Root traits differ between wet- and dry-adapted sets of faba bean accessions selected by FIGS

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Faba bean genetic resources

ICARDA
International Centre for Agricultural Research in the Dry Areas (Syria)

ICGR-CAAS
Institute of Crop Germplasm Resources, Chinese Academy of Agricultural Sciences (China)

ATFCC
Australian Temperate Field Crops Collection (Australia)

~ 7.5 million plant genetic resources

18% Food legumes

43,695 faba bean accessions

FIGS represents a dynamic, direct and practical approach that focuses on specific adaptive traits rather than on generalized measures of diversity.
Why faba bean 
(Vicia faba L.)?
During 2010-2011

201 accessions of faba bean from wet and 201 from dry region of the world, were chosen according to principals of the FIGS.
Measurements

- Stomatal morphology
- Stomatal function
- Relative Water Content
- Days to flowering
- Number of tillers
- Seed size (*major*, *equina*, *minor*)
ROC plots (left) and density plots class prediction (right) for dry and wet sets using the three models.

**rpart - caret**: Classification and Regression Training
**RF**: Random Forests
**SVM**: Support Vector Machines

Rank of measurements that contribute the most to discriminate the sets.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Drought related parameter</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leaflet temperature</td>
<td>34.91</td>
</tr>
<tr>
<td>2</td>
<td>Canopy temperature</td>
<td>13.68</td>
</tr>
<tr>
<td>3</td>
<td>Relative water content</td>
<td>12.46</td>
</tr>
<tr>
<td>4</td>
<td>Leaflet area</td>
<td>9.95</td>
</tr>
<tr>
<td>5</td>
<td>Stomatal length</td>
<td>6.70</td>
</tr>
<tr>
<td>6</td>
<td>Fertile tillers</td>
<td>4.72</td>
</tr>
<tr>
<td>7</td>
<td>Stomatal area</td>
<td>4.13</td>
</tr>
<tr>
<td>8</td>
<td>Transpiration rate</td>
<td>3.61</td>
</tr>
<tr>
<td>9</td>
<td>Stomatal area per unit area of leaflet</td>
<td>2.75</td>
</tr>
<tr>
<td>10</td>
<td>Photosynthetic rate</td>
<td>2.34</td>
</tr>
<tr>
<td>11</td>
<td>Days to flowering</td>
<td>2.21</td>
</tr>
<tr>
<td>12</td>
<td>Intercellular CO₂</td>
<td>1.64</td>
</tr>
<tr>
<td>13</td>
<td>Stomatal density</td>
<td>1.26</td>
</tr>
<tr>
<td>14</td>
<td>Water use efficiency</td>
<td>1.21</td>
</tr>
<tr>
<td>15</td>
<td>Stomatal conductance</td>
<td>0.86</td>
</tr>
<tr>
<td>16</td>
<td>Stomatal width</td>
<td>0.14</td>
</tr>
</tbody>
</table>
Distribution of FIGS sets before and after evaluation

Geographical distribution of the two sets based on *a priori* information (climate data)

Distribution of the two sets based on **PCA** of evaluation data
Objectives

• To test whether faba bean germplasm from drought-prone (dry) and drought-free environments (wet) differed in root traits.

• The initial findings were then tested in a subset of materials to examine response of wet and dry set accessions under drought conditions.
How the subsets chosen (6+6)
## Accessions used for root traits screening

