ICARDA
Science for Better Livelihoods in Dry Areas

CGIAR

GLOBAL CROP DIVERSITY TRUST
A Foundation for Food Security

# ICARDA's Genetic Resources Section

## *Integrated approaches on conservation and utilization of agrobiodiversity*

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**Genebank Manager**

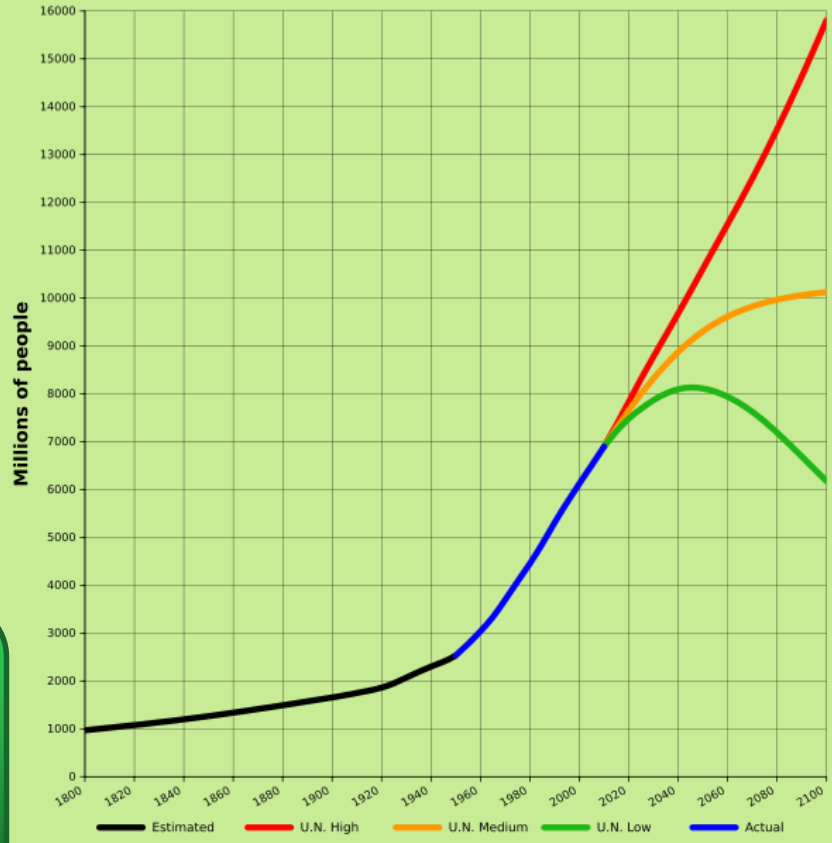
# CRITICAL CHALLENGES IN AGRICULTURE

## A. Ensure access to enough and nutritious food

- Today's world population….
  - ✓ Estimated approximately to 7.3 billions
- By 2050…
  - ✓ World population will grow to 9.2 billions (annual growth rate 0.7%)

### Two targets…

- ✓ Increasing production and energy content (carbohydrates, protein, fat) of staple foods
- ✓ Moving from "green revolution" to "revolution with greens"




World population estimates based on "high, "medium" and "low" projections (UN, 2010)

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# CRITICAL CHALLENGES IN AGRICULTURE

## B. Adaptation to climate change

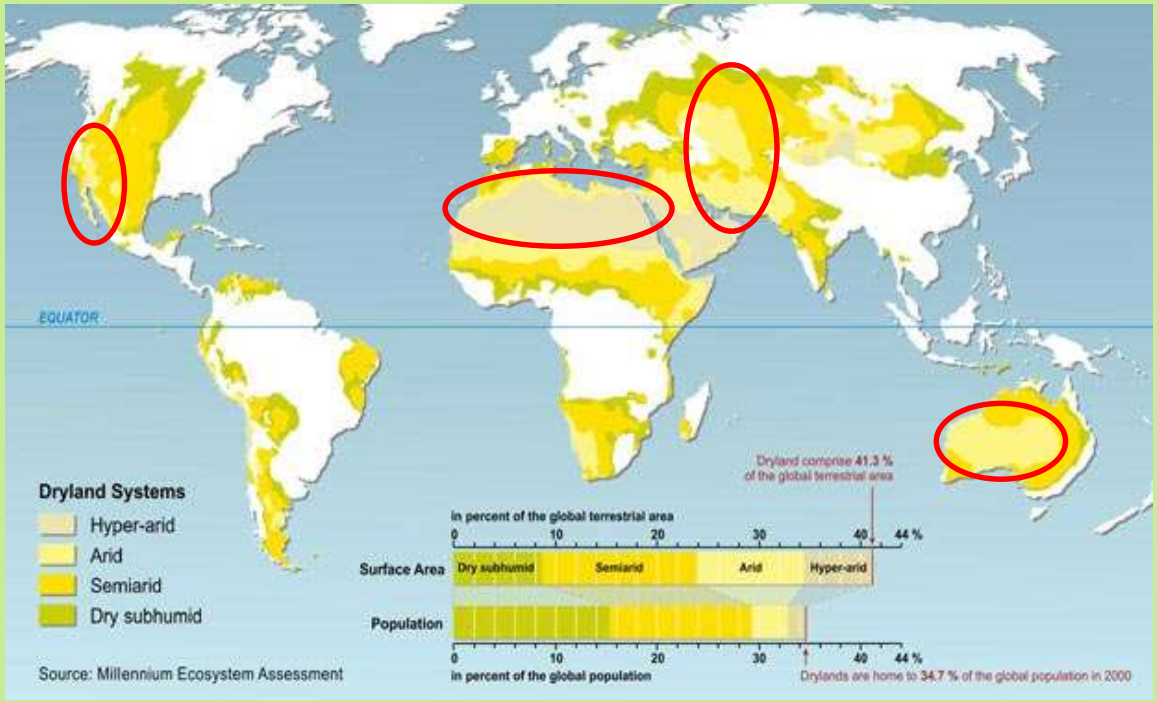
Global Climate Models all converge with regard to projections of:

- ✓ Increased frequency of drought, and
- ✓ high temperatures

In:

- ✓ central North America,
- ✓ northern Africa,
- ✓ central Asia, and
- ✓ western Australia

(Girvetz *et al.* 2009, Elert & Lemonick 2011)




Source: Millennium Ecosystem Assessment (2005)

http://oceanworld.tamu.edu/resources/environment-book/Images/drylandmap.jpg
Visited October 21, 2013

