keeping in long term conservation.

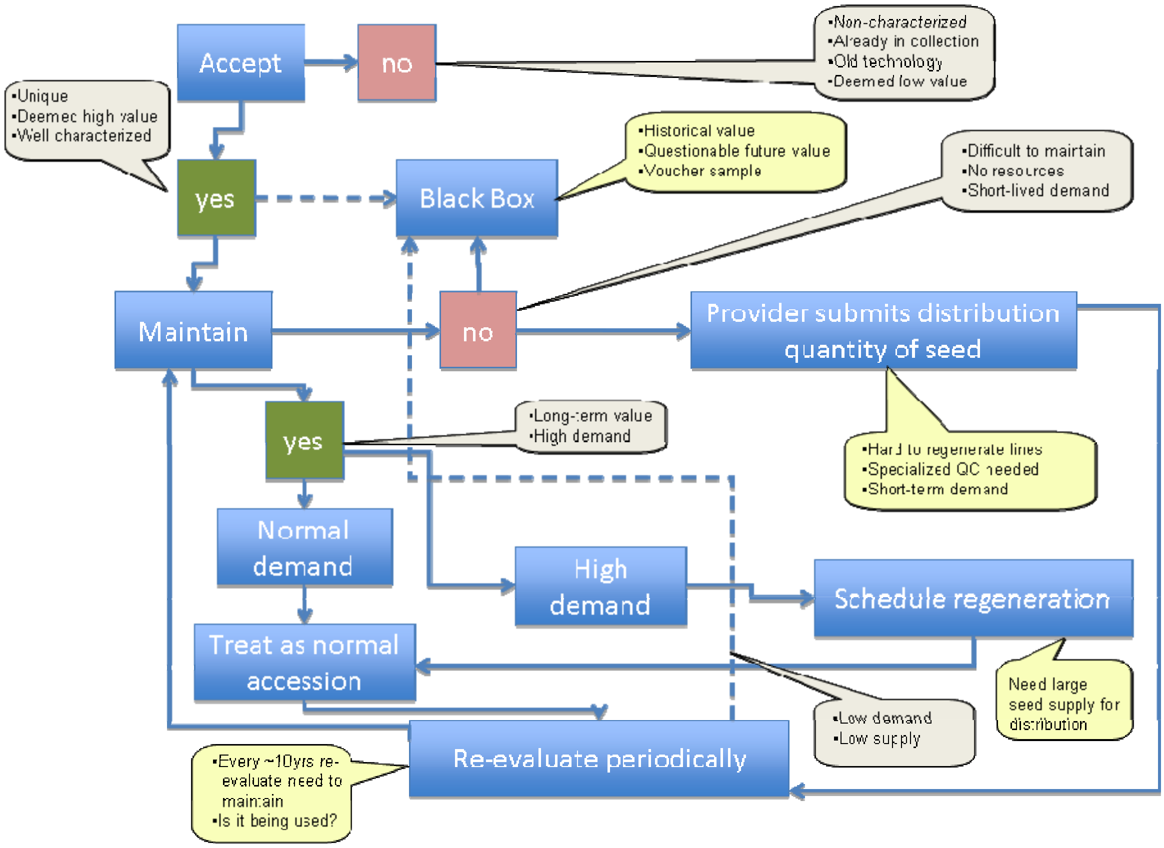

Figure 6.1. Decision tree offering specific examples for handling genetic stocks in genebanks.

Below are five potential choices a genebank curator/manager can make in accepting genetic stock collections:

1. Accept collection with a long-term commitment – treat as conventional germplasm: maintain in active and base collection. May or may not re-evaluate after a period of time (e.g. 10 yrs);
2. Accept for distribution only: treat as active collection but do not regenerate. When seed is gone the accession is retired;
3. Accept for distribution only: as in 2) above and decide after a period of time to a long-term commitment (e.g. genetic stock collections which continue in high demand);
4. Accept into black-box: no distribution;
5. Reject: do not take the genetic stock collection into the genebank.

These scenarios apply to seed crops but with clonal crops it is important to consider that cryopreservation is important for long-term preservation but it is costly, time consuming and difficult with 100's, and virtually impossible with 1000's of lines in a collection. One must consider that cryopreservation of a particular genetic stock collection may need a commitment for 10+ years just to put the collection into long-term storage!

7. Managing data related to genetic stock collections

One element which will aid future genebank managers faced with a decision as to whether or not to accept or maintain genetic stocks is the development of a central database for genetic stock collections and the ability to track use over time. Currently, even within crops, data on genetic stocks are scattered through a combination of public and private databases with little, if any ability to cross reference accessions or attributes between the databases. The ability to compare information between crops is even more problematic.

