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Status and Progress of Conservation and Utilization of Agricultural Genetic Resources in the Republic of Korea

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Abstract

The RDA Genebank project has been implemented as a national program in Rep. of Korea to collect, characterize, evaluate, rejuvenate, conserve and use plant, microorganism and animal genetic resources for food and agriculture since 1985. National Agrobiodivresity Center (NAC) has functioned as a central bank of the project in cooperation with other agricultural public and private sectors. This national network on genetic resources for food and agriculture currently preserves approximately 154,695 accessions of crops germplasm and wild relatives as the base collection of about 1700 species involving 26,125 accessions of clonal crops. About 100,000 accessions are conserved as active collection, which are able to distribute mainly for breeding and research purposes under the regulation of MTA between RDA Genebank and recipients worldwide. We have undertaken international collaboration with several Asian countries focusing on *ex situ* conservation of plant genetic resources. Research highlights on conservation and utilization of plant genetic resources are discussed.

Introduction

The RDA (Rural Development Administration) plays a key role in planning and supporting the national program on conservation and use of crop genetic resources. RDA Genebank (RDAGB) was established in 1988 and organized as a National Agrobiodivresity Center (NAC) of RDA on 3 November, 2006 of the completion of the new bank facilities. The genebank projects undertake research on germplasm collection, characterization, evaluation, conservation and documentation for future use. The Genetic Resources Council (GRC) and the Germplasm Advisory Committee (GAC) advise RDA with establishment of national strategies for Plant Genetic Resources (PGR) activities such as priority settings for collecting,

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and making recommendations to carry out characterization, evaluation, and utilization of PGR throughout the nation. Evaluation and regeneration of the PGRs are conducted jointly with other related research institutions. The seeds multiplication and the data evaluation at those related institutions are sent back to RDAGB for conservation and utilization.

The RDAGB's effort has been focused on the collection, conservation, and utilization of PGRs for using in research for crop improvement and other utilizations. Research infrastructure of PGR is very important in order to improve and utilize the collections. However, there are numerous problems encountered in the conservation and utilization of PGR in Korea. Also, social understanding and consensus (i.e. public awareness) on the important issues of genetic diversity or PGR are needed urgently. For realizing further development of food and agriculture and for achieving three objectives of the CBD, the RDAGB pursues the proposed activities for implementing Global Plan of Action (GPA) adopted by the International Technical Conference on Plant Genetic Resources in Leipzig, 1996 (FAO, 1996).

The conservation and utilization of PGRs need a long-term plan at the national and international level. Further efforts are required to develop additional databases for germplasm including additional image data, DNA profiles, and molecular characterization. The RDAGB has started the conservation of mutant and genetic stocks for genomic and functional researches. For upgrading characterization and evaluation data of PGRs through using genetic and biochemical tools including gene expression displays such as DNA microarray data has to be involved in the program of PGRs in the Republic of Korea.

In situ management of agro-biodiversity

The RDAGB has surveyed the distribution of some wild relatives of crop species and the diversity assessment of weedy type found in farmers' lands. The wild adzuki bean (*V. angularis* var. *nipponesis*) is a progenitor of the cultivated type (*V. angularis* var. *angularis*) and *V. nakashimae* is a wild relative (Fig. 1). Both two wild species are distributed in the whole regions of the Korean peninsula. The survey on the distribution of the wild adzuki bean and its relative species, *V. nakashimae,* has been conducted in the basins of 'Taebaek' and 'Jindo' in Korea. Seeds of 165 accessions were sampled for planting for further characterization in 2002. The RDAGB preserves about 1,000 accessions of wild soybean, which were collected during 1991-1995. The supplemental surveying on the wild soybean was implemented for the *in situ* management of crop wild species (Fig. 1).

The weedy rice was surveyed across the different regions based on the five rivers, Hangang, Geumgang, Nakdonggang, Yeongsangang, and Seomjingang. A total of 3599 accessions including collections from Jeju island were sampled from nine provinces and it had been done in 2002. These collections are complementary one for the previous weedy collections made by Dr. Suh in the Yeongnam University. These accessions were re-evaluated by comparative analysis based on phenotypic and DNA analysis during 2004-2005. The duplication and on-farm conservation status should be fully understood by the following study.

