LIVESEED

System-based breeding approach  
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Workshop 12-2-19, Biofach

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727230 and by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00090. The information contained in this communication only reflects the author’s view. Neither the Research Executive Agency nor SERI is responsible for any use that may be made of the information provided.
Why do we need system-based breeding?

1. Observations and trends
2. Framework of analysis
3. Concept of systems-based breeding

The scientific paper underlying this concept is:
Some observations
How does the breeding landscape look like?
Cross-licensing Agreements for Genetically Engineered Seed Traits
**CPVO figures: Main vegetable applicants 2017 (until 07/09/17)**

<table>
<thead>
<tr>
<th>Applicant</th>
<th>Country</th>
<th>N° applications</th>
<th>% change 2016-2017</th>
<th>Ranking change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monsanto Vegetable IP Management BV</td>
<td>Netherlands (USA)</td>
<td>91</td>
<td>- 20%</td>
<td>=</td>
</tr>
<tr>
<td>Rijk Zwaan Zaadteelt en Zaadhandel BV</td>
<td>Netherlands</td>
<td>63</td>
<td>- 24%</td>
<td>=</td>
</tr>
<tr>
<td>Enza Zaden Beheer BV</td>
<td>Netherlands</td>
<td>58</td>
<td>+ 14%</td>
<td>↑ 1</td>
</tr>
<tr>
<td>Nunhems BV</td>
<td>Netherlands</td>
<td>48</td>
<td>- 16%</td>
<td>↓ 1</td>
</tr>
<tr>
<td>Syngenta Seeds BV</td>
<td>Netherlands</td>
<td>47</td>
<td>+ 24%</td>
<td>=</td>
</tr>
<tr>
<td>Clause SA</td>
<td>France</td>
<td>34</td>
<td>+ 42%</td>
<td>↑ 2</td>
</tr>
<tr>
<td>Vilmorin SA</td>
<td>France</td>
<td>22</td>
<td>- 8%</td>
<td>=</td>
</tr>
<tr>
<td>Bejo Zaden BV</td>
<td>Netherlands</td>
<td>19</td>
<td>- 44%</td>
<td>↓ 2</td>
</tr>
<tr>
<td>Sakata Seeds Europe VB</td>
<td>Netherlands (JP)</td>
<td>10</td>
<td>+ 1000%</td>
<td>New entry</td>
</tr>
<tr>
<td>Semillas Fitó SA</td>
<td>Spain</td>
<td>6</td>
<td>+ 50%</td>
<td>New entry</td>
</tr>
<tr>
<td><strong>Total applications</strong></td>
<td>Till 7-9-17</td>
<td>440</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trend 1: Trait breeding

More and more plant breeding is becoming trait breeding

Systems breeding

Plant breeding

Trait breeding
## Patents on plant traits and use of Male Sterility in F1-hybrids

<table>
<thead>
<tr>
<th>Family</th>
<th>English Name</th>
<th>Use patents</th>
<th>Male sterility; PF = Protoplast Fusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabaceae</td>
<td>Beans</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>Broad bean</td>
<td></td>
<td>NA</td>
</tr>
<tr>
<td>Fabaceae</td>
<td>Pea</td>
<td>Yes</td>
<td>NA</td>
</tr>
<tr>
<td>Compositeae</td>
<td>Lettuce</td>
<td>Yes</td>
<td>NA</td>
</tr>
<tr>
<td>Compositeae</td>
<td>Chicory</td>
<td>Yes</td>
<td>Yes, PF</td>
</tr>
<tr>
<td>Compositeae</td>
<td>Sunflower</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>Spinach</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Chenopodiaceae</td>
<td>Beetroot</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Cucurbitaceae</td>
<td>Pumpkin / Zucchini (C. pepo)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Cucurbitaceae</td>
<td>Pumpkin (C. maxima)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cucurbitaceae</td>
<td>Cucumber</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Cucurbitaceae</td>
<td>Melon</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Cucurbitaceae</td>
<td>Watermelon</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Crucifereae</td>
<td>Head cabbage</td>
<td>Yes</td>
<td>Yes, PF</td>
</tr>
<tr>
<td>Crucifereae</td>
<td>Cauliflower</td>
<td>Yes</td>
<td>Yes, PF</td>
</tr>
<tr>
<td>Crucifereae</td>
<td>Broccoli</td>
<td>Yes</td>
<td>Yes, PF</td>
</tr>
<tr>
<td>Crucifereae</td>
<td>Chinese cabbage</td>
<td>Yes</td>
<td>Yes, PF</td>
</tr>
<tr>
<td>Alliaceae</td>
<td>Onion</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Alliaceae</td>
<td>Leek</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Solanaceae</td>
<td>Tomato</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Solanaceae</td>
<td>Sweet Pepper</td>
<td>Yes</td>
<td>(Yes)</td>
</tr>
<tr>
<td>Solanaceae</td>
<td>Pepper</td>
<td>Yes</td>
<td>(Yes)</td>
</tr>
<tr>
<td>Umbellifereae</td>
<td>Carrot</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Umbellifereae</td>
<td>Celery</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Umbellifereae</td>
<td>Fennel</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Trend 2: Loss of small crops in breeding

