Varieties for organic production

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Organic agriculture: 4 Basic Principles

Organic agriculture is often known as:

- No chem-synthetic fertilisers
- No chem-synthetic pesticides, fungicides and herbicides
- No GMOs
Control versus Resilience model

Risk management model
- Risk oriented
- Eliminate variability
- Continuous monitoring and direct intervention
- High long-term risk
- Static equilibrium

Resilience model
- System oriented
- Make use of variability
- Enhance self-regulating capacity and indirect management
- Low long-term risk
- Dynamic equilibrium

(After Ten Napel et al. 2006)
Systems approach: multipurpose varieties

- for food & feed
- for straw, compost
- for weed suppression
- for soil structure
Why organic plant breeding?

- Organic agriculture (OA) is in development and requires improved varieties that are better adapted to the ecological and ethical principles of OA.
  - Varieties that allow the organic system to work!

- The fact that organic growers use modern, ‘conventional’ varieties does not mean that they are the best to optimise organic farming systems
Sources for organic seeds (Wolfe et al. 2009)

1. Conventional breeding programs

2. Breeding for organic agriculture: partly in conv. selection fields (e.g. F1-F5) and partly in organic fields (e.g. F6-F8)

3. Breeding in organic agriculture: programs completely under organic production
Summary table of traits for adaptation to low-external input systems

<table>
<thead>
<tr>
<th>Management</th>
<th>Breeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mineral, but lower level of organic, slow releasing fertilizers</td>
<td>Nutrient efficiency</td>
</tr>
<tr>
<td></td>
<td>Early vigor</td>
</tr>
<tr>
<td></td>
<td>Explorative root system</td>
</tr>
<tr>
<td>No herbicides and need to reduce weed control labor</td>
<td>Weed suppression and weed competitiveness</td>
</tr>
<tr>
<td></td>
<td>Early vigor</td>
</tr>
<tr>
<td>No pesticides and fungicides</td>
<td>High level of resistance</td>
</tr>
<tr>
<td></td>
<td>Induced resistance</td>
</tr>
<tr>
<td></td>
<td>Genetic variation</td>
</tr>
<tr>
<td>No GMOs</td>
<td>Advanced classic breeding methods in combination of MAS</td>
</tr>
<tr>
<td>Less means to mask environmental variation</td>
<td>Required varietal characteristics: Yield stability, Robustness, flexibility</td>
</tr>
</tbody>
</table>
Yield and yield stability in organic onion production (due to downey mildew)

Onion Variety Trials 2001-2003

CV = 26.4%

Yield (t/ha)

- year effects
- variety effects

CV = Coefficient of variation (%) is the variability over years (standard deviation/average yield)
Correlation between yield in organic and conventional agriculture

onion variety trials 2001-2003

R=0.56
Changes of ranking under organic and conventional growing conditions

Fig. 1. Genotypic change in rank between organic and conventional wheat nurseries. The top five ranking genotypes for yield in both organic and conventional systems were compared at each location. Genotypes are ranked from 1 = highest yield to 35 = lowest yield.

(Murphy et al. 2007)
Nitrogen use efficiency (NUE) in cabbage

150 kg N/ha (left) and 300 kg N/ha (right)
Below-ground traits:
Diverse concepts of breeding for NUE (nutrient uptake and utilisation)

(Lammerts van Bueren & Struik 2017)
Below-ground traits: Breeding for 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
Below-ground traits
Selecting for improved interaction with mycorrhiza’s

Adaptation to organic soil fertility management, also requires:

- Varieties capable cooperating with beneficial soil micro-organisms, such as mycorrhiza’s (AMF)

(Scholten et al., 2005)
No herbicides: weed pressure
Wheat: erectophile (left) or planophile (right)?
Weed suppressive ability: leaf orientation, leaf width, leaf and plant length

Cultivar: *Sperber* (erectophile) (EISELE 1995)

Cultivar: *Carolus* (planophile) (EISELE 1995)
Weed suppressive ability:
At later growth stages: plant (straw) length

- more straw
- more shade for weed competitiveness in later growth stages
- less ear diseases
Changes in wheat varieties from 1900 - 1980

A. 5 regional varieties ca. 1900
B. 3 varieties of 1950
C. 1 variety of 1965
D. 4 varieties of 1980
Wheat with clover undersown: erect types
Weed suppressive ability?
But sometimes erect types are required...

Leek and onion need erect plant types
### Traits included in organic ideotype scores for barley (Latvia)

<table>
<thead>
<tr>
<th>Traits</th>
<th>Growing stage (GS) according to Zadoks et al. (1974)</th>
<th>Relative weight (%) in the Organic Ideotype Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain yield</td>
<td>After harvest</td>
<td>40</td>
</tr>
<tr>
<td><strong>Traits contributing to competitive ability against weeds</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canopy height at stem elongation stage</td>
<td>GS 31-32</td>
<td>20</td>
</tr>
<tr>
<td>Crop ground cover</td>
<td>GS 31-32</td>
<td>10</td>
</tr>
<tr>
<td>Width of flag leaves</td>
<td>GS 47 – 51</td>
<td>2</td>
</tr>
<tr>
<td>Length of flag leaves</td>
<td>GS 47 – 51</td>
<td>2</td>
</tr>
<tr>
<td>Lodging resistance</td>
<td>GS 90</td>
<td>2</td>
</tr>
<tr>
<td>Plant height at maturity</td>
<td>GS 90</td>
<td>6</td>
</tr>
<tr>
<td><strong>Traits related to growing period</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal time to heading</td>
<td>GS 51</td>
<td>5</td>
</tr>
<tr>
<td>Thermal time to maturity</td>
<td>GS 90</td>
<td>5</td>
</tr>
<tr>
<td><strong>Disease resistance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resistance to leaf diseases (powdery mildew and net blotch)</td>
<td>From GS 32 onwards</td>
<td>6</td>
</tr>
<tr>
<td><strong>Traits related to grain quality</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume weight</td>
<td>After harvest</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total 100</td>
</tr>
</tbody>
</table>