<table>
<thead>
<tr>
<th>Set</th>
<th>Accession number</th>
<th>Country</th>
<th>Province</th>
<th>Altitude (m)</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Seed size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet set</td>
<td>Aurora/2</td>
<td>Sweden</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>minor</td>
</tr>
<tr>
<td></td>
<td>IG 114476</td>
<td>Bangladesh</td>
<td>Dhaka</td>
<td>50</td>
<td>23.8167</td>
<td>90.0833</td>
<td>paucijuga</td>
</tr>
<tr>
<td></td>
<td>IG 99501</td>
<td>China</td>
<td>Zhejiang</td>
<td>299</td>
<td>28.8167</td>
<td>121.1</td>
<td>equina</td>
</tr>
<tr>
<td></td>
<td>IG 114985</td>
<td>Nepal</td>
<td>Kosi</td>
<td>140</td>
<td>26.4664</td>
<td>87.4469</td>
<td>paucijuga</td>
</tr>
<tr>
<td></td>
<td>IG 132238</td>
<td>China</td>
<td>Guangdong</td>
<td>200</td>
<td>24.36</td>
<td>115.59</td>
<td>equina</td>
</tr>
<tr>
<td></td>
<td>IG 117833</td>
<td>China</td>
<td>Yunnan</td>
<td>1680</td>
<td>24.8594</td>
<td>103.278</td>
<td>major</td>
</tr>
<tr>
<td>Dry set</td>
<td>IG 13987 (ILB 938)</td>
<td>Ecuador</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>equina</td>
</tr>
<tr>
<td></td>
<td>Mélodie/2</td>
<td>France</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>minor</td>
</tr>
<tr>
<td></td>
<td>IG 11689</td>
<td>Afghanistan</td>
<td>Baghlan</td>
<td>1640</td>
<td>35.6</td>
<td>69.1667</td>
<td>minor</td>
</tr>
<tr>
<td></td>
<td>IG 131708</td>
<td>Tajikistan</td>
<td>Khudzhand</td>
<td>2000</td>
<td>39.378</td>
<td>68.591</td>
<td>minor</td>
</tr>
<tr>
<td></td>
<td>IG 72309</td>
<td>Syria</td>
<td>Damascus</td>
<td>931</td>
<td>33.4333</td>
<td>36.0833</td>
<td>major</td>
</tr>
<tr>
<td></td>
<td>IG 13505</td>
<td>Cyprus</td>
<td>Nicosia</td>
<td>320</td>
<td>35.0667</td>
<td>33.0667</td>
<td>major</td>
</tr>
</tbody>
</table>

\[a\] more information on accessions available at: [https://www.genesys-pgr.org/](https://www.genesys-pgr.org/)
Evaluating 12 accessions (6 wet and 6 dry set)

- Well watered conditions
- Randomized complete block with 4 replicates

(4 accessions, 2+2 wet \ dry)  
response to drought stress

- Completely randomized factorial design with 4 replicates

Water holding capacity = 18% (w/w)  
Each box (7.72 kg) brought to WHC by adding 1400 ml of water

- Stress treatment plants got 50 % of field capacity.

Soil : sandy soil with organic matter 3-6 % (m). pH 6.7, Ca 1300, P 21, K 130, Mg 113
Experimental units

How the experimental units arranged
Experiment 1

Root profile after 32 days

Wet set

IG 114476
IG 114985
Aurora/2
IG 132238
IG 117833
IG 99501

Dry set

IG 131708
IG 11689
Mélodie/2
ILB 938
IG 72309
IG 13505

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### Characteristics of the roots and shoot of faba bean accessions (32-day-old seedlings)