Examples of databases available for use with genetic stocks include:

- Crop specific databases (e.g. *Musa* Germplasm Information System - MGIS)
- CGIAR database: System wide Information Network on Genetic Resources - SINGER
- EURISCO
- GRIN – the USDA Germplasm Resources Information Network
- GRIN-GLOBAL – a global plant genebank information management system available early
  in 2011
- GENESYS – the Global Gateway to Genetic Resources

A fundamental challenge in the development or adoption of a genetic resource database for genetic stock collections is that genetic stocks will potentially have a new set of non-traditional users whose main concern may have nothing to do with conservation of genetic resources. Further, unlike conventional genetic resources, the involvement of the supplier/developer will be needed to facilitate use. A dynamic database linking the developer with the user could be important as will be a database which can rapidly evolve to accommodate the very rapid evolution of not only genetic stocks, but also the science associated with genetic stocks. These challenges may require vastly different thinking in database design, use, applications and the ability to interface genetic resource databases with other non-genetic resource databases.

Therefore, databases supporting genetic stock collections within the current genetic resources genebanks will need to address a different set of motivations, vocabulary, different types and priorities for descriptors and also have the ability to adjust quickly to evolving technological and scientific advances. Coupled with these requirements will be the active involvement of non-curators (the developers/suppliers/users of the genetic stocks) in the development and evolution of databases for genetic stocks.

Specific questions related to the development/use of current genebank databases for genetic stocks include:

- What kind of additional info should be attached to genetic stocks?
- How will specific descriptors for genetic stocks be generated if different from existing ontologies?
- What are the important traits?
- What should be kept, what can be omitted?
- What can be public or not?
- Where is the information today?
- What are the issues with distribution?

- Who will curate the information generated?

In general, it would be ideal to have a single central location for information on genetic stocks for researchers from any crop to find information on genetic stocks from other crops. However this does not mean a single location to physically house genetic stocks. A big question is whether existing genetic resources databases are even adequate for genetic stock collections? Certainly two databases, one for genetic stocks and one for traditional collections, would not be the most efficient for curators or users. A question whether GRIN-Global will be suited to handle both traditional and genetic stocks collections remains to be answered.

8. Intellectual Property issues

There may be challenges regarding Intellectual Property (IP)/Intellectual Property Rights (IPR)/legal issues in the genebanking of genetic stocks which may be unique or at minimum potentially different in magnitude and scope with genetic stocks than with traditional genetic resources. These could include:

A. The legal basis for distribution:

- Genetic stocks may have unique conditions of acceptance and/or distribution;
- These conditions may and will change over time;
- Prior commitments may influence or force different rules for different genebanks: e.g. CGIAR centres with FAO agreement, GCP consortium agreement, databases operating under EU laws.

B. Ethical concerns:

- Acquisition and use of traditional knowledge may not be much different from traditional genetic resources but is still a factor;
- Where technology was developed in the generation of the genetic stocks there may be the need to acknowledge in the publications the contribution of any provider, or if developed by more than one person, there will be the need to acknowledge any co-authors, etc.;
- Genetic stocks may pose unique circumstances in regard to adherence to ethical guidelines, international treaties, etc.

C. To maintain unencumbered public distribution of the collections, in some cases early responsibilities for defensive actions to keep material freely available may be needed:

- Public disclosure of information about materials in a way that satisfies conditions of "prior art";
- Prior art should satisfy the needs of Patent and Plant Variety Protection (PVP) examiners as "users" of genebank information.

D. Additional issues:

- There will be a more rigorous need for feedback on use which may involve IP;
- Genetic stock collections may mean that the genebank has to accept and distribute proprietary materials;
- There may be increased need for cooperation with the private sector (e.g. Affymetrix. Lumina, etc.) which may have different interests and agendas.

Genetic resources are much more than genetic stocks accessions and CGIAR centres must keep track of their main focus (genetic resources) and realize that some genetic stock collections may not fit into the current standard operating procedures. The Mission of sustainable increase, improvement of livelihoods is critical for the CGIAR centres and they must consider how each collection, whether traditional or genetic stocks, fits into this mission. For example, CGIAR centres need to determine if they are ready to accommodate and distribute proprietary genetic stocks collections, GMOs containing no agriculturally important trait, non-breeding material, etc. While engaging private partners and other genebanks with experience in managing genetic stocks will help, it is likely that the commitment surrounding each genetic stock collection must be defined prior to a CGIAR centre committing to accepting and distributing genetic stocks.

