Continuum between conservation and utilization of genetic resources

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Sources: Wheat Initiative (Vision paper)
Complementary *ex situ* and *in situ* conservation approaches

**Genetic resources: Continuum conservation to utilization**

**Ex situ Conservation**
- Collect
- Conserve
- Evaluate
- Deploy

- Enrich with new accessions
- Use best practices
- Identify valuable traits
- Use in pre-breeding and breeding

**In situ conservation**
- Assess
- Designate
- Manage
- Promote

- Status and Threats
- Selection hot spots
- Management Plan
- Valorization Awareness

**Novel diversity**

**Rehabilitation Diversification**
Role of CGIAR Centers in conserving and using genetic resources

- Unique collections composed mainly of landraces and wild relatives;
- 15,000 samples distributed annually
- Breeding programs for barley, wheat, lentil, chickpea, faba bean and grass pea

<table>
<thead>
<tr>
<th>Crop</th>
<th>No of accs.</th>
<th>Crop</th>
<th>No of accs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>30,201</td>
<td><em>Pisum</em> spp.</td>
<td>6,121</td>
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<tr>
<td>Bread wheat</td>
<td>14,681</td>
<td><em>Trifolium</em> spp.</td>
<td>5,883</td>
</tr>
<tr>
<td>Durum wheat</td>
<td>20,526</td>
<td><em>Vicia</em> spp.</td>
<td>6,388</td>
</tr>
<tr>
<td>Primitive wheat</td>
<td>1,022</td>
<td><em>Faba</em> bean</td>
<td>10,034</td>
</tr>
<tr>
<td><em>Aegilops</em> spp.</td>
<td>4,843</td>
<td><em>Chickpea</em></td>
<td>15,195</td>
</tr>
<tr>
<td>Wild <em>Triticum</em></td>
<td>2,079</td>
<td><em>Lentil</em></td>
<td></td>
</tr>
<tr>
<td>Wild <em>Hordeum</em></td>
<td>2,359</td>
<td><em>Wild Cicer</em></td>
<td>547</td>
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<tr>
<td>Not mandate cereals</td>
<td>179</td>
<td>Wild <em>Lens</em></td>
<td>605</td>
</tr>
<tr>
<td><em>Lathyrus</em> spp.</td>
<td>4,289</td>
<td>Range &amp; Pasture</td>
<td>7,358</td>
</tr>
<tr>
<td><em>Medicago</em> annual</td>
<td>9,120</td>
<td>Others</td>
<td>50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>155,387</strong></td>
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</table>

- 749,656 accessions (717,205 seeds; 23,529 in vitro and 27,763 accessions in field genebanks
- Distribution: ~ 2000 requests; ~ 130,000 samples distributed to > 100 countries
- Operational breeding programs supplying elite germplasm
Relocation of genebank activities to Lebanon and Morocco

<table>
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<tr>
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<th>2015-2016</th>
<th>2016-2017</th>
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<tr>
<td></td>
<td>Regenerated</td>
<td>Svalbard/Routine</td>
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<td>Morocco</td>
<td>16,066</td>
<td>14,847/1,219</td>
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<td>Lebanon</td>
<td>13,456</td>
<td>4497/8959</td>
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<table>
<thead>
<tr>
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<th>2015-2016</th>
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<tr>
<td></td>
<td>Svalbard</td>
<td>Out</td>
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<tr>
<td>October 2015</td>
<td>38,073</td>
<td></td>
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<tr>
<td>September 2017</td>
<td>54,354</td>
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Core genebank activities and science-based approaches

Gap analysis
Collection
Conservation
Regeneration
Characterization
Documentation
Distribution

Ex-situ

FIGS approach
Identify Breeders sought traits
Evaluation & gene mining

Pre-breeding
Transfer useful genes to elite germplasm
Gene introgression

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>Total</th>
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<tbody>
<tr>
<td>GRS</td>
<td>9 003</td>
<td>16 198</td>
<td>18 856</td>
<td>11 829</td>
<td>6 986</td>
<td>9 600</td>
<td>7317</td>
<td>9370</td>
<td>72 472</td>
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<tr>
<td>Repatriation</td>
<td>0</td>
<td>1 053</td>
<td>1 394</td>
<td>1 547</td>
<td>0</td>
<td>2 300</td>
<td>1000</td>
<td>300</td>
<td>6 294</td>
</tr>
<tr>
<td>Svalbard</td>
<td>0</td>
<td>0</td>
<td>30 566</td>
<td>63 787</td>
<td>7 760</td>
<td>8 559</td>
<td>3 229</td>
<td>2 574</td>
<td>116 475</td>
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<tr>
<td>Inside ICARDA</td>
<td>15 005</td>
<td>13 611</td>
<td>5 088</td>
<td>8 724</td>
<td>5 014</td>
<td>1 731</td>
<td>2279</td>
<td>1314</td>
<td>59 173</td>
</tr>
<tr>
<td>Outside ICARDA</td>
<td>8 965</td>
<td>16 031</td>
<td>9 007</td>
<td>8 303</td>
<td>6 772</td>
<td>2 400</td>
<td>2271</td>
<td>1291</td>
<td>50 868</td>
</tr>
</tbody>
</table>

