Genetics and Plant Physiology – 2014, Volume 4 (1–2), pp. 13–21
Special Issue (Part 1) – Conference “Plant Physiology and Genetics – Achievements and Challenges”
24 - 26 September 2014 – Sofia, Bulgaria

Available online at http://www.ifrg-bg.com

PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE (PGRFA) – MAINTENANCE AND RESEARCH

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Accepted: *21 October 2014*

Summary: Plant genetic resources play a major role for global food security. The most significant and widespread means of conserving plant genetic resources is *ex situ* conservation. Most conserved accessions are kept in specialized facilities known as genebanks. World-wide 7.4 million accessions are stored in 1 750 *ex situ* genebanks. One of the ten largest *ex situ* collections of our globe is located at the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) in Gatersleben, Germany, safeguarding about 150 000 accessions from 3 212 plant species and 776 genera comprising wild and primitive forms, landraces as well as old and more recent cultivars.

Since the majority of genebank holdings globally are stored as seed, seed storability is of exceptional importance for germplasm preservation. At IPK, research on seed longevity was initiated for a range of crops maintained over decades. Variation between and within crop species was detected and genetic analyses were initiated. Results obtained for several crop species are presented.

Citation: Börner A., S. Landjeva, M. Nagel, M. A. Rehman Arif, M. Allam, M. Agacka, T. Doroszewska, U. Lohwasser, 2014. Plant Genetic Resources for Food and Agriculture (PGRFA) – Maintenance and Research. *Genetics and Plant Physiology*, Conference “Plant Physiology and Genetics – Achievements and Challenges”, 24-26 September 2014, Sofia, Bulgaria, Special Issue (Part 1), 4(1–2): 13–21.

Keywords: *Ex situ* conservation; Genetic mapping; Germplasm; Long term seed storage; Seed longevity.

Plant Genetic Resources – The global view

The *ex situ* conservation of plant genetic resources for food and agriculture (PGRFA) is a global concern and plays a central role for food security in the future. The germplasm is conserved in genebanks supported by public or private institutions. *Ex situ* genebank collections comprise seed genebanks, field genebanks and collections maintained via *in vitro* or cryo preservation. Most species native to temperate climate

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zones have ‘orthodox’ seeds, i.e. they can be dried down to low moisture contents without damage to be conserved in specially designed cold stores. Under such conditions seeds are expected to maintain a high level of vigour and viability for decades. Field genebanks and *in vitro* or cryo preservation are used primarily for species which are either vegetatively propagated or which have non-orthodox seeds. It is estimated that worldwide 90% of genebank holdings are seeds, i.e. seed storage is the predominant mode of plant genetic resources conservation (FAO 1998). Globally there are 1 750 *ex situ* genebanks housing about 7.4 million accessions. The ten largest collections are listed in Table 1 (FAO 2010).

Considering major crop groups (Figure 1), about 45 percent of all the accessions in the world’s genebanks are cereals. Food legumes are the next largest group, accounting for about 15 percent of all accessions while vegetables, fruits and forage crops each account for 6-9 percent of the total number of accessions maintained *ex situ*. Roots and tubers, as well as oil and fibre crops each account for 2-3 percent of the total (FAO 2010).

The largest numbers of *ex situ* accessions are of wheat, rice, barley and maize accounting for 77 percent of the total cereal collections. Other large germplasm holdings include bean, sorghum, soybean, oat, groundnut and cotton (FAO 2010). Details are given in Table 2.

In early 2008, the Svalbard Global Seed Vault (SGSV) was established as a safety net for *ex situ* seed collections of the world’s crops. Located in the permafrost, 130 metres into a mountainside on an island just 800 km from the North Pole, SGSV provides unprecedented levels of physical security. On August 24, 2014

Table 1. The ten largest germplasm collections on Earth.

Institution	Country	Accessions
NPGS (National Plant Germplasm System)	USA	508 994
ICGR-CAAS (Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Science)	China	391 919
NBPGR (National Bureau of Plant Genetic Resources)	India	366 333
VIR (N. I. Vavilov Research Institute of Plant Industry)	Russia	322 238
NIAS (National Institute of Agrobiological Science)	Japan	243 463
CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo)	Mexico	173 571
IPK (Leibniz-Institut für Pflanzengenetik und Kulturpflanzenforschung)	Germany	148 128
ICARDA (International Center for Agricultural Research in the Dry Areas)	Syria	132 793
ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)	India	118 882
IRRI (International Rice Research Institute)	Philippines	109 161