In the decision tree to aid curators in making decisions regarding including genetic stocks in their genebank outlined in this report (Figure 6.1), feedback from donors and the user communities is critical to decision making at virtually all points. However, curators can't currently require a user to provide feedback and curators seldom have the time to be diligent in following up on germplasm use, even for traditional genetic resources. However, under the International Treaty on Plant Genetic Resources for Food and Agriculture, users are obligated to provide feedback on use to the Governing Body of the Treaty, unless the genetic resources are in development. Two questions pertaining to this is whether genetic stocks would ever be classified as anything other than in development and also whether there is a mechanism for enforcing the feedback. One option may be to ask the Governing Body to be more proactive in requiring users' feedback.

The handling of Intellectual Property Rights (IPR) for genetic materials and specific recommendations for genetic stock conservation strategies vary greatly between genebanks and countries. Below is a brief summary of how some genebanks are currently handling genetic stocks:

- NBPgenetic resources, India has the responsibility of keeping genetic stocks as well as genetic resources. NBPgenetic resources does not distribute material with IPR attached but will keep material as a reference sample. For old material, NBPgenetic resources is going back to the provider of the material to see if they will release it publically. If there are no IPR attached to the material or no longer apply, the material goes into the public domain.
  - ICAR maintains a registry of new varieties and material kept by NBPgenetic resources in a separate module for the 15 year legal IPR delay and after this it goes into public domain. Farmers can also register their material for 15 years. Maintenance of genetic stock collections are funded by the government
  - No distribution restrictions based on proposed use exist.
  - National distribution occurs with an MTA even to public genebanks and the rules are so clear that there is virtually no rejection of requests for genetic resources within India.
  - India has different rules for distribution within the country versus outside the country – the National Barrister Society has to approve all exports of any genetic material.
- NIAS, Japan distributes material in the public domain for research, education, and breeding purposes only. The material cannot be used for commercial purposes.

Requests are rejected if strict criteria are not followed. Requests for genetic material from the private sector within country are accepted if the private entity accepts a national MTA.

- *Arabidopsis* community has organized itself to support the service as grant funding contains provisions to provide the derived material into the public access.
  - There is a policy not to ship to schools
- USDA-National Plant Germplasm System does not distribute any genetic materials with any IPR or other restrictions over use. Further, material with IPR or some Agreement attached is not accepted unless there is a defined date of 20 years or less in the future when the material will be made public. The one exception to this policy is material covered by the International Treaty on Plant Genetic Resources for Food and Agriculture, where the National Plant Germplasm System does accept and distribute material covered by the SMTA of the Treaty despite not being a party to the Treaty.
  - If the recipient wants to pass it on to third party, this is fine as the US system does not track 3rd party distribution.
  - The U.S. system does ask for voluntary use and data back.
  - Other than the Treaty, the IPR exceptions for inclusion into the U.S. system include cultivars covered by Plant Variety Protection (PVP) and Plant Registration. For a period of up to 20 years, the genetic materials must be available under some terms by the donor and will not be distributed by the National Plant Germplasm System although voucher material must be deposited with the National Plant Germplasm System. After this 20 year period of restricted distribution, the material is released to the public domain and distributed as outlined above according to the policy of the National Plant Germplasm System.
  - There are no restrictions or differences in distribution national or internationally to countries which the U.S. has diplomatic relations with.
- CGIAR system does not require material to be immediately available if the material has IPR connected with it. In these cases, the material can enter the genebank, however, it will have to be made available to the public under CGIAR policy for genetic resources after some time to fit into the mission of improving livelihoods. This can only happen if the terms have been negotiated by reducing the IPR duration.
  - If IPR issues are linked to the material, it may not be possible to use the SMTA and therefore acceptance may be an institutional decision rather than solely the decision of the genebank curator (often taken by the centre's Board).
  - Only material under development has specific clauses for exemption in addition to the SMTA.
  - The recipient of material may also limit distribution as some CGIAR centres have a policy not to ship to entities without a biosafety handling policy in place
  - Genetic stocks will likely fit into one of the categories above but accepting them with "carte blanche" will further stretch genebank resources and therefore decisions at the curator level will have to be considered.
  - It has to be noted that the cost of maintaining and distributing clonal genetic stocks (cassava, banana, potato, etc.) will be much higher than seed crops.

As previously mentioned, decisions regarding the acceptance of genetic stock collections will have to consider many factors, the handling of different types of IPR being one of them. Since many collections will have unique crop-specific issues, at least initially, it would be prudent for the curator, DG and board to initiate discussions regarding guidelines for accepting and distributing genetic stocks.