Wild *Vigna* Weedy Rice

Fig. 1. The comparison of seeds in *Vigna angularis* and *V. nakashimae* (left), and the characteristics of plant and spike type of weedy rice (right).

The surveys have been conducted over several years (Ahn *et al*. 1994). The result shown the crop landraces disappeared very fast from the farms in Korea. Only 26% of the various crop landraces could be found according to the survey in three locations in South Korea in 1993 relative to 1985. A similar trend could be expected in other rapidly developing countries. One of the main reasons for the genetic erosion of landraces is their rapid replacement by a much narrower spectrum of bred cultivars improved cultivars. Other reasons are the simplified cropping systems and young people migration into city due to mechanization of agricultural system. The status of landraces maintained on farms at different geographic locations in South Korea was investigated in 1985, 1993, and 2000. Therefore, 274 farms were established in the remote mountainous areas such as ‘Pyungchang’ and ‘Youngduk’ in 1985. However, the number of farms was eventually reduced to 44 (16.1%) in 2000. The numbers of farms were reduced from 170 to 18 (10.6%) in sub mountainous areas,

from 537 to 65 (12.1%) in plain cultivating areas, 463 to 66 (6.6%) in suburb areas and from 34 to 1 (2.9%) in Jeju Island. Jeju Island is the biggest island in Korea. Thus, 1478 farms held landraces in 1985, in which 194 (13.1%) farms were still cultivating at least one landrace in 2000. It is a general tendency that farming areas near to cities would lose crop landraces resulting from changing to new commercial cultivars. According to the species diversity is based on the number of crop species kept by farms, the relative retained proportions of crop species appeared to be 29.3%, 35.5%, 28.6%, and 4.5%, respectively, in different farming areas in 2000, compared to that of 1985. With average, about 28.2% of crop species were maintained in 2000 *versus* in 1985. More diversity of crop species was cultivated in the plain and rural farming areas rather than the remote mountainous farming areas. In general, the total number of varieties hold by farms has been also drastically decreased. The number of varieties in remote mountainous areas was relatively higher than that of other areas.

The industrialization of agriculture led farmers to change their traditional varieties to new-bred ones or simplify diverse varieties into one or a few. About 35% farmers were holding landraces because of high quality (35%), 34% because of importance of heritage for home consumption while 31% for other preferred reasons (Fig. 2). On the other hand several reasons were also identified which forced the farmers to avoid use of landraces. Among these, 25% for farmers having no land anymore as they moved to cities, 23% for quitting farming, 9% for shifting to new varieties, 17% for cheap prices relative to new varieties, 19% for lack of labour, and 7% for unknown reasons.

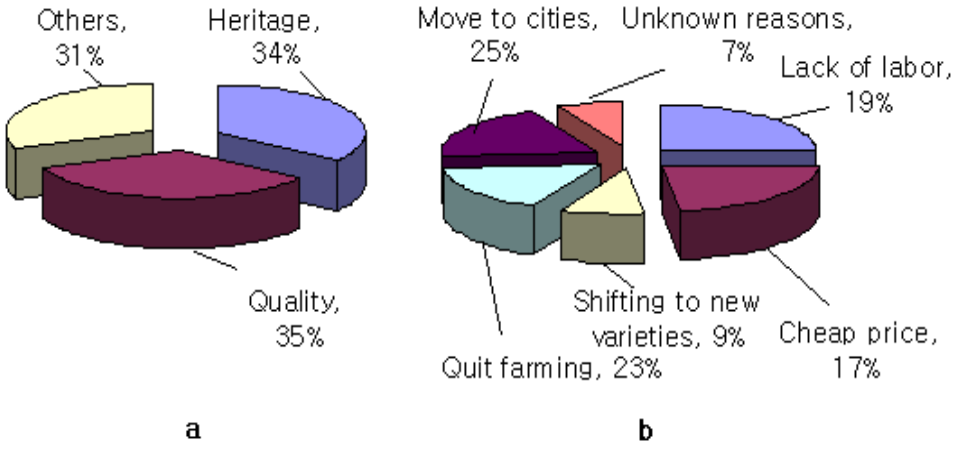


Fig. 2. The preference and avoidance for cultivating landraces in farms in Korea.