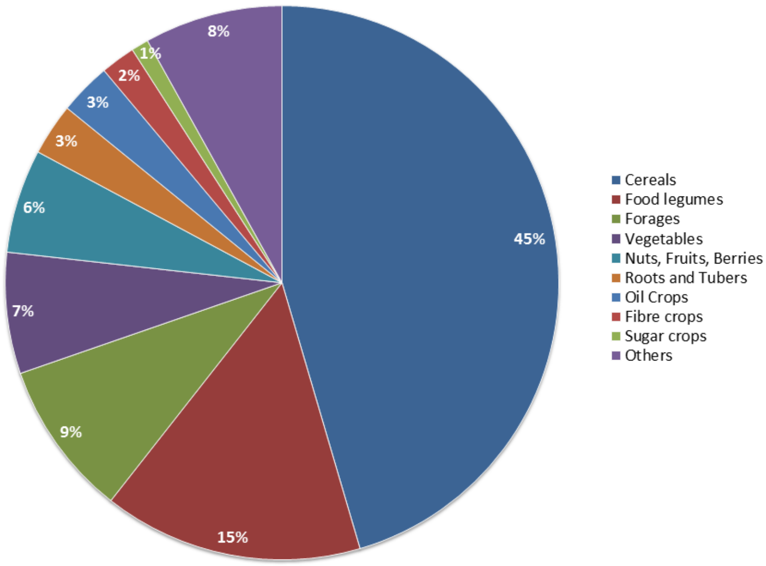

Figure 1. Contribution of major crop groups in total *ex situ* collections.

Table 2. The ten largest world-wide germplasm collections by crop.

Crop	Genus	Accessions
Wheat	*Triticum*	856 168
Rice	*Oryza*	773 948
Barley	*Hordeum*	466 531
Maize	*Zea*	327 932
Bean	*Phaseolus*	261 963
Sorghum	*Sorghum*	235 688
Soybean	*Glycine*	229 944
Oat	*Avena*	130 653
Groundnut	*Arachis*	128 435
Cotton	*Gossypium*	104 780

it housed 824 625 accessions belonging to 899 genera and 4 740 species. All accessions are safety duplicate copies of material already held in *ex situ* collections elsewhere. All materials remain under the ownership of the depositor. Details of the collections deposited in SGSV are provided in Tables 3 and 4 (http://www.nordgen.org/sgsv/).

The Federal *ex situ* genebank for agricultural and horticultural crops in Germany

With a total inventory of 150 000 accessions from 3 212 plant species and 776 genera, the 'Federal *ex situ* Genebank of Germany' in Gatersleben holds one of the most comprehensive collections worldwide. Details are given in Table 5.

Table 3. The ten largest depositors contributing to the Svalbard Global Seed Vault.

Institution	Country	Accessions
CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo)	Mexico	130 291
IRRI (International Rice Research Institute)	Philippines	116 668
ICARDA (International Center for Agricultural Research in the Dry Areas)	Syria	116 484
ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)	India	104 000
NPGS (National Plant Germplasm System)	USA	69 307
CIAT (Centro Internacional de Agricultura Tropical)	Colombia	47 898
IPK (Leibniz-Institut für Pflanzengenetik und Kulturpflanzenforschung)	Germany	36 534
PGRC (Plant Gene Resources of Canada)	Canada	25 868
IITA (International Institute of Tropical Agriculture)	Nigeria	18 813
CGN (Centre for Genetic Resources, The Netherlands)	Netherlands	18 642

Table 4. Inventory of accessions deposited at Svalbard Global Seed Vault by continents.

Continent	Accessions
Africa	125 320
Antartica	2
Asia	307 501
Europe	95 604
North America	180 273
Oceania	5 709
South America	53 099
Unknown	57 117
Total	824 625

Table 5. Inventory of the Gatersleben *ex situ* collection as on June 30, 2013 (Anonymous 2014).

Assortments	Accessions
Cereals and Grasses	65 876
Legumes	28 046
Vegetables	21 512
Oil, Fibre, Dye Plants	5 510
Medicinal, Spice Plants	8 278
Forage Crops	14 271
Potatoes	6 124
Others	1 762
Total	151 379

Seed storage is managed in large cold chambers at -18°C. Seeds are kept in glass jars, covered with bags containing silica gel (Figure 2). The maintenance of the collection requires regeneration. Each year between 8 and 10% of the collection is grown either in the field or in glasshouses. Regeneration is carried out locally to ensure genetic integrity and to minimize genetic erosion. Voucher specimens, photographs and written documentation are used to monitor the identity of the

Figure 2. View of the cold store (left) and glass jars carrying seeds of wheat (right).