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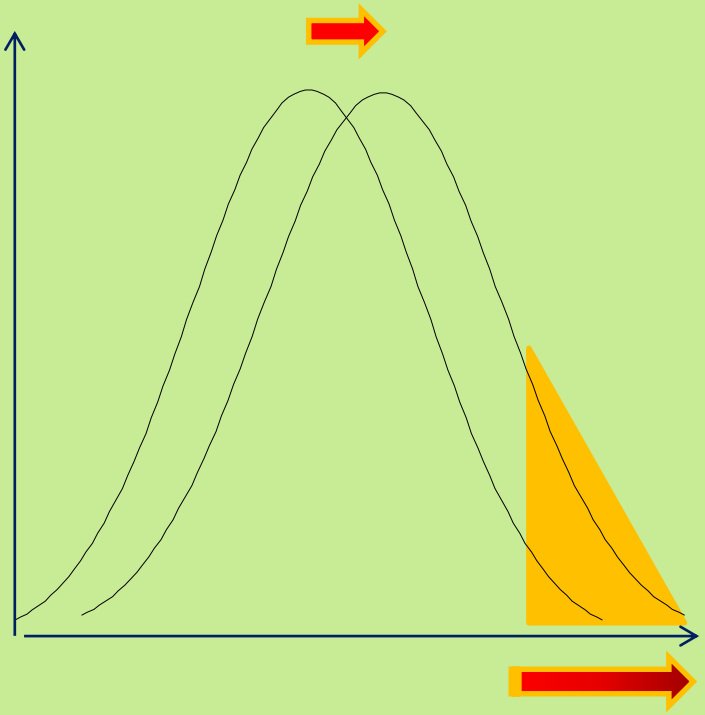
# CRITICAL CHALLENGES IN AGRICULTURE

## B. Adaptation to climate change (continue…)

**Heat stress** will increase vulnerability ofcrops ..more than drought.
(Semenov & Shewry 2011)

- ✓ Eleven of the last 12 years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1880).
  (Intergovernmental Panel on Climate Change, 2007)
- ✓ The year 2014 ranks as Earth's warmest on record (since 1880).
  (NASA and NOAA, 2014)



**This will require to aim for yield and environmental adaptation in unprecedented/different circumstances!**

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# BIOLOGICAL DIVERSITY

*"…the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."*

(CBD, 1992)

**Biodiversity comprises all living things together with their characteristic traits. Included with these traits are the cultural traits which characterize different people living on Earth.**

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# AGRICULTURAL BIODIVERSITY

The variable forms and functions of all living organisms that are useful in agriculture today or have potential usefulness in the future.

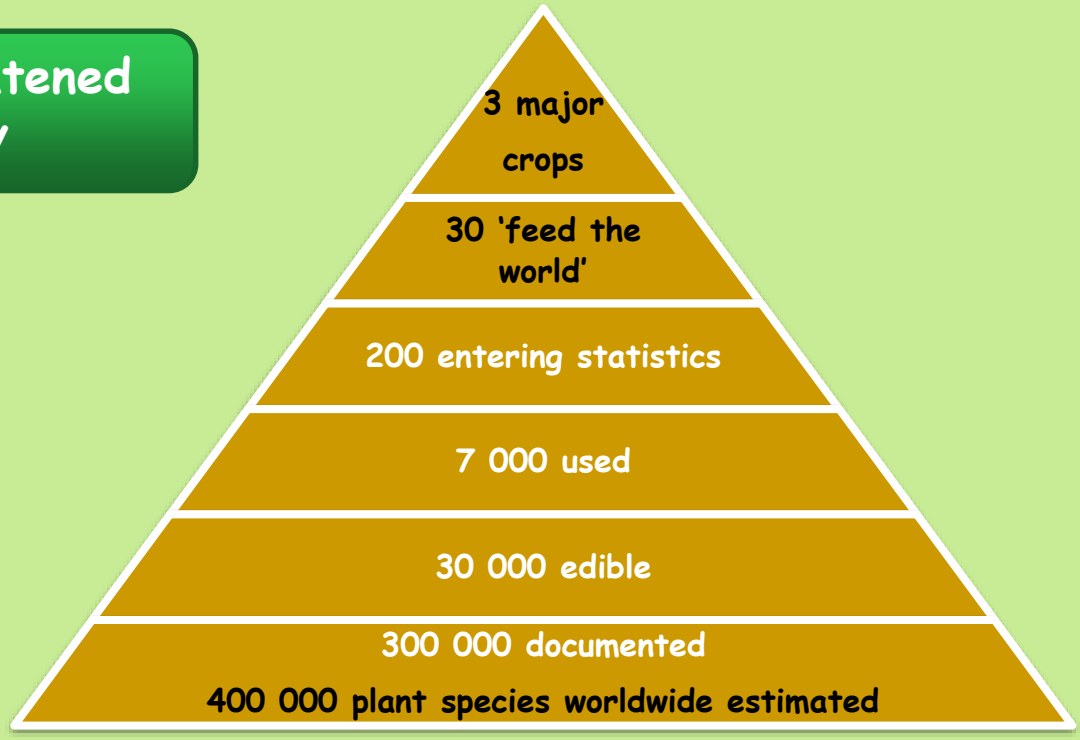
- ✓ It includes all crop plants, domestic animals, yeasts and other useful food processing organisms, N and P-fixing soil bacteria, etc., as well as their ancestral or related wild species at the genetic, species and ecosystem levels, which are necessary to sustain the key functions of the agro-ecosystem.

**It is the outcome of the interactions among genetic resources, the environment and the management systems and practices used by farmers and represents the basic element for safeguarding national and global food security.**

## However…

- ✓ Both inter- and intraspecific diversity is declining in the present agricultural systems.
- ✓ Similar trend is observed for many other traditional cultural, agricultural and natural resources.

## Agrobiodiversity is threatened seriously and increasingly




source: FAO, 1996

## Decline in genetic variability bears…

- ✓ Epidemics of pests and diseases due to a greater genetic vulnerability
- ✓ Lack of adaptation to climate change and related environmental adversities
- ✓ Lack of genetic variation for specific quality traits
- ✓ Reaching performance plateaus, etc.

## Therefore…

**A more efficient use of plant genetic diversity is a prerequisite for meeting the challenges of development, food security and poverty alleviation.**

# PLANT GENETIC RESOURCES

- The overall genetic diversity of cultivated species and their wild relatives, which have the potential to contribute in crop breeding (Hawkes, 1983).
  - ✓ Currently grown commercial varieties (cultivars)
  - ✓ Obsolete cultivars (expired legal protection)
  - ✓ Breeding lines and genetic stocks
  - ✓ Local varieties/landraces
  - ✓ Primitive forms of crop plants collected from the centres of origin and diversity of the species.
  - ✓ Crop wild relative species

