Designing multi-criteria sorghum ideotypes in changing climate and societal contexts: implications for plant phenotyping and modelling

Alessandra Fracasso - UNICAT
Delphine Luquet – CIRAD, AGAP Unit
1. Current & future challenges for Agriculture in Europe
2. Need for multiple & multi-criteria ideotypes: a role for sorghum
3. Implications for sorghum crop physiology - Some recent examples
4. Phenotyping challenges: complementarities to be valorized in a network
5. Role of crop modelling: predict optimal GxE interactions & ideotypes
6. Outlooks
CURRENT AND FUTURE CHALLENGES FOR AGRICULTURE

- Climate change impact on spring/summer crops
CURRENT AND FUTURE CHALLENGES FOR AGRICULTURE

• adaptation to future climatic scenario: are we ready?
CHALLENGE OF MULTIPLE AND MULTI-CRITERIA IDEOTYPES

- **Trait packages**: production X stability (adaptation), multi-purpose crops...
- **Trait linkage** (covariation, trade-offs): opportunity or limit to breeding
- **Which trait(s), where / when?**
CURRENT AND FUTURE CHALLENGES FOR AGRICULTURE

• An increasing role for sorghum?

Vadez et al. 2011; Tack et al. 2017
SORGHUM CROP PHYSIOLOGY IN A PRE-BREEDING CONTEXT

Which trait(s) for what?

End-Uses

Adaptation

Mitigation

Phenotyping Diversity, co-variations

Insight for breeding?

Traits, alleles, genes, ideotypes

For targeted end-uses & environments

Which trait(s) for what?

End-Uses

Adaptation

Mitigation

Phenotyping Diversity, co-variations

Insight for breeding?

Traits, alleles, genes, ideotypes

For targeted end-uses & environments

GLU (mg.g⁻¹)

5 10 15 20 25

Which trait(s) for what?

End-Uses

Adaptation

Mitigation

Phenotyping Diversity, co-variations

Insight for breeding?

Traits, alleles, genes, ideotypes

For targeted end-uses & environments

GLU (mg.g⁻¹)

5 10 15 20 25
**RECENT EXAMPLE - BIOMASS FOR THE FUTURE PROJECT (1)**

Internode histochemical traits impact on industrial properties & phenotyping challenge

Field study over 8 (biocomposites) to 24 (methanisation), 3 sites in 2013 in Southern France

**Industrial properties related to genetic variability of these traits**

<table>
<thead>
<tr>
<th>Methanisation (BMP)</th>
<th>BMP Nm/gMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>adlSndf</td>
<td>-0.62</td>
</tr>
<tr>
<td>hemiSndf</td>
<td>0.50</td>
</tr>
<tr>
<td>Perc_BlueZ2</td>
<td>0.55</td>
</tr>
<tr>
<td>SMS</td>
<td>0.57</td>
</tr>
<tr>
<td>IVDfD</td>
<td>0.62</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biocomposite (eg. elasticity)</th>
<th>Young Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMS</td>
<td>-0.84</td>
</tr>
<tr>
<td>SMO</td>
<td>-0.84</td>
</tr>
<tr>
<td>Sugars</td>
<td>-0.66</td>
</tr>
<tr>
<td>Perc_BlueZ2</td>
<td>-0.53</td>
</tr>
<tr>
<td>Perc_SdZ1</td>
<td>0.64</td>
</tr>
<tr>
<td>ADL</td>
<td>0.77</td>
</tr>
<tr>
<td>NDF</td>
<td>0.81</td>
</tr>
<tr>
<td>ADF</td>
<td>0.86</td>
</tr>
<tr>
<td>CBW</td>
<td>0.87</td>
</tr>
</tbody>
</table>

→ Challenge of **phenotyping existing genetic diversity** to dissect the genetic architecture of these traits

**Jaffuel et al.** 2018 Sorghum international conference South Africa

**Carrere et al.** Waste and Biomass Valorization, 2017
Recent Example - Biomass for the Future Project (2)

Development of phenotyping pipelines: increase the throughput and the traits captured

**Histology phenotyping pipeline**

- Experimental design (Field, greenhouse)
- Sample fixation (Alcohol/Acetic acid), Store at 4°C
- Cutting/Vibratome (80μm)
- Histochmical staining, Ponga
- Class slide scanning (virtual slide Nanoscaner)

---

**NIRS phenotyping**

- Lignin
- (Hemi)Cellulose
- Sugars

... 

Valorized in **Multi-site phenotyping for GWAS**

Eg. NIRS (Vilnius et al. under prep.)

---

Verdeil et al. under prep.; Jaffuel et al. 2018 Sorghum international conference, South Africa
RECENT EXAMPLE - BIOMASS FOR THE FUTURE PROJECT (3)

Genotypic response to water availability of stem biomass production & properties

8 genotypes - 2 field water treatments – 2013-2015 (France)

- stem growth & [lignin], ↑ [sugar]

GxE explained at internode & tissue level

 Trait package to be phenotyped on populations / panels under water deficit
 Toward their genetic study and valorisation in a breeding context

Perrier et al. 2017 Frontiers; Luquet et al. GCB bioenergy
A RECENT EXAMPLE – PHENOTYPING FOR DROUGHT TOLERANCE

Fracasso et al., 2017 Frontiers
A RECENT EXAMPLE – PHENOTYPING FOR...AT DIFFERENT SCALES

Lab phenotyping

Field phenotyping

Root architecture

Chlorophyll fluorescence

Mean canopy temperatures of three areas of crop corresponding to three irrigation treatments (T2, T3 and T4 with decreasing amounts of irrigation applied)

2nd European Sorghum Congress 2018
CONTROLLED ENVIRONMENT VS. FIELD PHENOTYPING: COMPLEMENTARITY & IMPLICATIONS (TOOLS, DATA MANAGEMENT AND USE)

Trait based, standardized scenario

Crop, trait/yield relations

Data management & use

Predict GxExM & ideotypes

Specific requirements
- Imagery phenotyping (e.g. drone)
- Env't characterization

Innovation in breeding in WA
Sorghum as a pioneer crop
CROP MODELLING: INTEGRATING KNOWLEDGE, OPTIMIZING GxE&M & IDEOTYPING

Modeling optimal cycle duration (parameter) in maize
Sowing date according to current’s farmer strategy

° Models and sites are available for sorghum
(biomass, grain, multi-purpose; Adam et al. 2017; Luquet et al. 2018)
° Opportunity for innovation in support to sorghum breeding
OUTLOOKS: WHAT IS WORTH BEING COMBINED

• Biological understanding of multicriteria ideotypes (end-uses, sustainability, adaptation…): trait packages

• Trait diversity & genetic determinisms combining controlled env & field phenotyping

• Crop modelling: integrate knowledge & support ideotype & trait impact evaluation for current & future climatic scenario

• Partnership, networks, facilities in Europe to be valorized for sorghum