Axeltitel

ICARDA
Science for better livelihoods in dry areas
FIGS approach links adaptive traits, environments (and associated selection pressures) with genebank accessions (e.g. landraces and crop wild relatives)

If a dependency exists between environmental parameters and the emergence of an adaptive trait within an in-situ population then we can use this relationship to predict where adaptive traits are likely to occur elsewhere.
**FIGS pathways and outcomes**

- **User define a trait and set size**
  - No data available
  - Data assembly
  - Filtering to mimic selection pressure
  - Subset formation maximizing environmental diversity
  - Evaluation

- **Data available**
  - Data assembly
  - Machine learning algorithms
  - Metrics for validation
  - Trait prediction for unobserved accessions → assign a probability to an accession
  - Evaluation

- **Evaluation**

- ✓ Relevance of FIGS in identifying sources of resistance to stresses in bread wheat, durum wheat, lentil, chickpeas and faba bean.

- ✓ FIGS is applied by ICARDA to reply to requests by supplying more than 95 FIGS sets to partners worldwide.

- ✓ Fine tuning is a continuous task and further development is needed.

- ✓ FIGS processes are packed into R package and ultimately to a graphic user interface for a wider use.
### Results of the evaluation of FIGS subsets

#### Sought traits

<table>
<thead>
<tr>
<th>Trait</th>
<th>Total accessions</th>
<th>Resistant/tolerant accessions</th>
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</thead>
<tbody>
<tr>
<td>Fusarium wilt</td>
<td>192</td>
<td>15</td>
</tr>
<tr>
<td>Beet western yellows virus</td>
<td>182</td>
<td>9</td>
</tr>
<tr>
<td>Chickpea chlorotic stunt virus</td>
<td>182</td>
<td>2</td>
</tr>
<tr>
<td>Alfalfa mosaic virus</td>
<td>182</td>
<td>1</td>
</tr>
<tr>
<td>Aschocyta blight</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>Cold tolerance</td>
<td>150</td>
<td>18</td>
</tr>
<tr>
<td>Drought tolerance</td>
<td>150</td>
<td>46</td>
</tr>
<tr>
<td>Salinity tolerance</td>
<td>200</td>
<td>15</td>
</tr>
<tr>
<td>Pod borer</td>
<td>375</td>
<td>0</td>
</tr>
<tr>
<td>Leaf minor</td>
<td>200</td>
<td>2</td>
</tr>
</tbody>
</table>

#### Significant findings:
- **Sunn pest** – first time in bread wheat
- **RWA resistance** – new gene indicated
- **Hessian fly** - resistance to Syrian bio-type
- **Powdery mildew** – 2 new functional genes
- **Salinity** – 20% of salinity set showed resistance compared to only 3% of core set
- **Drought** – FIGS performed better than core
Importance of precision phenotyping and genotyping

15,384 landraces
1,549 landraces from drought prone environments
ICARDA starts the use of traits hotspot distribution maps to predict where most likely the occurrence of adaptive traits.

- Based on aridity index, we can identify accessions of cultivated and wild relative species with potential adaptation to heat and drought (T. dicoccoides, Ae. searsii, Ae. kochii, Ae. vavilovii).
- Salt tolerance in Ae. bicornis.
- New collecting missions organized using algorithms for adaptive traits.
Importance of genetic resources
Importance of introgressing adaptive genes from wild relative species

Dr. N. Borlaug:

(ICAORDA, May 2005)

“There are many good genes in the wild species and we should use them more in breeding”
Importance of introgressing adaptive genes from wild relative species

- **T. boeoticum**
- **T. urartu**
- **T. dicoccoides**
  - probably different from *Yr15*
- **Ae. speltoides**

- yellow rust resistance
- leaf rust resistance
- earliness
- high productive tillering
- spike productivity
- plant productivity
- plant height
- drought tolerance
- Sunn pest resistance
- Russian wheat aphid resistance
- *Septoria tritici* resistance