**Most of the times…**

**The term is restricted in the categories of plant germplasm which is not protected by special legislation.**

# CENTERS OF ORIGIN OF CROPS

I. China (crops: soybean, buckwheat, rice)

II. a. India, b. Indochina (crops: banana, sugarcane, yam, rice)

III. Central Asia (N. India, Afghanistan, Turkmenistan) (crops: wheat)

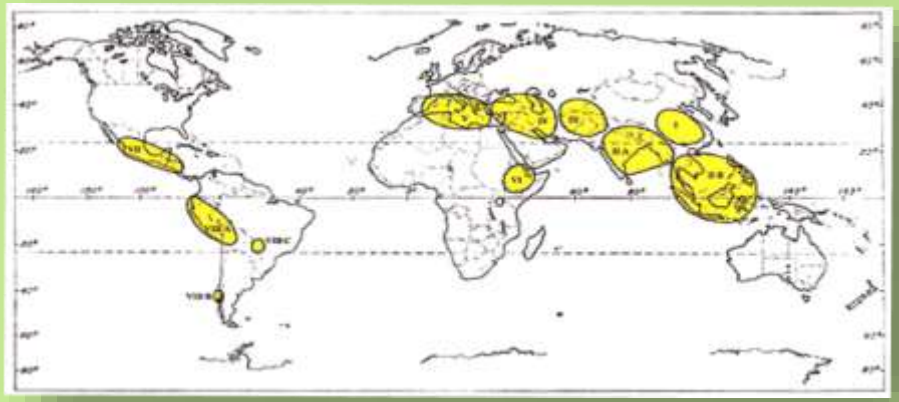
IV. Near East (fertile crescent) (crops: wheat, barley, rye, chickpea, lentils, figs)

V. Mediterranean (crops: oat, rapeseed)

VI. Abyssinia (crops: barley, sorghum, millet)

VII. Southern Mexico and middle America (crops: maize, common bean, sweet potato)

VIII. North-eastern south America (Bolivia, Ecuador, Peru) (crops: potato, lima bean, groundnut, cassava)



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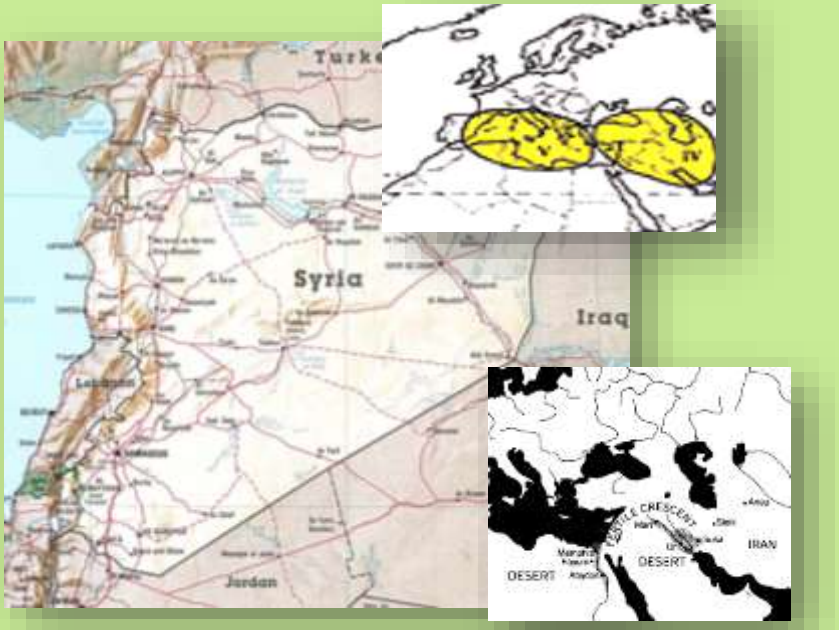
## Ex situ germplasm collections…

- Increased enormously in number and size over the last decades
  - ✓ Global efforts to conserve plant genetic resources for food and agriculture (PGRFA) … sometimes with support from international community
- Worldwide…
  - ✓ 1 700 genebanks are registered and conserve over 7 million accessions, including major crops, minor or neglected crop species, together with trees and wild plants (FAO, 2010).

## ICARDA's Genebank…

- Holds one of the largest collections
  - ✓ Conjunction between Near East and Mediterranean Centers of Origin.
  - ✓ The heart of the area that first crop domestication occurred (Fertile Crescent).

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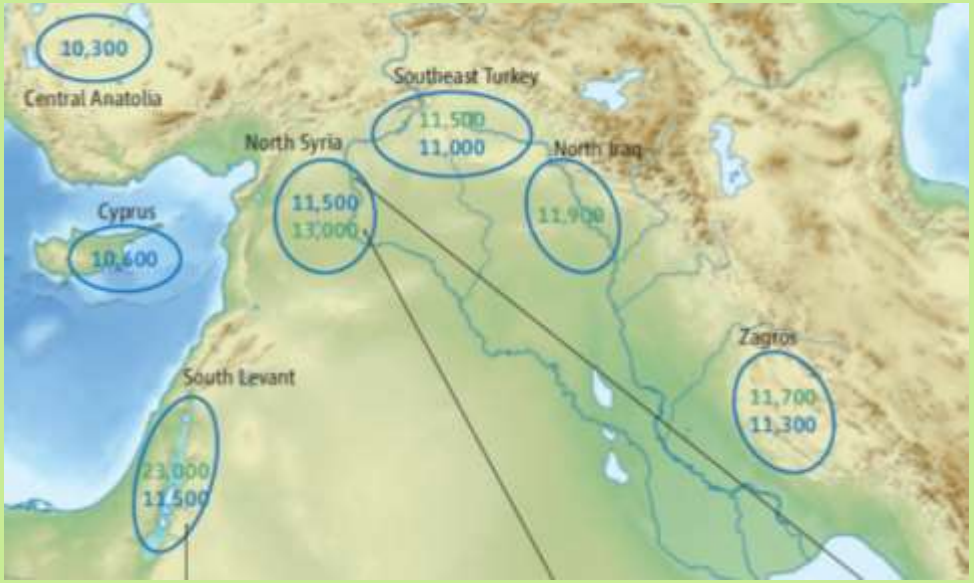
# ICARDA's Genebank…

**At the heart that first crop domestication occurred (Fertile Crescent)…**







a) Mortar and pestle from Wadi Hammeh in the southern Levant, 14,000 years ago. b) Bases querns in a room at Jerf el Ahmar, northern Syria and c) Quern from Tell 'Abr, northern Syria, all dated to 11,300 years ago. From Wilcox (*Science* 341, 39 (2013)).

# Decentralization of Genetic Resources Activities at ICARDA

Active and base collections and regeneration of faba bean, *Lathyrus*, forage legumes, range species and crop wild relatives

Safety duplication

Second level safety duplication

Safety duplication

Active and base collections and regeneration of cultivated cereals and lentil and chickpea

Active and base collections in Syria

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# ICARDA's Active Collection: September 2016

| Crop | No of accs. | Crop | No of accs. |
|---|---|---|---|
| Barley | 30,201 | *Pisum* spp. | 6,121 |
| Bread wheat | 14,681 | *Trifolium* spp. | 5,883 |
| Durum wheat | 20,526 | *Vicia* spp. | 6,388 |
| Primitive wheat | 1,022 | Faba bean | 10,034 |
| *Aegilops* spp. | 4,843 | Chickpea | 15,195 |
| Wild *Triticum* | 2,079 | Lentil | 13,907 |
| Wild *Hordeum* | 2,359 | Wild *Cicer* | 547 |
| Not mandate cereals | 179 | Wild *Lens* | 605 |
| *Lathyrus* spp. | 4,289 | Range & Pasture | 7,358 |
| *Medicago* annual | 9,120 | Others | 50 |
| **Total** | | | **155,387** |

| Crop genepool | Global Ranking | % acc. globally |
|---|---|---|
| Barley | 2nd | 18 |
| Wheat | 3rd | 11 |
| Chickpea | 2nd | 15 |
| Faba bean | 1st | 48 |
| Lentil | 1st | 51 |
| *Lathyrus* | 1st | 36 |
| *Medicago* | 1st | 28 |
| *Pisum* | 2nd | 15 |
| *Trifolium* | 2nd | 11 |
| *Vicia* | 1st | 13 |
| **Overall** | **2nd** | **5.6** |