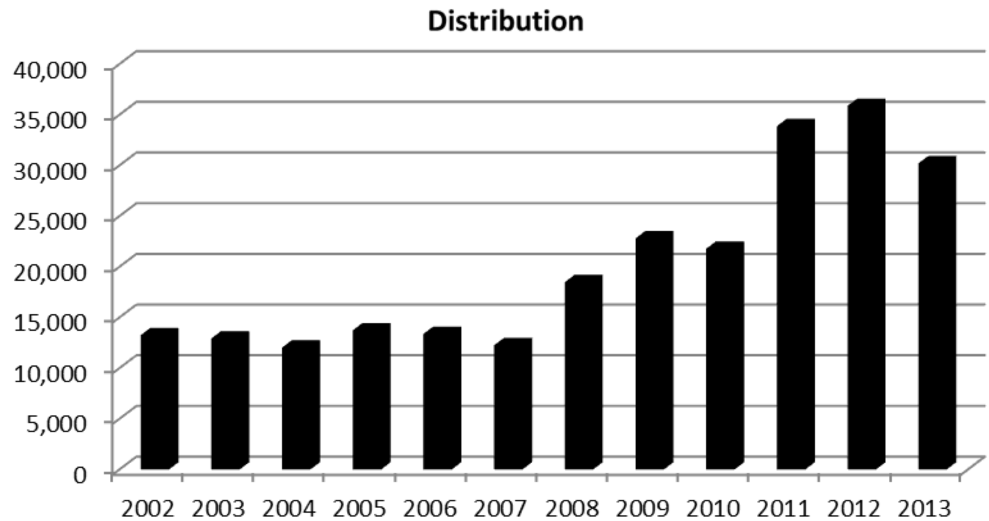

Figure 3. Amount of distributed accessions between 2002 and 2013.

material. Special attention has to be given to out-pollinating species, which are either multiplied in small glasshouses or in isolation plots in the field (Börner et al. 2012).

Between 2011 and 2013 about 30 000 samples were distributed annually. In comparison to previous years this represents a substantial increase (Figure 3). The average handling time from receipt of the signed standardised Material Transfer Agreement (sMTA) until dispatchment of the seeds/tubers/plants is 13 days.

Seed conservation/longevity

Since the majority of genebank accessions globally is stored in the form of seed, seed longevity is of particular importance for germplasm preservation. At the IPK, research was initiated for a range of crops stored in the genebank since the 1970s. Variation between crop species was detected for seeds stored at ambient conditions (around 20°C and 50% relative humidity) (Nagel and Börner 2010). Pea (*Pisum sativum*) and common bean (*Phaseolus vulgaris*) retained the viability over the longest period (29 and