It will be important to measure, compare and monitor the differences in managing conventional genetic resources versus genetic stocks. While the IPR issues may be confusing and changing fast, thereby making decisions problematic, a potentially more difficult part of the decision making process will be the uncertainty about non-IPR issues including:

- What new opportunities will arise with genetic stocks? How will these affect use and how can we predict an increase in use to ensure we meet customer expectations?
- Will it make a difference if genetic stocks come from sources that are not party to the Treaty?
- Likely, advances in genetic stocks will occur in a single species and how can we use this knowledge and prior precedent when managing subsequent collections from completely different crops, often with different genebank and curator restraints? Customers may only see similar technology which they want to use to research similar problems with no knowledge, interest or concern for genebank or IPR differences between the crops.
- How will we value genetic stocks in our collections? Are genetic stocks of lower value than conventional genetic resources when we acknowledge a collection will be short lived?
- Because genetic stocks are research tools and used more for upstream research compared to traditional genebank materials, they could be viewed in a different category. Does it matter that most of the time, genetic stocks may not be distributed for an immediate GRFA use?

It is clear that IPR restraints and issues will accompany collections derived from or containing GMOs. In these cases, CGIAR centres must comply with the regulatory laws and policies of their host institution and the recipient institution. This alone will cause variation between collections in the way different genetic stocks is to be handled. Distribution will have similar issues as GMOs cannot be sent to countries without a biosafety policy in place.

The USDA has dealt with restricted materials in the National Plant Germplasm System, such as PVP and Plant Registrations materials, by accepting voucher specimens into the National Plant Germplasm System provided they are available publically at a future date, not to exceed 20 years. The USDA accepts others' material into a black-box category for secure long-term storage free of charge as it is deemed to be for the public good and is publically available by the donor under some terms. This black-boxed material is held by the USDA under an MTA which states the material does not belong to the US government and therefore is not part of the National Plant Germplasm System.

Recommendations

Recommendations for CGIAR genebanks in the handling of genetic stock collections

1. **An inventory needs to be made of where genetic stock collections are located and who is responsible for the distribution and maintenance of these stock collections for all key crops.**
2. **A letter should be prepared and distributed through the newsletters of the crop groups to highlight the urgency of inventorying and safeguarding genetic stock collections.**
3. **User communities should be a key part of the effort to inventory, collect and safeguard genetic stock collections for target crops.**
   a. **The crop curators at the CGIAR Centres should the point person for crops under their care;**
   b. **The CGIAR Centre curators know the crop communities and should work with them to identify these collections;**
   c. **The CGIAR system is not a traditional entry point for genetic stocks but they should play a key role in the preservation of these valuable genetic tools.**
4. **CGIAR Centres should actively support the conservation of genetic stocks of value and importance as they are tools which can further the mission of sustainably increasing and improving livelihoods.**
5. **A database system(s) is needed which can accommodate data from genetic stocks collections.**
   a. **This database should accommodate data from multiple crops so a comparison between collections from different crops is facilitated;**
   b. **The database needs to identify and list descriptors of use for genetic stock collections to keep terms in common;**
   c. **When available GRIN-Global should be evaluated to determine if it can be used as a single database for genetic stock collections.**
6. **Workshops containing groups of curators/genebank managers, such as attended this workshop, this should meet periodically to ensure the proper identifying, prioritizing and care for genetic stock collections.**
7. **Clear internal Policy Rules need to be used when exchanging genetic stocks.**

Appendix 1. Workshop participants

Name	Organization	Crop of interest / topic of interest
Arnaud, Elizabeth	CGIAR, Bioversity International	Several / Information systems
Ellis, Dave	USDA	Several / management, co-organizer
Gill, Bikram	Kansas State University	Wheat, barley
Glaszmann, Jean-Christophe	GCP/CIRAD	Rice, GR Support service
Henson Appolonio, Victoria	CGIAR, CAS-IP	Policy issues
Kawase, Makoto	NIAS	Several / management
Kurata, Nori	NIG	Rice
Lagoda, Pierre	IAEA	Rice, cassava, *Musa* / mutants
May, Sean	University of Nottingham	*Arabidopsis*
Ogbonnaya, Francis	CGIAR, ICARDA	Wheat, barley
Re Manning, Francesca	CGIAR CAS-IP	Policy issues
Rouard, Mathieu	CGIAR, Bioversity International	*Musa* / bioinformatics
Roux, Nicolas	CGIAR, Bioversity International	*Musa* / Activity coordinator
Sackville Hamilton, Ruaraidh	CGIAR, IRRI	Eice
Sharma, Shivali	CGIAR, ICRISAT	Chickpea
Sharma, Shyam	NBPGR	Several / management
Thiriet, Janis	CGIAR, Bioversity International	Assistant to Nicolas Roux
Tohme, Joe	CGIAR, CIAT	Beans, cassava
Tuberosa, Roberto	University of Bologna	Wheat, barley