(1) Based on GENESYS information
Total accessions: 3,631,898 in 482 institutions

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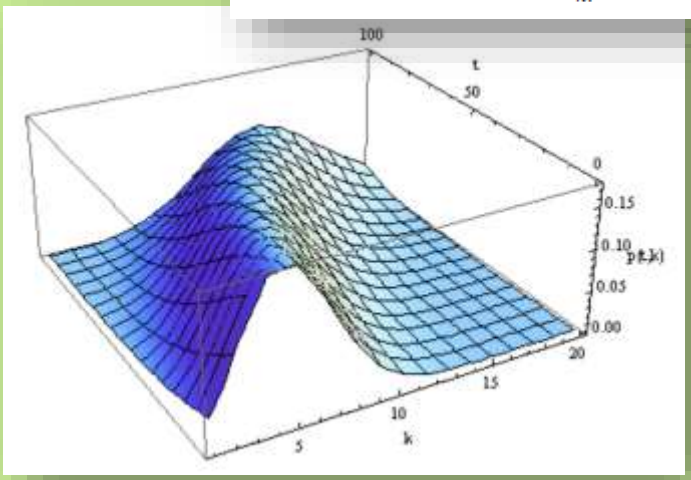
# COMPONENTS OF GENEBANK MANAGEMENT SYSTEM

- ✓ Policy framework (national and international regulations, legislations, etc.).
- ✓ Genebank objectives (what to conserve, services provided to users, expected outputs, approaches to achieve, etc.).
- ✓ Routine genebank operations (germplasm collection, characterization and evaluation, information management, germplasm exchange, etc.).
- ✓ Developing improved conservation and utilization strategies.
- ✓ Assessment of economic cost, creation of insurance value and optimization efficiency of genebank operations.

$$\Pr[(N(t+\tau)-N(t))=k]=p_1(k)=\frac{e^{-\lambda\tau}(\lambda\tau)^k}{k!},k=0,1,\ldots,$$

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# POLICY FRAMEWORK

- External policies increasingly influence genebanks objectives and operations.
- Genebanks establishment per se was based on external stakeholders (breeding institutes and government agencies).

**The establishment of CGIAR in 1971…**

**…and its International Agricultural Research Centers by the World Bank, supported FAO, the UNDP, and the governments of 19 industrialized countries.**


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# POLICY FRAMEWORK (continue…)

## Changes in the international policy environment

- International Undertaking (IU) on PGRFA
  - ✓ Adopted from the Commission on Genetic Resources for Food and Agriculture as a non-binding agreement in 1983.
  - ✓ PGRFA are considered as *"common heritage of mankind"*
  - ✓ Aims at the facilitation of international germplasm collection and exchange for scientific purposes on a *bona fide* basis.

- Convention on Biological Diversity (CBD)
  - ✓ Came into force in 1993 and has a legally binding character.
  - ✓ First time recognized *"National sovereignty"* over plant genetic resources.
  - ✓ Plant genetic resources are not a free good but have *"commercial value"*
  - ✓ *"Fair and Equitable"* sharing of benefits between donors and users of germplasm following the use of PGRFA in breeding.
  - ✓ Emphasis on bilateral negotiations and agreements.

Convention on Biological Diversity

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# POLICY FRAMEWORK (continue…)

## International Treaty (IT) on PGRFA

- ✓ Adopted in 2001 and came to replace the former IU
- ✓ Legally binding character aiming at exploration, conservation and sustainable use of plant genetic resources.
- ✓ Deals with the establishment of Multilateral System (MLS) of Access and Benefit Sharing.
- ✓ MLS includes major but not all crops that are under the management of the contracting parties and in the public domain.

## Intellectual property rights

- ✓ Plant variety protection through the introduction of plant breeders' rights (UPOV, CPVO, national regulations, etc.)
- ✓ Assigns the right for variety registration to the breeder, allowing the use of variety in further breeding programmes by third parties.
- ✓ Patent rights limit access of third parties to protected material (genes, pollen, seeds, etc.) having direct impact on PGRFA use.

CPVO
Community Plant Variety Office

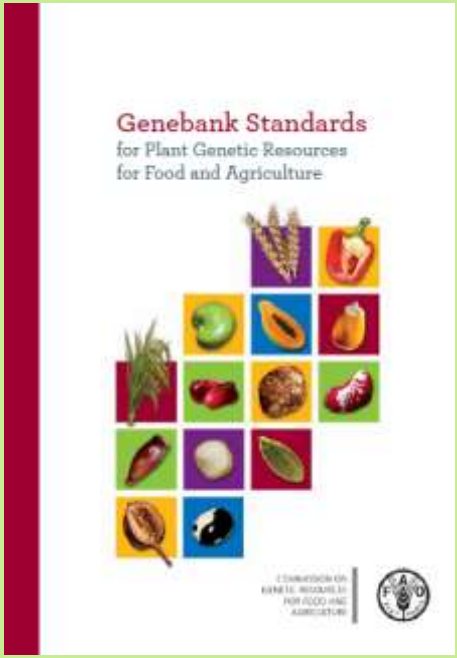
Europäisches Patentamt
European Patent Office
Office européen des brevets

# GENEBANK OBJECTIVES

- Critical examination of the precise objectives of a genebank and identify the constraints under which genebank operates.
- Development of clear objectives renders possible to establish detailed annual workplans against which performance can be regularly assessed and practices modified.

## Current FAO Genebank Standards…

…are adequate and represent the best practice for genebanks, though a genebank manager should interpret and modify these standrads according to local conditions.

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# GENEBANK OBJECTIVES (continue…)

## What to conserve?

- Two options…
  - ✓ Genebank collection is confined to germplasm from the country in which is located (option promoted by CBD – *Article 9*).
  - ✓ Genebank collection is extended to accommodate germplasm from a wider geographical region or from specific genepools.

**In every case, the collections comprise germplasm that can be used in agricultural production and breeding in the respective country as well as for the requirements of a wider user community.**

# GENEBANK OBJECTIVES (continue…)

## Decisions depend on…

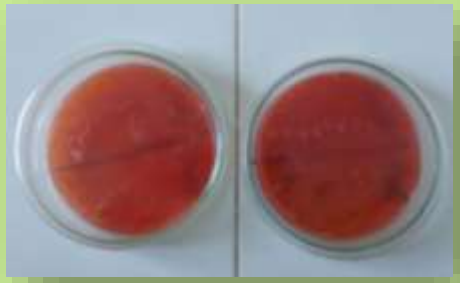
- Scope of the collections maintained
  - ✓ Coverage of all crops that play a role in national agriculture
  - ✓ Setting priorities to species representation (e.g. depending on availability of germplasm elsewhere, limiting coverage of the collection to germplasm from particular agroecological zones, etc.).