Ex situ conservation

Wild relatives of crop species have potential uses in improving agronomic characters and disease resistances. The major wild relatives in RDAGB are wild soybean (950 accessions), medicinal plants (714 accessions) and *Allium* species (1466 accessions). During last three years, the 1304 wild *Raphanus* accessions were collected from Jeju Island and southern coastal regions in Republic of Korea. As for the wild *Vigna* collection, the 76 accessions of wild adzuki bean, 88 *V. nakashimae* and one weedy type of *V. angularis* were collected in the regions of Taebaek and Jindo. In total 3,599 accessions of weedy rice from farmers' fields were collected for a case study for the diversity maintained in on-farm status before Genetically Modified Organisms (GMO) releasing (Table 1).

Table 1. The status of domestic collection of weedy rice (2002~2003)

Sources	Gyeonggi	Gangwon	Chungcheong	Jeolla	Gyeongsang	Jeju	Total
No. of accessions	298	218	1005	807	508	763	3599

Seed storage facilities of the RDAGB were built newly last November, 2006 according to the international standards set by the International Plant Genetic Resources Institute (IPGRI) and the Food and Agricultural Organization (FAO) of the United Nations. It has the capacity to store as many as 500,000 accessions with its medium-and long-term seed storage rooms, respectively (Table 2). The 264 m^2 long-term storage room is set at the condition of –18±1 ^oC temperature with 40% relative humidity (RH). The 674 m^2 mid-term storage room is set at 4±1 ^oC temperature with 30% relative humidity (RH). Seeds are dried to 3% to 8% moisture content prior to their storage. Packing room is set at 20±3 ^oC and 30% RH. In addition, a few national as well as private research institutes have short-term storage facilities where temperature is maintained at 5 ^oC to 12 ^oC.

Seeds to be stored for a long term are packed in aluminium foil bags, dehydrated and kept in –18 ^oC storage room, while the seeds for medium-term storage are packed into a PET bottle with silica-gel and kept in 4 ^oC storage room. The duplicated collections are kept at the National Yeongnam Agricultural Institute under National Institute of Crop Science for safety purpose.

Table 2. Preservation facilities and preserved accessions of RDAGB (2007)

Facility	Condition & area	Practical duration & capacity	Preserved accessions	Type of germplasm
Long-term	–18°C, 40% RH 264 m^2	> 100 years 500 x10^3 Acc.	86,373	Seeds
Medium-term	4°C, 30% RH 674 m^2	> 10 years 500 x10^3 Acc.	10,000 154,695	Mutants Seeds
Field Genebank	Field & greenhouse	1~50 years	26,175	Vegetatively propagated materials

The accessions after collection and introduction are submitted for tagging with temporary storage numbers. Basically, new accessions need primary multiplication and characterization for permanent storage. All the passport data and related characterization details are databased. Curators of corresponding PGR are charged with the management of related activities through the entire process. RDAGB takes IT (Introduction) No. for permanent storage and has a temporary storage number system for new accessions.

RDA seed genebank conserves 117,275 accessions of cereal crops, 18,617 of industrial and medicinal plants, 14,984 of vegetables and fruit trees and 3,819 of forage crops and other germplasm, collected within the country and abroad (Table 3). With respect to the vegetatively propagated germplasm, 45 field gene-banks maintain 26,175 accessions consisting of fruit trees, flowers, vegetables, medicinal plants, tuber crops, shrubs, grasses, and other germplasm (Table 4). As mentioned above, the RDAGB has started a systematic conservation of mutants for genomic researches since 2003. Basically, the RDAGB plays long-term conservation of mutants. Active collections are operated by each university or institute, which had developed each mutant population. Around 10,000 accessions of mutants are kept in long-term storage for safe conservation of these mutants now.