(Kokare et al. 2017)
Traits for reduced susceptibility to pest and diseases

Downy mildew resistance urgently needed in onion production

Onion Variety Trials 2001-2003

(Lelystad, 2002)
Required traits for reduced susceptibility to pest and diseases

Or additional morphological and physiological plant characteristics that can support reduced susceptibility,

- such as wax layer on leaves reducing trips damage

(Voorrips et al. 2008)
Required traits for reduced susceptibility to pest and diseases

Or additional morphological and physiological plant characteristics that can support reduced susceptibility,

- such as wax layer on leaves
- less compact ear (cereals)

(Cultivars with a compact ears are always susceptible for Fusarium head blight)

(A. Osman, LBI)
Required traits for reduced susceptibility to pest and diseases

Or additional morphological and physiological plant characteristics that can support reduced susceptibility,

- such as wax layer on leaves
- less compact ear (cereals)
- better root system (continuous growth)
- early maturing (escape)
<table>
<thead>
<tr>
<th></th>
<th>Organic Protocol</th>
<th>Conventional Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research site</td>
<td>Managed organically, in accordance with EU regulation 2092/91, for at least three years</td>
<td>Managed conventionally with mineral fertilisers; chemical pest and disease control</td>
</tr>
<tr>
<td>Seed</td>
<td>• Not chemically treated</td>
<td>• Chemically treated</td>
</tr>
<tr>
<td>Crop husbandry</td>
<td>• According to organic farm management practice</td>
<td>• according to conventional management practice; part of the trial is conducted without chemical protectants</td>
</tr>
<tr>
<td>Plant characteristics, which are not observed in conventional spring wheat VCU *</td>
<td>• recovery from mechanical harrowing</td>
<td>• not observed</td>
</tr>
<tr>
<td></td>
<td>• tillering</td>
<td>• not observed</td>
</tr>
<tr>
<td></td>
<td>• speed of closing the crop canopy</td>
<td>• not observed</td>
</tr>
<tr>
<td></td>
<td>• canopy density</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• stay green index</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• distance of ear-flag leaf</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• compactness of the ear</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• resistance against sprouting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• black molds in the ear</td>
<td></td>
</tr>
<tr>
<td>Evaluation baking quality</td>
<td>• evaluation on whole wheat bread without artificial bread improvers</td>
<td>• evaluation on white bread with addition of ascorbic acid</td>
</tr>
</tbody>
</table>

* Other aspects that are observed and listed in the conventional protocol as well as in the organic protocol are not mentioned.
Exploiting genetic diversity
e.g. ‘heterogeneous material’

Composite cross populations:
► Multiple crosses

Crop mixtures (e.g. lupine/wheat):
► breeding for combinability
Exploiting genetic diversity

- 1. Grow many varieties – *not always practical, little interaction*
- 2. Grow variety mixtures – *good for in-field interactions; no new genetic variation*
- 3. Grow segregating populations – *evolutionary breeding, inter crossing continuously renewing genetic diversity*
Why populations? Resilience driven!

An assembly of genetically different individuals offers:

- **Capacity**: more characters than a pure stand
- **Complementation**: different genotypes may complement each other
- **Compensation**: if some fail, others take their place
- **Competition**: this is the major factor that may work against the three ‘Cs’ above, particularly with limited resources.
Composite crosses in UK (2000 onwards): selecting of parent lines (at least 5 or more...)
Production of 190 cross combinations (ORC and John Innes Institute, UK)
Composite cross breeding process

Bulking progeny and exposing it to natural selection
EU experiment in NL (wheat, 2014-2017)

Draft report of Edwin Nuijten/LBI and Ad Toussaint/NAK:

- For buyers important to know what is
  - Breeding method (parents, breeding scheme)
  - Production method (history, growing conditions, region, …)

- CCPs can be distinguished by morphological and quality traits (e.g. baking quality, disease resistance, plant length, etc)

- Some populations are more stable than others, depending on year and location

- Normal rules should apply for seed quality
Observations EU LIVESEED project until now:

- What heterogeneous material will bring is a learning process,
- that requires time to find out pro’s and contra’s that might differ per crop species;
- Development of heterogeneous material will be different per crop species, depending on crop characteristics during growth and multiplication, market demands and type of value chain or food system.
- Note: heterogeneous material is an addition to organic variety concept, not a replacement!
Overlap between conventional and organic varieties

The degree of overlap between conventional and organic suited varieties depends on:

- the crop requirements
- the growing conditions (high or low input)
- applied breeding techniques or strategies
Thank you so much!