- User groups
  - ✓ Private and public sector breeders and researchers… focus of collection on acquiring accessions with useful traits (e.g. pest resistance). Crop wild relatives and other exotic material can be included.
  - ✓ Farmers' communities that need varieties adapted to the agroecosystems and farming systems… focus shifts from accessions with useful individual traits to varieties that represent overall added value.
  - ✓ Genebank mandate specifies maintenance of agricultural heritage of the country… focus is mainly on old neglected landraces and on the conservation of traditional diversity.

# *Rhizobium* spp. Collection at ICARDA

A unique collection of 1,380 strains of *Rhizobium* held at ICARDA's genebank

- Fully equiped *Rhizobium* laboratory at Rabat
- Activities:
  - ✓ Collecting samples from Marchouch fields (chickpea and lentil)
  - ✓ Isolation of about 80 strains from nodules of chickpea and lentil
  - ✓ Starting preliminary characterization using some biochemical tests (Congo Red, Gram strain, Bromothymol Blue, Cristal Violet, etc.)



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## GENEBANK OBJECTIVES (continue…)

- Infrastructure and budget
  - ✓ Effective seed storage constitutes major consideration in relation to other more expensive and less reliable storage methods (e.g. *in vitro*, cryopreservation, field plantations).
  - ✓ Genebank has to regenerate newly introduced accessions as well as accessions with viability below an acceptable threshold… collection maintained limited the space.

**Better documentation and information system, enhances demands, contributing to the exhaustion of stocks requiring larger fraction of budget for regeneration limiting the chance for expanding collection**

**The better you are the more expenses for regeneration/multiplication you need**

# Regeneration and Characterization 2016 at ICARDA

| Taxon | Lebanon | | | Morocco | | |
|---|---|---|---|---|---|---|
| | Svalbard | Others | Total | Svalbard | Others | Total |
| Bread wheat | | 3253 | 3253 | 2798 | 45 | 2843 |
| Durum wheat | | 910 | 910 | 3925 | 3 | 3928 |
| Primitive wheat | | | | 429 | 30 | 489 |
| *Aegilops* | 1259 | 566 | 1825 | | | 0 |
| Wild *Triticum* | 1259 | 523 | 1782 | 116 | | 116 |
| Barley | | 286 | 286 | 3935 | 306 | 4241 |
| Wild *Hordeum* | | 222 | 222 | 90 | 6 | 96 |
| Chickpea | | 680 | 680 | 2274 | | 2274 |
| Wild *Cicer* | | 343 | 343 | | | 0 |
| Lentil | | 404 | 404 | 2016 | 2040 | 4056 |
| Wild *Lens* | | 412 | 412 | | | |
| Faba bean | 1040 | | 1040 | | | |
| *Lathyrus* | 1040 | 171 | 1211 | | | |
| *Pisum* | | 6 | 6 | | | |
| *Medicago* | | 322 | 322 | | | |
| *Trifolium* | | 430 | 430 | | | |
| *Vicia* | | 437 | 437 | | | |
| Range/Pasture | | 393 | 393 | | | |
| *Others* | | 270 | 270 | | | |
| **Total** | **4598** | **9628** | **14226** | **15583** | **2400** | **18013** |

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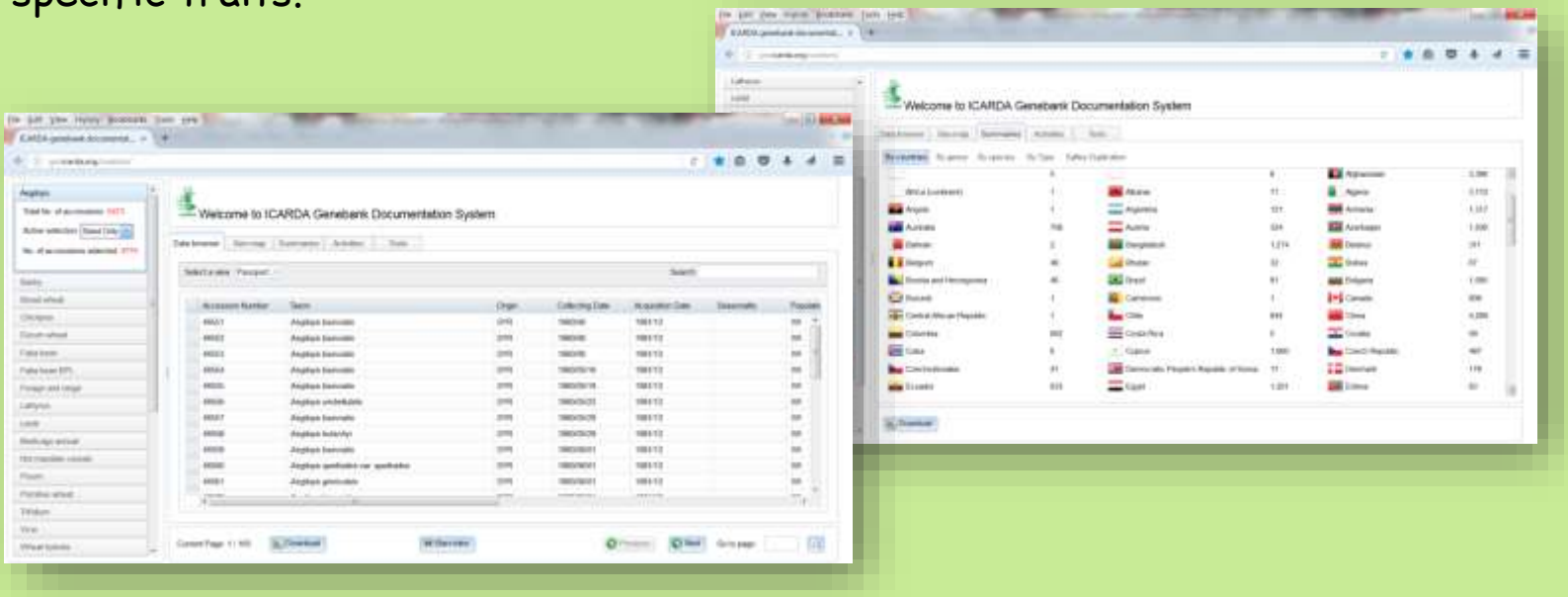
# GENEBANK OBJECTIVES (continue…)

## Services provided to the users

- …vary widely depending on the genebank and the end users
  - ✓ Information on passport data of the accessions is the minimum requirement.
  - ✓ Additional information (e.g. characterization and evaluation data) should be provided in order a genebank promote the use of its collection.
  - ✓ Development of an open access database allowing selection of accessions with specific traits.