Developing and adopting *in vitro* conservation system for recalcitrant seeds and vegetatively propagated PGRs is also a major research program of RDAGB. The experiment for optimizing conditions for ultra low temperature using liquid nitrogen is being undertaken for potato, tea and garlic genetic resources (Kim *et al*. 2002; 2004). In the cryopreservation of potato *in vitro* shoot tips, stepwise increase of sucrose from 0.3M to 0.8M in pre-culture medium resulted in the highest survival. Dehydration with PVS3 solution for 90 minutes or

PVS2 + PVS3 solution for 60 minutes showed higher survival than with other solutions tested. Primary shoot tips only showed high survival to cryo-exposure in pre-culture for three or five weeks, while middle part shoot tips showed a high survival in pre-culture for six or eight weeks.

Table 3. Germplasm collections in the RDAGB (~2007)

Crops	Number of species	Number of accessions	Ratio (%)
Cereal crops	414	117,275	75.8
Industrial & medicinal plants	258	18,617	12.1
Vegetables & fruit trees	462	14,984	9.6
Forage crops & others	643	3,819	2.5
Total	1777	154,695	100.0

Table 4. Collections of vegetatively propagating plants in the RDAGB (~2007)

Crops	Number of accessions
Fruit trees	7,962
Vegetables	2,500
Ornamental plants	5,403
Others	10,310
Total	26,175

The droplet-vitrification protocol was applied to unripe inflorescences of plants of four Korean garlic field collections at Danyang, Suwon, Mokpo and Namhae, to establish a cryopreserved germplasm collection. The protocol applied was consisted of preculture for 3~5 days at 10°C on solid MS medium with 0.3 M sucrose, loading for 40 min in liquid medium with 35% PVS3, dehydration with PVS3 vitrification solution for 150 min, cooling in 5 µl droplets of PVS3 vitrification solution placed on aluminum foil strips by dipping these strips in liquid nitrogen, warming them by plunging the foil strips into pre-heated (40°C) 0.8 M sucrose solution for 30 s and further incubation in the same solution for 40 min (Fig. 3). A total of over 800 accessions of five clonal *Allium* species, including garlic, were stored in liquid nitrogen for long-term conservation using unripe inflorescences, cloves or bulbils. In addition to *Allium* species, currently 93 accessions of potato and 560 accessions of Korean ginseng seeds were stored in liquid nitrogen for cryopreservation.

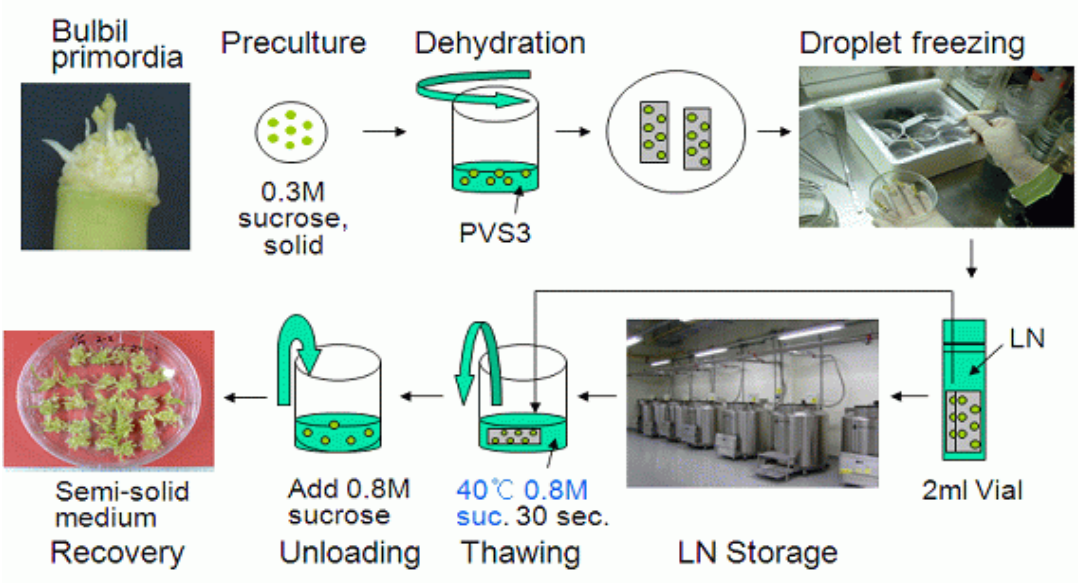


Fig. 3. Cryopreservation protocol for garlic unripe inflorescences by droplet-vitrification procedure.