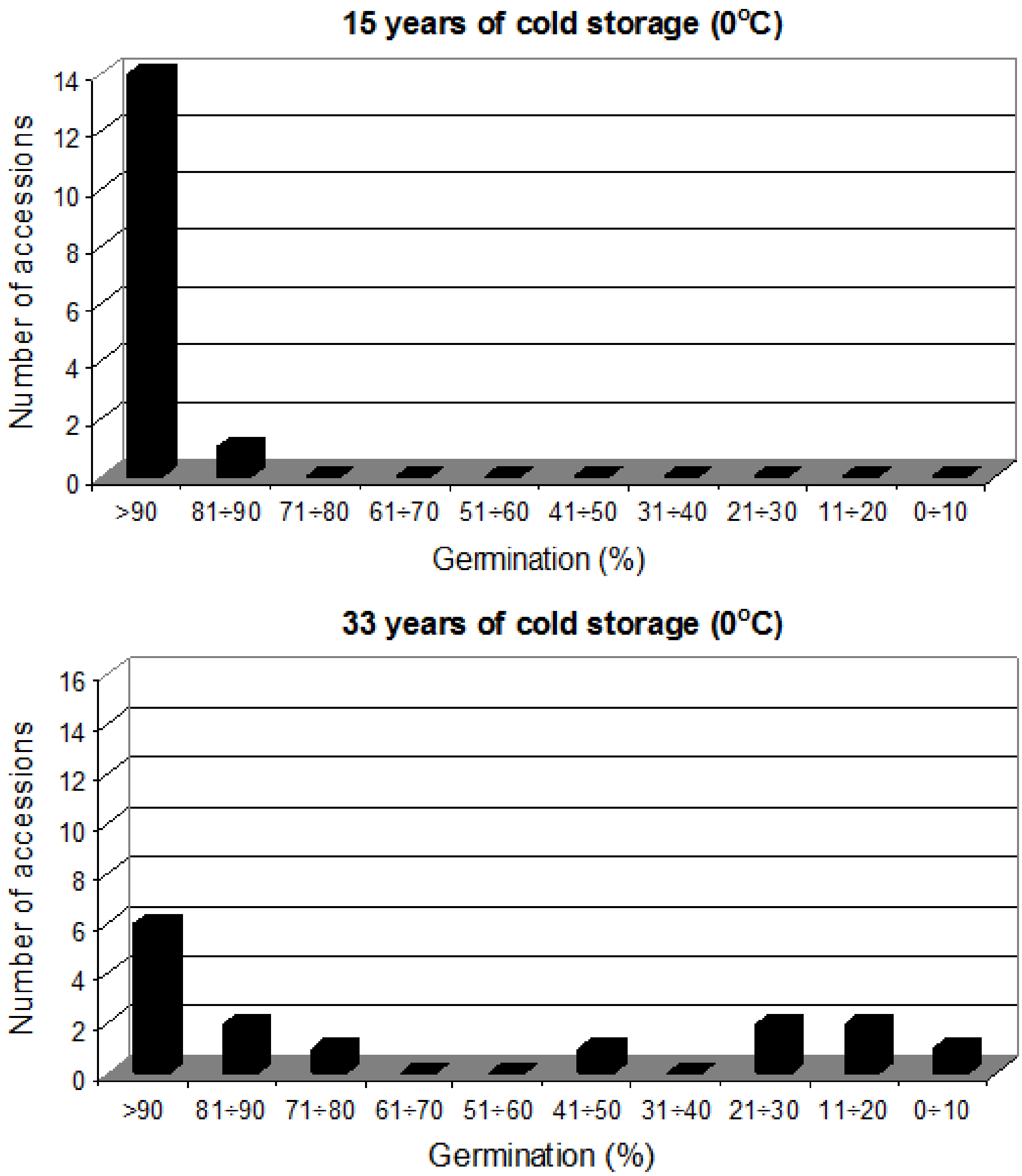

Figure 4. Longevity of wheat accessions stored at 0°C for 15 and 33 years, respectively.

21 years, respectively) whereas chive (*Allium schoenoprasum*) seeds survived for only five and lettuce (*Lactuca sativa*) for seven years. It was clearly indicated that seed deterioration behavior is species specific. However, there are also hints for an intraspecific variability as demonstrated for wheat in Figure 4 (Landjeva et al. 2008). Whereas after 15 years of storage at 0°C high germination rates were maintained for nearly all accessions analysed, an increased variation ranging between 90% and <10% germination was obtained after more than 30 years of storage determined by the genotype.

Further investigations on intraspecific variation of genebank collections stored between 26 and 33 years were performed by Nagel et al. (2010). Six species including barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), rye (*Secale cereale*), sorghum (*Sorghum bicolor*), oilseed rape (*Brassica napus*) and flax (*Linum usitatissimum*) and stored at either 0°C or/and -15°C were considered (Table 6). Whereas high germination was found within the first five years of storage, accessions of most species separated strongly after >20 years (Figure 5).

Recently, comprehensive studies on seed longevity in tobacco (*Nicotiana*) were initiated by Agacka et al. (2013, 2014). Seeds stored at different temperatures (20°C, 0°C, -15/-18°C) were investigated. The authors demonstrated that decreasing the temperature from 20 to 0°C increases the storability of tobacco seeds from about 10 to 30 years. Decreasing the temperature