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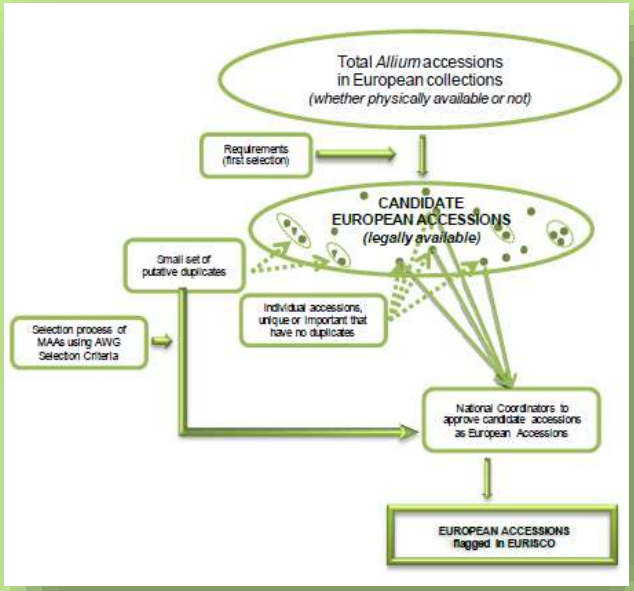
# GENEBANK OBJECTIVES (continue…)

- Establishment of core collections at institutional or international level
  - ✓ It consists of a limited number of the accessions of an existing collection (~10%), chosen to represent the genetic spectrum of the whole collection.
  - ✓ Facilitation of systematic evaluation of germplasm avoiding repetition of same/similar entries.
  - ✓ Highlights that part of the collection which best represents specific characters, or traits that are most useful for breeders (e.g. pest and disease resistance, abiotic stress traits, etc.).

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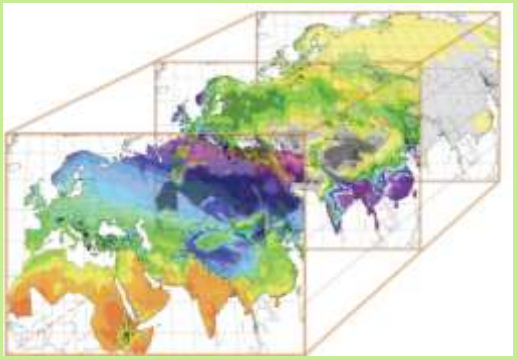
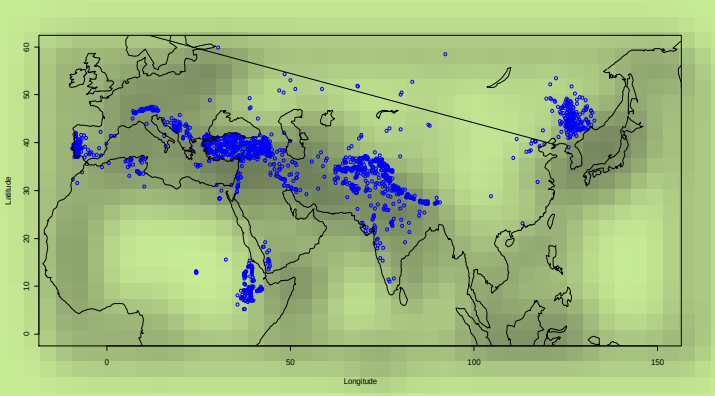
# Development and use of FIGS approach at ICARDA

- The Focused Identification of Germplasm Strategy (FIGS) is a rational approach to exploit large genetic resources collections
  - ✓ Links traits (phenotype), environments (and associated selection pressure) with genebanks accessions (landraces and wild relatives)
  - ✓ Efficient and effective method to mine genebanks accessions for useful traits to the breeders






www.icarda.org

Quantification of trait-environment relationship *(a-priori* information)

Develop trait subsets

Evaluation and refining algorithms

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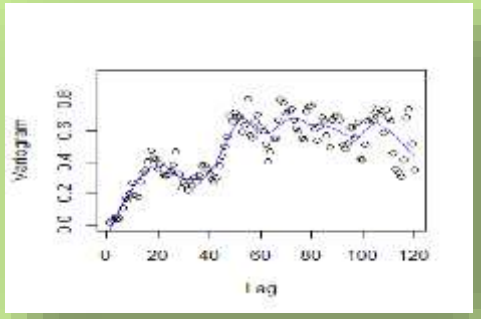
# GENEBANK OPERATIONS

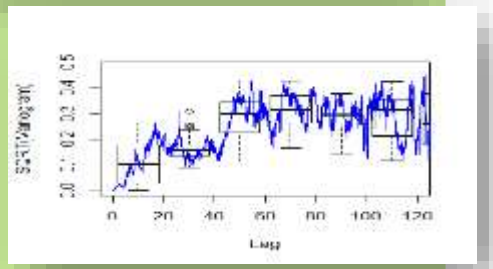
- Key-routine operations in the development and management of a genebank
  - ✓ Collecting expeditions, acquisition of germplasm.
  - ✓ Germplasm health and plant quarantine.
  - ✓ Conservation methods and strategies.
  - ✓ Germplasm viability monitoring.
  - ✓ Regeneration strategies.
  - ✓ Characterization and evaluation approaches.
  - ✓ Information management.
  - ✓ Conditions for germplasm exchange.

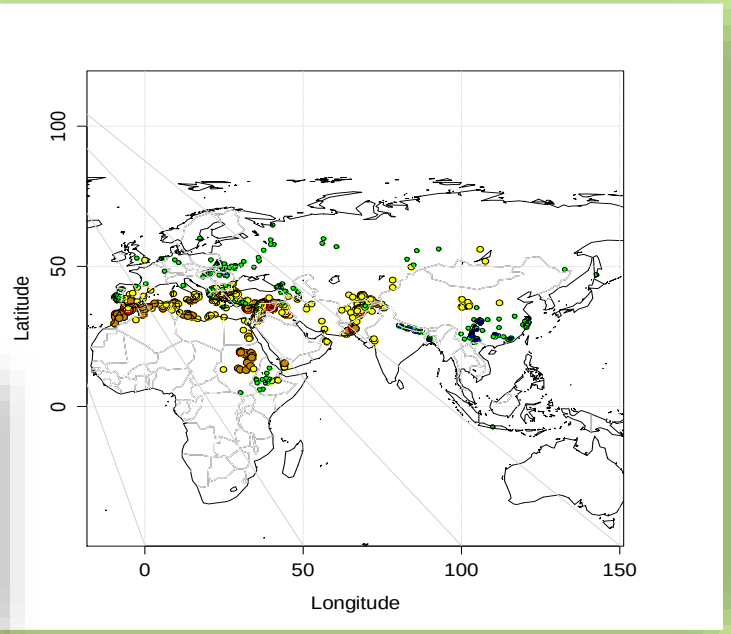
# GENEBANK OPERATIONS (continue…)

## Collecting expeditions, acquisition of germplasm

- Geographical Information System (GIS) and Remote sensing
  - ✓ GAP analysis using compiled data
  - ✓ Focused Identification of Germplasm Strategy (FIGS) using GIS environmental layers for targeting traits (e.g. drought, heat, salinity tolerance) *in situ*