• National diets are becoming more diverse, world wide diets are increasingly more similar (Khoury et al. PNAS 2014).

• Of the 30,000 edible species we grow only 150,

• 95% of our human food calories originate from 30 crop species (WHO & CBD, 2015)
  ➢ Small crops are orphans in breeding
  ➢ Breeding should put more efforts into improving small crops!
CPVO: Main species in vegetable sector per number of applications
(1995 – 4 November 2016)
CPVO: Number of applications in the vegetable sector per crop

Top ten 2016

- Lettuce: 192
- Tomato: 127
- Melon: 80
- Pepper: 65
- Cucumber/gherkin: 45
- Onion: 25
- Pea: 13
- French bean: 13
- Endive: 10
- Watermelon: 10

Top ten 2017 (until 07/09)

- Lettuce: 128
- Tomato: 118
- Pepper: 32
- Melon: 29
- Cucumber/gherkin: 22
- Watermelon: 15
- Pea: 11
- Endive: 6
- Eggplant: 6
- Cornsbad: 6

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Trend 3: Breeding for (longterm) ecosystems services?

- Biodiversity and ecosystems services are key factors that contribute to:
  - natural pest control
  - pollination
  - nutrient (re)cycling
  - soil conservation (structure and fertility)
  - water provision (quality and quantity)
  - carbon sequestration

Genetic variation in root biomass in grass (Lolium multiflorum). Deru et al. Euphytica 2014
Trend 4: Organic 3.0 (IFOAM 2015): Broadening the organic scope for 2030

Five dimensions:
- Ecology
- Society
- Culture
- Accountability
- Economy

How to transform those criteria into breeding?
Trend 5: SDGs of UN - targets for ecological and societal resilience

- Published in 2015

How to integrate those goals into breeding?
Trend 6: New developments in organic breeding

- Breeding for diversity:
  - Composite Cross Populations (CCPs)
  - Suitability to mixed cropping
  - More diversity within varieties

- Initiatives in breeding with involvement of the value chain

- Opening up of seed laws: new possibilities
Framework of analysis (adapted after Bawden, 2010)

Subjectivism

Objectivism

Holism

Reductionism

Different rationales, different fears and hopes
Four breeding orientations (paradigmatic positions)

- Community-based breeding
- Ecosystem-based breeding
- Corporate-based breeding
- Trait-based breeding

Holism

Subjectivism

Objectivism

Reductionism
Each position has strengths and weaknesses
Need for optimal interaction and synergy
5th breeding orientation: systems-based breeding

‘System’: civil society, policy, nature, agriculture, and value chains and markets as interrelated and mutually dependent components of the entire system

All partners should commit themselves to a collectively learning process to achieve this shift!
Required change in attitude

Three key-elements

1. Corporate Social Responsibility
2. Circular Economy & True Cost accounting
3. Fair & Green Policy
From attitude to action

Three key-elements:

1. Knowledge development & Integration
2. Breeding strategies & Tools
3. Entrepreneurship
From action to achievement: 6 goals

Six key-elements (goals):

1. Social justice
2. Food quality, security and safety
3. Food and seed sovereignty
4. Agro-biodiversity
5. Ecosystem services
6. Climate robustness