[Image of genotypes and their associated adaptive genes]
Grain yield (kg/ha) of promising lines of bread and durum wheat compared to best checks at Breda (2007-08 dry season) and Tel Hadia (2004-05 wet season)
Hessian fly resistant durum wheat varieties are released in Morocco, all derived from interspecific crosses (tripartite collaboration between INRA-Morocco, Kansas State University-USA and ICARDA)
Useful traits transferred from synthetic hexaploid wheat

1. Synthetics have exponentially increased genetic diversity in wheat

   1. Yield under drought and irrigated conditions
   2. Multiple disease
      • Leaf, stem, and yellow rusts
      • Yellow Leaf Spot (= tan spot) resistance
      • Nematode resistance
      • *Septoria tritici* blotch resistance
      • Salinity tolerance
      • Pre-harvest sprouting tolerance
      • Insect pests tolerance

After introducing a novel DD genome (*Ae. tauschii*), now work starting on using novel AABB genome (*T. dicoccoides* and *T. dicoccum*) in new synthetics.

van Ginkle and Ogbonnaya 2007; Ogbonnaya 2010
Varieties released by partners

- **232 varieties** released in the past 10 years
- 2013, the 1st year of movement out of Aleppo was the best one
Needs for further improvement of quality and nutritional attributes

% β-Glucan

Sample
Strengthening NARS capacities

- Providing technical backstopping for establishment of genebanks in 14 countries;
- Training of 287 persons on all aspects related to genetic resources conservation and use during past 5 years;
- Holds black boxes for Afghanistan, Iraq, Syria and Yemen;
- Contribution to the development of West Asia and North Africa regional strategy for conservation and use of genetic resources;
- Repatriation of genetic resources;
- Providing seeds for diversification and rehabilitation of degraded farming systems.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number accessions repatriated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afghanistan</td>
<td>2217</td>
</tr>
<tr>
<td>Canada</td>
<td>172</td>
</tr>
<tr>
<td>Algeria</td>
<td>32</td>
</tr>
<tr>
<td>Egypt</td>
<td>1228</td>
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<tr>
<td>Erirea</td>
<td>435</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>176</td>
</tr>
<tr>
<td>Georgia</td>
<td>102</td>
</tr>
<tr>
<td>India</td>
<td>2316</td>
</tr>
<tr>
<td>Iraq</td>
<td>439</td>
</tr>
<tr>
<td>Jordan</td>
<td>1452</td>
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<tr>
<td>Lebanon</td>
<td>1598</td>
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<tr>
<td>Morocco</td>
<td>3722</td>
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<tr>
<td>Oman</td>
<td>53</td>
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<tr>
<td>Palestine</td>
<td>1006</td>
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<tr>
<td>Portugal</td>
<td>121</td>
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<tr>
<td>Russia</td>
<td>825</td>
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<tr>
<td>Saudi Arabia</td>
<td>41</td>
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<tr>
<td>Syria</td>
<td>522</td>
</tr>
<tr>
<td>Turkmenistan</td>
<td>42</td>
</tr>
<tr>
<td>Tunisia</td>
<td>4351</td>
</tr>
<tr>
<td>Turkey</td>
<td>2000</td>
</tr>
<tr>
<td>Yemen</td>
<td>192</td>
</tr>
<tr>
<td>Total</td>
<td>21096</td>
</tr>
</tbody>
</table>
Emergency seed relief: key for agricultural recovery

- Assisting in assessment of emergency seed relief to identify immediate needs and sourcing right varieties;
- Multiplication and supply by ICARDA of 87 tons of foundation seeds of landraces of wheat, barley, lentil and chickpea requested by farmers;
- Development of community based seed enterprises for production and delivery of quality seeds of landraces and improved varieties.
Importance of promoting in situ/on-farm conservation of dryland agrobiodiversity

Status and threats assessed

Awareness increase and information sharing

Collection and ex situ Conservation/management

Low-cost technologies for in situ conservation/management

Appropriate policies and legislations

Conservation and sustainable use of Agrobiodiversity

Benefit sharing and funding

Regional and international collaboration

Improvement of income/Livelihoods of custodians

Add value technologies

Alternative sources of income
Conclusions and recommendations

- More collecting is needed mainly to save the wild relative species under-represented in the *ex situ* conserved collections.
- FIGS approach has shown its relevance for finding rare alleles and novel diversity for complex traits. However, it can be improved to take into consideration the virulence of diseases and insects and can be fine tuned by the use of the results of precision phenotyping and genotyping;
- Genotyping and phenotyping are critical for efficient use of genetic resources;
- Landraces have contributed significantly to the breeding efforts, however CWR are not exploited calling for substantial pre-breeding efforts.
- Need to promote *in situ/on-farm* conservation and sustainable use of dryland agrobiodiversity