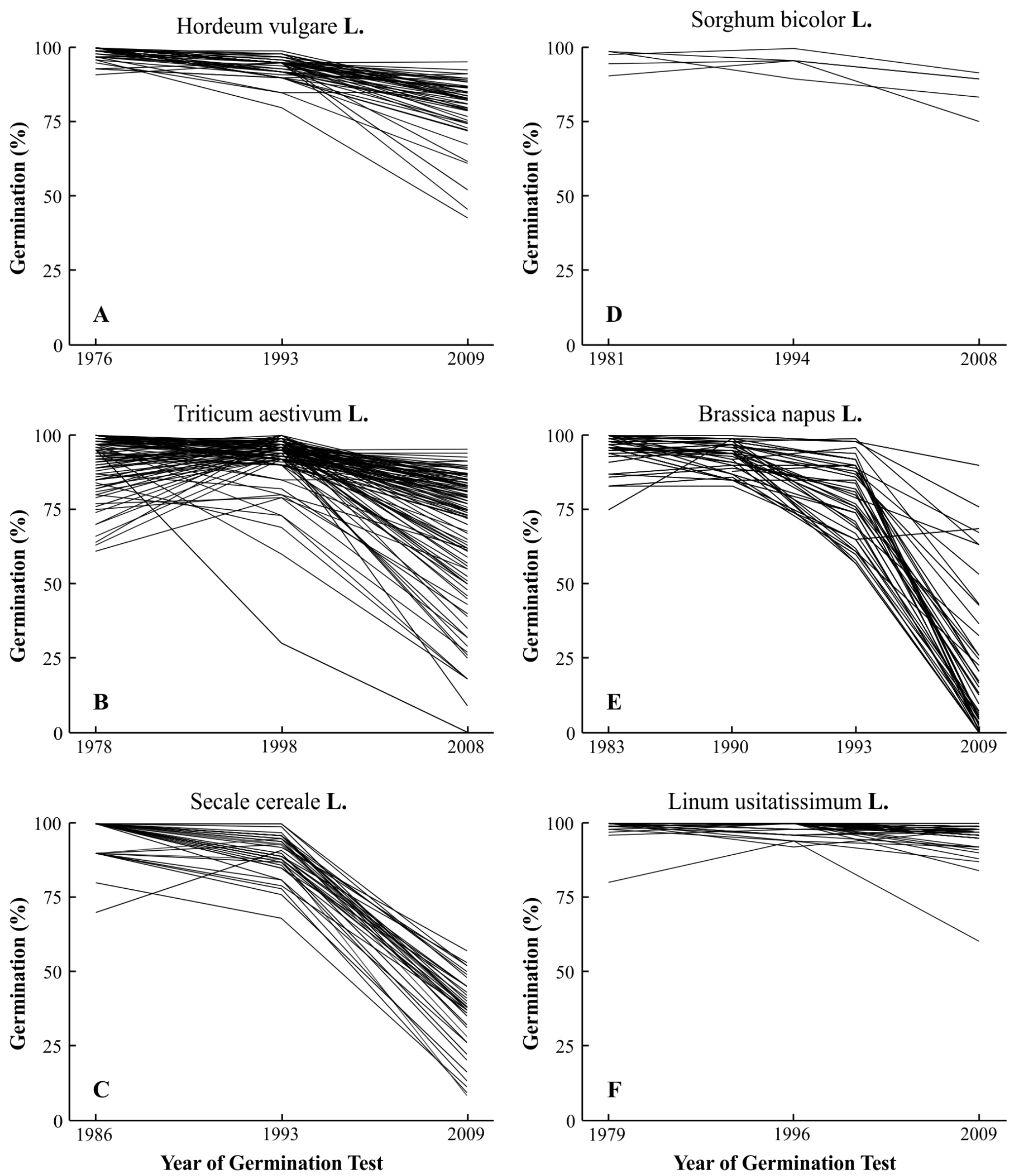

Figure 5. Mean germinations of barley (A), wheat (B), rye (C), sorghum (D), oilseed rape (E) and flax (F) accessions in different years of testing.

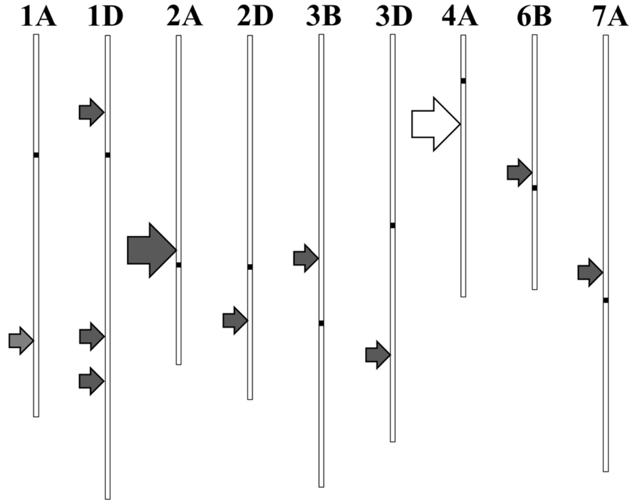

Figure 6. QTL for seed longevity (black arrows) and dormancy (empty arrow) detected in a bi-parental wheat mapping population.

further to -15/-18°C, an increase to more than 50 years, measured by a germination threshold higher than 75%, can be reached. As in other species, intraspecific variation was noticeable.

First attempts on determining genetic loci responsible for seed storability were made in Arabidopsis (Bentsink et al. 2000) and rice (Miura et al. 2002). At IPK in Gatersleben, studies were performed on barley (Nagel et al. 2009), wheat (Landjeva et al. 2010, Rehman Arif et al. 2012), and oilseed rape (Nagel et al. 2011). One example for wheat (Rehman Arif et al. 2012) showing loci for seed longevity and dormancy in wheat is given in Figure 6.

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