The RDAGB is developing a DNA Bank for the accessions, focused on Korean originated landrace. So far, the DNA stocks of 15,000 accessions have been established and kept in –20 ^{o}C at the refrigerators. After developing DNA profile with the molecular markers, the data will be distributed to the researchers of the RDA institutes for mining of genes related to important traits.

Utilization of genetic diversity

Characterization and evaluation data may help researchers to search for desired combinations of traits and request to the RDAGB for the supply of appropriate seed samples. Characterization and evaluation of the stored germplasm samples are carried out by scientists working both in RDAGB and various crop experiment stations of RDA. The RDA descriptors were developed by partially modifying the IBPGR/IPGRI descriptions. About 75% of the stored germplasm by RDAGB has been characterized by 2007, and evaluated for various traits including physiological responses, disease and pest susceptibility, yield productivity, and other agronomic features (Table 5). The national project on regeneration and characterization is progressing well in collaboration with all the institutes under the RDA. By

2007, 115,999 accessions have been regenerated and characterized. In 1991, the RDAGB was designated as the centre of world sesame germplasm collections by FAO and IPGRI, and since then 1,600 accessions of sesame have been characterized and evaluated.

Table 5. Characterization status of germplasm preserved in the RDAGB (~2007)

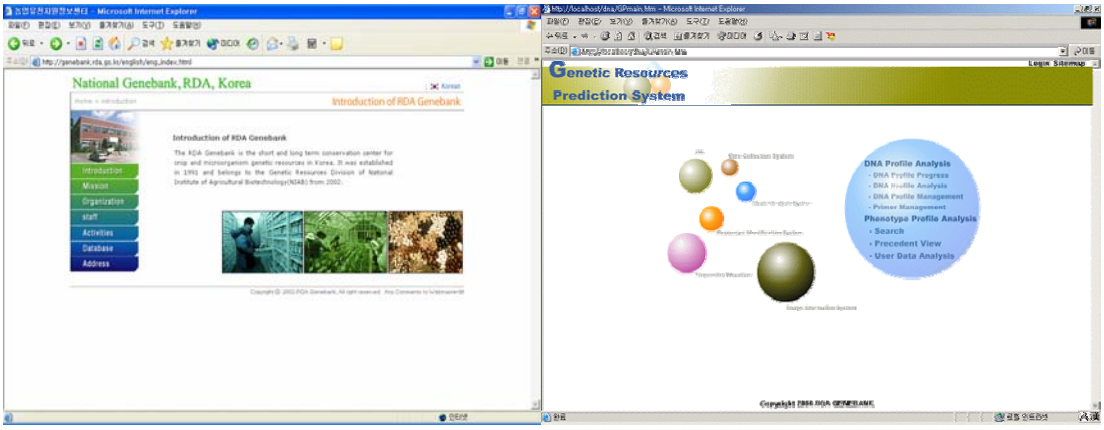
Crops	No. of preserved accessions	No. of characterized accessions	Ratio (%)
Cereals	117,275	94,011	80.1
Industrial & medicinal plants	18,617	11,656	62.6
Vegetables	14,984	8,365	55.8
Others	3,819	1,967	51.5
Total	154,695	115,999	74.9

* The RDAGB did not count the rate of characterized accessions since 2002 because different crops have been scored by different numbers of descriptors.

Information and capacity building

The information of germplasm preserved in RDAGB consists of passport, seed stock, characterization, evaluation, and distribution data. Passport data are a set of primary information for each accession, and accessible to the germplasm users (Fig.4). Also, an annual inventory of new accessions is released so that the users can know about the new acquisitions. Stock database is available on institute's intranet system for genebank management purposes. Characterization data, based on RDA crop-specific descriptors including image database are computerized for management and utilization of plant germplasm. A special software for taking image data of stored accessions was developed. This program helps to determine grain shape and measures their sizes. Image database also has a search function that can be used to identify unfamiliar specimens and accessions by matching the grain shape. The seed image database has been developed for the 25,000 conserved accessions of about 100 species. The information system of RDAGB can be accessed at *http://genebank.rda.go.kr/*. The database for vegetatively propagated PGR is under construction in collaboration with the institutions holding accessions in their field genebanks.