Likelihood of an area yielding traits of resistance to drought

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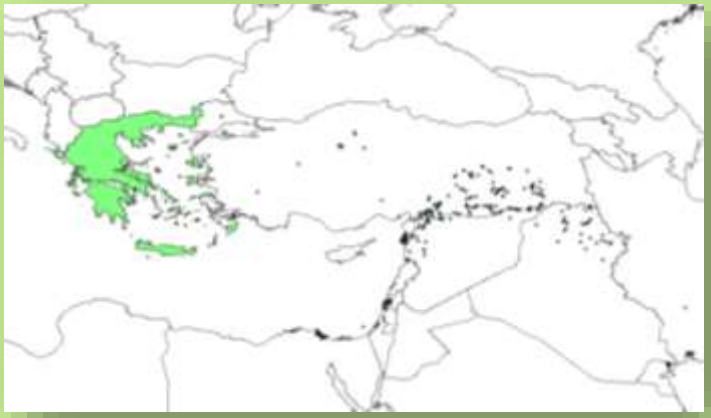
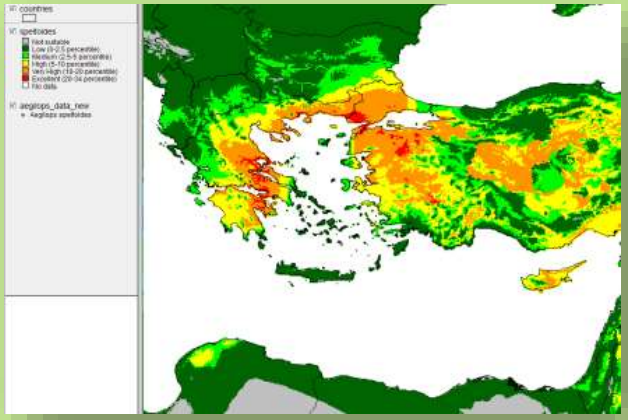
## Colllecting missions (continue…)

## Application of GAP Analysis for delimitation of the target region

- ✓ Target species presence reported.
- ✓ Target species ecosystems present.
- ✓ Target species ecology present.



Delimitation of the target region for collecting *Aegilops speltoides* in Greece



# GENEBANK OPERATIONS (continue…)

## Germplasm health and plant quarantine

- Uncontrolled germplasm introductions in the past had been the reason for dramatic epidemics caused by novel pests and diseases for which local crops had no resistance.
- Infection and contamination of accessions with pathogens may cause several problems in genebank management (impact on seed longevity, negative influence on characterization and evaluation, destroy of susceptible accessions, etc.).

**A genebank is the most obvious point of entrance of alien germplasm**

**Therefore the genebank manager has to device an appropriate and detailed germplasm health monitoring strategy, taking into account national quarantine regulations.**

# Seed Health Laboratory at ICARDA

- Two fully equiped SHL at ICARDA, Lebanon and Morocco
- Activities:
  - ✓ Testing of 3,388 incoming (destroyed 698) and 1,730 outgoing seed samples for ICARDA Morocco.
  - ✓ Field inspection at Marchouch of 11,750 entries
  - ✓ Coordination with local authorities for obtaining phytosanitary certificates

# GENEBANK OPERATIONS (continue…)

## Conservation methods and strategies

- *Ex situ* conservation (conservation off-site)
  - ✓ Seed storage (orthodox seeds)… the most widely used and convenient method of *ex situ* conservation.
    - ❖ **Base collection** (50-100 years): set of accessions, each of which is distinct and as close as possible to the original sample (Most Original Sample). Storage condition of -18°C and 3-7% seed moisture content.
    - ❖ **Active collection** (~ 30 years): dynamic character, immediately available for the purposes of multiplication and distribution for use, research, characterization, evaluation and utilization. Storage conditions of 4°C and 3-7% seed moisture content, 20-25% RH.
    - ❖ **Security backup:** collection deposited at different location under a "black box" for safety purposes.

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# GENEBANK OPERATIONS (continue…)

## Conservation methods and strategies

- *Ex situ* conservation (conservation off-site)
  - ✓ Field genebanks: for the conservation of clonal crops, crops with recalcitrant seeds or crops that rarely produce seeds.
    - ❖ Management can be the same as used during routine farming.
    - ❖ Conserved material can be readily characterized and evaluated and then accessed for research and use.
    - ❖ Major constraints, cost of maintenance and natural hazards.
  - ✓ *In vitro* conservation: maintenance of explants in a sterile, pathogen-free environment.

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# GENEBANK OPERATIONS (continue…)

## Conservation methods and strategies

- *In situ*/on farm conservation (conservation on-site)
  - ✓ Certain areas rich in indigenous wild relatives of crop plants can merit particular care and protection.
  - ✓ Allows the species to evolve under the selective pressures applied by nature (natural reserve conservation) or humans (under cultivation on farm).

# GENEBANK OPERATIONS (continue…)

## Germplasm viability monitoring

- Accurate assessment of initial viability of accessions prior to storage.
- Standards for viability monitoring have been developed by FAO (Genebank Standards, 1994; 2013), initial germination value >85% for most seeds e.g. cereals, and >75% for some vegetables or CWR.
- Awareness for variation in longevity, seed dormancy and other properties among accessions of the same species or among genotypes of the same accessions.

**Regeneration should not be undertaken unnecessarily (costly, risky)**

**Development of monitoring procedures that guarantee effective and efficient conservation.**

# GENEBANK OPERATIONS (continue…)

## Regeneration strategies

- … It constitutes a key process in genebank management since accessions are vulnerable to loss and change.
  - ✓ Status of seed introductions (viability, health status, etc.) is unknown.
  - ✓ Ensures sufficient quantity and optimum quality of seeds, (provided that takes place under controlled conditions).