<table>
<thead>
<tr>
<th>Accessions</th>
<th>Root length (cm)</th>
<th>Shoot length (cm)</th>
<th>Root DM (g)</th>
<th>Shoot DM (g)</th>
<th>Root / Shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aurora/2</td>
<td>49.43</td>
<td>22.67</td>
<td>0.679</td>
<td>0.649</td>
<td>1.05</td>
</tr>
<tr>
<td>IG 114476</td>
<td>48.17</td>
<td>21.27</td>
<td>0.256</td>
<td>0.305</td>
<td>0.84</td>
</tr>
<tr>
<td>IG 99501</td>
<td>40.20</td>
<td>25.60</td>
<td>0.524</td>
<td>0.607</td>
<td>0.86</td>
</tr>
<tr>
<td>IG 114985</td>
<td>51.73</td>
<td>19.60</td>
<td>0.372</td>
<td>0.314</td>
<td>1.18</td>
</tr>
<tr>
<td>IG 132238</td>
<td>41.80</td>
<td>28.37</td>
<td>0.469</td>
<td>0.913</td>
<td>0.51</td>
</tr>
<tr>
<td>IG 117833</td>
<td>47.80</td>
<td>24.90</td>
<td>0.462</td>
<td>0.542</td>
<td>0.85</td>
</tr>
<tr>
<td><strong>mean</strong></td>
<td><strong>46.52</strong></td>
<td><strong>23.73</strong></td>
<td><strong>0.460</strong></td>
<td><strong>0.555</strong></td>
<td><strong>0.88</strong></td>
</tr>
<tr>
<td><strong>SEM</strong></td>
<td><strong>1.85</strong></td>
<td><strong>1.30</strong></td>
<td><strong>0.058</strong></td>
<td><strong>0.093</strong></td>
<td><strong>0.10</strong></td>
</tr>
<tr>
<td>ILB 938</td>
<td>41.37</td>
<td>26.03</td>
<td>0.524</td>
<td>0.729</td>
<td>0.72</td>
</tr>
<tr>
<td>Mélodie/2</td>
<td>51.13</td>
<td>25.07</td>
<td>0.551</td>
<td>0.820</td>
<td>0.67</td>
</tr>
<tr>
<td>IG 11689</td>
<td>43.37</td>
<td>26.20</td>
<td>0.518</td>
<td>0.526</td>
<td>0.98</td>
</tr>
<tr>
<td>IG 131708</td>
<td>49.67</td>
<td>26.07</td>
<td>0.640</td>
<td>0.845</td>
<td>0.76</td>
</tr>
<tr>
<td>IG 72309</td>
<td>46.50</td>
<td>34.10</td>
<td>0.831</td>
<td>1.256</td>
<td>0.66</td>
</tr>
<tr>
<td>IG 13505</td>
<td>49.73</td>
<td>30.90</td>
<td>0.847</td>
<td>1.209</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>mean</strong></td>
<td><strong>46.96</strong></td>
<td><strong>28.06</strong></td>
<td><strong>0.652</strong></td>
<td><strong>0.897</strong></td>
<td><strong>0.75</strong></td>
</tr>
<tr>
<td><strong>SEM</strong></td>
<td><strong>1.60</strong></td>
<td><strong>1.47</strong></td>
<td><strong>0.062</strong></td>
<td><strong>0.115</strong></td>
<td><strong>0.05</strong></td>
</tr>
</tbody>
</table>
Root growth in wet and dry set under well watered conditions (6+6)
Effects of water treatments on the root dry weight in dry and wet set accessions (2+2).

<table>
<thead>
<tr>
<th>Accession</th>
<th>Wet set (%)</th>
<th>Dry set (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>99501</td>
<td>51%</td>
<td>49%</td>
</tr>
<tr>
<td>114985</td>
<td>49%</td>
<td>10%</td>
</tr>
<tr>
<td>Mélodie/2</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td>ILB 938</td>
<td>30%</td>
<td></td>
</tr>
</tbody>
</table>

**Experiment 2**

- **Wet set**
  - 99501
  - 114985
- **Dry set**
  - Mélodie/2
  - ILB 938
Effects of water treatments on the shoot dry weight in dry and wet set accessions (2+2).

Experiment 2

Wet set

Dry set

Shoot DM (g)

Accession

99501
114985
Mélodie/2
ILB 93ε

64%
51%
39%
37%
Effects of water treatments on the stomatal conductance in dry and wet set accessions (2+2).

Experiment 2

Stomatal conductance (mol m$^{-2}$ s$^{-1}$)

Accession

- 99501
- 114985
- ILB 938
- Mélodie/2

Wet set

Dry set

Control

Drought
Root length in response to water deficit

Experiment 2

Root length (cm) vs. Days after sowing

- 99501 control
- 114985 control
- Melodie control
- ILB 938/2 control
- 99501 drought
- 114985 drought
- ILB 938/2 drought
- Melodie drought
Conclusions

• The results supported that germplasm sets originating from environments with contrasting seasonal water availability will display root traits differences when they exposed under water stress.

• FIGS can reduce the cost and increase efficientness of germplasm evaluation by reducing the number of accessions screened while providing a higher probability of identifying sought-after traits.

• Further studies should be conducted under conditions where taproot expansion is not restricted.
Acknowledgments

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Emil Aaltosen Säätiö

ICARDA

Department of Agricultural Sciences, HU

FIGS

Finnish Doctoral Program in Plant Science

Niemi Säätiö
Thank you for your attention
Climate change and crop production

**Positive impacts**
- CO₂-fertilization, productivity
- Longer growing season (high lat. & alt.)
- Growing new crops
- Warmer climate for plant production (high lat. & alt.)

**Negative Impacts**
- Heat stress
- Drought stress
- Increased soil erosion
- Increased weed growth
- Increase pest infestation
- Planning issue due to less reliable forecast
- Melting snow and ice, rising global sea level
- Losing biodiversity

**Combined impacts**
- Accelerate mutation rate

**Climate change**
- Average temperature
- CO₂ concentration
- O₃ concentration

Impacts on diseases can be + or -, depending on host-pathogen interaction