A new trial has been conducted to develop an integrated system for utilizing information of conserved germplasm. The integrated information system includes passport data, characterization data, GIS information, web-based core-set development, DNA profile data and their compounding data (Park *et al*. 2004). This system is more focusing on the utilization of PGRs (Fig. 4). The RDAGB is able to provide a processed data of each crop in case study for increasing utilization of stored germplasm.



<Main homepage of the RDAGB> <Integrated system for utilization>

Fig. 4. The main homepage for the RDAGB and a new integrated system of PGRS under the developing for providing characterization, core-sets, GIS ,and DNA profile data.

Policy and legislation

"RDA Genebank realizes its international obligations for sharing benefits arising from the use of introduced PGR and abides by the policies established under the auspices of the Convention on Biological Diversity (CBD) and the International Treaty of the FAO." The RDAGB believes in free-distribution of the germplasm it holds under international convention and with mutual agreement. The national management guideline of genetic resources for supporting germplasm activities was established under the Ministry of Agriculture and Forestry in 2007. The consideration for becoming a member of the ITPGRFA is subjected to relevant bodies under the government.

Future plan for PGR activities

The national program on plant genetic resources includes all the activities of public organizations such as government institutes and universities, and public sectors. There were more efforts for improving the national systems on sustainable conservation and utilization during last three years. The following descriptions are ongoing activities, which are strongly supported by the national program of plant genetic resources in Republic of Korea.

In situ conservation and development

a. Surveying genetic diversity of collections of *Camellia* species in Republic of Korea within the next two years.
b. Surveying Abies koreana at national level over the next three years.
c. Supporting on-farm management to restore diversity of landraces on farmers' lands.
d. Developing molecular systematics using molecular methods and evolutionary studies of genome diversification.

Ex situ conservation

a. Collecting and conserving wild *Pyrus* and *Malus* species from their natural habitat.
b. Collecting and conservation of landraces of persimmon from farmers' fields.
c. Developing national secure conservation system for genetic stocks and mutant lines for functional genomic research through cooperative project with research institutions and universities within the next 10 years.
d. Regenerating the accessions of low viability in collaboration with breeding institutions, organized by RDA (2009~2013).
e. Expanding the vegetatively propagated collections to university and private sector, in addition to the collections under RDA (2010~2012).
f. Developing in vitro and cryopreservation technology for lily, chrysanthemum and fruit trees within the next three years.

Utilization of plant genetic resources

a. Characterizing and evaluating 10,000 accessions through the cooperative projects with the breeding institutions.

b. Developing landrace core collection of barley, red pepper, Chinese cabbage and corn based on agronomic characters and molecular markers within the next three years.
c. Developing DNA profiles of core sets of main crops including UUC crops and vegetatively propagating crops, and molecular characterization methods to add value to PGR.
d. Constructing expression profiles of resistant genes in rice germplasm using RNA profiles.
e. Providing landrace varieties to farmers for assisting the development of sustainable agriculture systems.
f. Surveying under-utilized crop species according to their regional distributions and identifying their strong points in markets.
g. Developing and providing characterization and evaluation data for landraces of rice, soybean, barley and wheat to facilitate their uses in breeding programs.

Institutions and capacity building

a. Developing a strong national program for conservation and sustainable utilization of PGR in the Rep. of Korea, with a focus on PGRFA.
b. Developing a clearing-house mechanism to promote utilization of PGR originating from the Rep. of Korea including landraces and crop wild relatives.
c. Developing a safety backup system for duplication of plant genetic resources in Asian region through international cooperation.
d. Developing a web-based network program to provide characterization and evaluation data of PGR.

For implementing *in situ* conservation, the survey on wild relatives of crop species and on-farm collections will be continued on *Comellia, Pyrus* and *Diospyros kaki* for next several years. As for *ex situ* conservation, the RDAGB is establishing a national system for vegetatively propagating accessions which are independently maintained in each public institutes under the RDA. The seed collections in the universities are merging into one national conservation systems by national project now. The RDAGB has developed a managing system for networking of national collections of plant genetic resources.

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