**Development of procedures that maintain genetic integrity to the highest degree at maximum cost-effectiveness.**

## GENEBANK OPERATIONS (continue…)

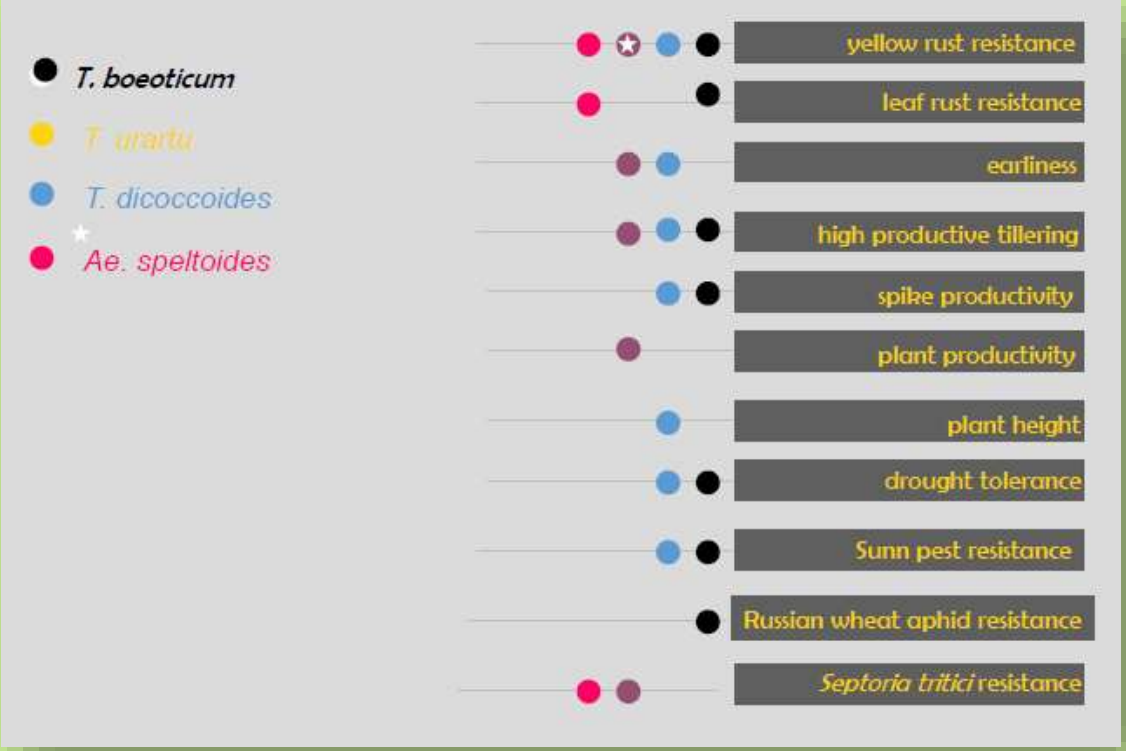
## Characterization and evaluation approaches

- Characterization involves determination of expression of highly heritable traits (morphological, biochemical, molecular)
  - ✓ "Traditional" characterization according to IPGRI Descriptor Lists.
  - ✓ Tool for rational management procedures (identify possible duplicates, grouping of germplasm accessions, etc.).
  - ✓ Appropriate characterization makes significant contribution to breeders (identification of appropriate parents for segregates with maximum diversity, prediction of heterosis, etc.).

# Pre-Breeding Activities

- The incorporation of novel diversity (genes) from wild material to the cultivated germplasm

## Novel genetic diversity for wheat identified in wide crosses

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# Pre-Breeding Activities at ICARDA

- Wheat (synthetic wheats, iterspecific crosses with *Aegilops* species)
- Barley (interspecific crosses with *Hordeum spotaneum* and *Hordeum bulbosum*)
- Grasspea (interpsecific crosses with wild material)

| Variety | *Hordeum bulbosum* | Seed number | Embryo number | Plant regenerated |
|---|---|---|---|---|
| Oussama | Hb24 | 6 | 1 | 0 |
| Rabat071 | Hb24 | 5 | 3 | 0 |
| ACSAD60 | Hb24 | 9 | 2 | 1 |
| Tiddas | Hb24 | 4 | 1 | 1 |
| Aglou | Hb24 | 12 | 0 | 0 |
| Aglou | Hb25 | 12 | 3 | 2 |
| Aannouceur | Hb25 | 18 | 0 | 0 |
| Arig8 | Hb24 | 4 | 0 | 0 |
| Arig 8 | Hb25 | 8 | 2 | 1 |
| ACSAD60 | Hb25 | 5 | 2 | 1 |

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# Developing improved conservation and utilization strategies (continue)

## Quality management system

- Aims to the active and explicit guidance and administration of the genebank in terms of standards.
  - ✓ It can be certified to ensure that agreed quality standards are applied.
  - ✓ It needs flexibility, in order to accommodate changes in the working environment of the genebank.
  - ✓ Requires active participation of management and staff.

- Development of eight SOPs for ICARDA's Genebank
  - ✓ Acquisition of Genetic Resources at ICARDA
  - ✓ Distribution of Genebank accessions at ICARDA
  - ✓ Safety duplication of genetic resources at ICARDA
  - ✓ Conservation of forage legumes at ICARDA
  - ✓ Regeneration and characterization of cultivated and wild forage legumes at ICARDA
  - ✓ Regeneration and characterization of cultivated and wild food legume germplasm at ICARDA
  - ✓ Regeneration and Characterization of cultivated and wild cereal genetic resources at ICARDA
  - ✓ Sampling roots of legumes and Isolation of *Rhizobium* species from nodules at ICARDA

## ASSESSMENT OF ECONOMIC COST

- Very difficult to assess the economic value of maintaining plant genetic resources in genebanks or *in situ*.
- No reliable method to value the various intangible benefits to agriculture before this germplasm is actually "transformed" in commercial varieties whose values can be subsequently assessed.
  - ✓ The immense value of landrace of Norin 10 could never be envisaged before it was successfully bred to almost all modern wheat varieties.

**The easiest practical approach adopted for genebank assessment is to divide the overall cost of running a genebank to the number of samples it conserves.**

**Annual cost/acc.**

**CIMMYT, wheat accessions: 0.19 – 8.08 $ (old vs. new accs.)**
**CIAT, cassava accessions: 17.09 – 26.22 $ (field vs. *in vitro*)**

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# Assessment of economic cost (continue)

**Table 2**
Expected insurance value (million €).

| Crops | Year of triggering event | Probability of triggering event | | |
|---|---|---|---|---|
| | | 10% | 20% | 40% |
| Wheat | 45 | 58.75 | 119.64 | 235.00 |
| | 60 | 22.01 | 44.82 | 88.04 |
| | 80 | 13.57 | 27.63 | 54.27 |
| Tobacco | 45 | 43.09 | 87.76 | 172.38 |
| | 60 | 16.14 | 32.87 | 64.57 |
| | 80 | 9.95 | 20.67 | 39.81 |
| White cabbage | 45 | 10.27 | 20.93 | 41.11 |
| | 60 | 3.85 | 7.85 | 15.40 |
| | 80 | 2.37 | 4.83 | 9.49 |
| Pulses | 45 | 12.66 | 25.78 | 50.65 |
| | 60 | 4.74 | 9.66 | 18.97 |
| | 80 | 2.92 | 5.95 | 11.70 |
| Vetches | 45 | 40.40 | 80.27 | 161.60 |
| | 60 | 15.13 | 30.82 | 60.54 |
| | 80 | 9.33 | 19 | 37.32 |
| Grapes | 45 | 60.49 | 123.19 | 241.99 |
| | 60 | 22.66 | 46.15 | 90.65 |
| | 80 | 13.97 | 28.45 | 55.89 |
| Sugar beets | 45 | 23.17 | 47.20 | 92.70 |
| | 60 | 8.68 | 17.68 | 89.11 |
| | 80 | 5.35 | 10.90 | 21.41 |


Ecological Economics

Valuing insurance services emerging from a gene bank: The case of the Greek Gene Bank

Xepapadeas et al., 2014

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# Thank You for Your Attention!

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