Breeding lettuce for improved robustness by efficient capturing of below-ground resources

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Some key notions

“Robustness is a property that allows a system to maintain its function despite external and internal perturbations”

H. Kitano, 2004

Plasticity is the ability to respond to environmental cues and to adapt to fluctuating availability of resources
The Horticultural Paradigms...

Conventional

Continuous and optimal water and nutrient management
- Minor demands on the root system
- Breeding of genotypes with high shoot:root ratios
- Focus on increasing yield

Low Input/Organic

Fewer means to control growing conditions
- Less abundant and less regular water and nutrient supply
- More dependent on the soil biological, physical and chemical properties
Plastic varieties for Low Input/Organic systems

Less sensitive to variations in water and nutrient availability

Require less input

Improved Resource Capture & Use Efficiency

Plasticity

Lower dependency on Resource Supply

Robustness

Yield Stability

(happy grower 😊)

How?!
It is easy...

HOW TO DO EVERYTHING.

1.  
2.  

Developing a QTL-based eco-physiological model to predict root system architecture in lettuce

**Step 1**
Measure RSA, RC & SD under limiting growing conditions
- 2 cultivars

Measure RSA, RC & SD under field conditions
- 4 cultivars

**Step 2**
Eco-physiological model correlating RSA vs. RC

**Step 3**
Genotyping of the 150 cultivars
- 1365 SNP markers

**Step 4**
Find QTL associated with RC

**Step 5**
Elaborate a QTL-based eco-physiological model for RSA & RC

Predict RSA using RC data under field conditions
- 150 genotypes

Phenotyping

Genotyping

Modelling
Step 1: Root “Morpho/physiology” of Resource Capture in Time and Space

Greenhouse trials

* 2 cultivars
* Application of temporary or localized drought and nutrient supply
* Measurement of shoot & root growth, and resource capture in time and space

Field trials

* 4 cultivars
* Application of two types of transplanting stress
* Measurement of shoot & root growth, and resource capture in time and space
Drought
Root expansion was stimulated in the **stress compartment**

N-Shortage
Root expansion was stimulated in the **optimal compartment**
Step 2: Designing an eco-physiological model correlating Resource Capture and Root Development in Time and Space

Conceptual framework based on the findings published in:

- Kerbiriou et al. 2013. Shoot growth, root growth and resource capture under limiting water and N supply for two cultivars of lettuce (*Lactuca sativa* L.). *Plant and Soil* (online)
Step 4: QTL associated with Resource Capture and Use efficiency

- 150 genotypes
- 4 trials – 2 replicates per trial
- 2 environments (Wageningen and Voorst) → 2 trials per environment
- 2 samplings per trial: Intermediate and final harvest
- At sampling: Measurement of Soil Moisture Content and Nitrate concentration in each 10 cm layer over a 40 cm layer profile
- Shoot biomass and other field observations at final harvest only
Significant genotypic-phenotypic associations found on the 4th chromosome (Distances in cM) – Analyses performed using Genstat 15th Ed.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Wageningen</th>
<th>Voorst</th>
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<tbody>
<tr>
<td>Trial #</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Conditions</td>
<td>Dry &amp; Cool</td>
<td>Moist &amp; Warm</td>
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<tr>
<td>Sampling #</td>
<td>Inter</td>
<td>Final</td>
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<td>All NO₃ in profile</td>
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<td>[NO₃] in L1</td>
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<tr>
<td>[NO₃] in L2</td>
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<td>[NO₃] in L3</td>
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<td>135</td>
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<td>[NO₃] in L4</td>
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<td></td>
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<tr>
<td>All H₂O in profile</td>
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</tbody>
</table>

QTL potentially involved in Nitrate capture were previously associated with root elongation by Johnson et al. (2000) in a wild x cultivated cross.
Breeding robust varieties: are roots the Holy Grail?

* We need robust varieties that can perform in a broad range of growing conditions
* Plasticity in root behaviour creates robustness
* In Lettuce, an improved root system (higher root mass, improved spatial distribution) can increase resource capture efficiency in time and space
* Genotypic variation exists in such traits
* Large G x E interactions highlight the need for a model
* Innovative breeding strategies based on indirect approaches and tapping in a pool of traits that have not yet been fully exploited are promising
Thank you for your attention!