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

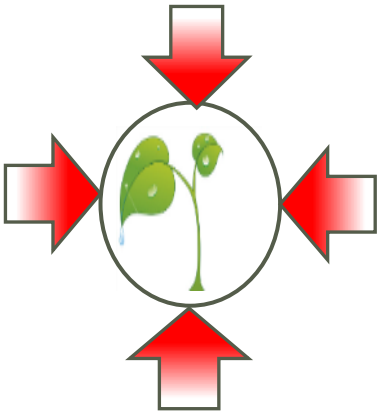
Plasticity is the ability to respond to environmental cues and to adapt to fluctuating availability of resources

The Horticultural Paradigms…

Conventional

Continuous and optimal water and nutrient management

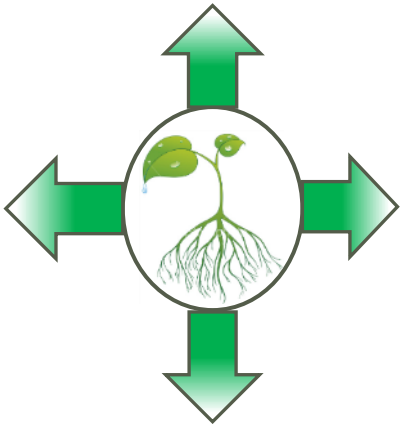
- Minor demands on the root system
- Breeding of genotypes with high shoot:root ratios
- Focus on increasing yield



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 → Lower dependency on Resource Supply → Robustness → Yield Stability

Plasticity

How?!

(happy grower ☺)

It is easy…

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

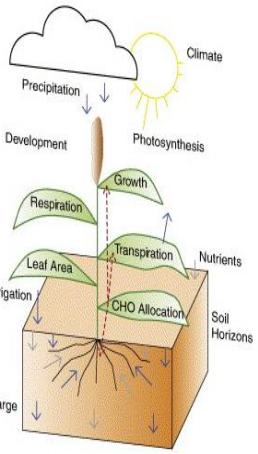
Measure RSA, RC & SD
under field conditions
4 cultivars

Step 2

Eco-physiological model correlating RSA vs. RC

Predict RSA using RC data
under field conditions
150 genotypes

Phenotyping



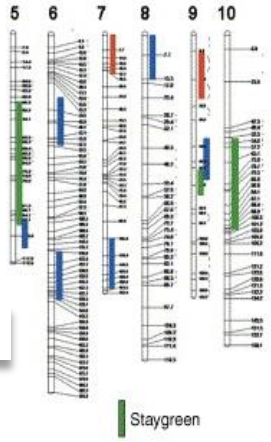
Modelling

Step 3

Genotyping of the 150 cultivars
1365 SNP markers

Step 4

Find QTL associated with RC



Genotyping

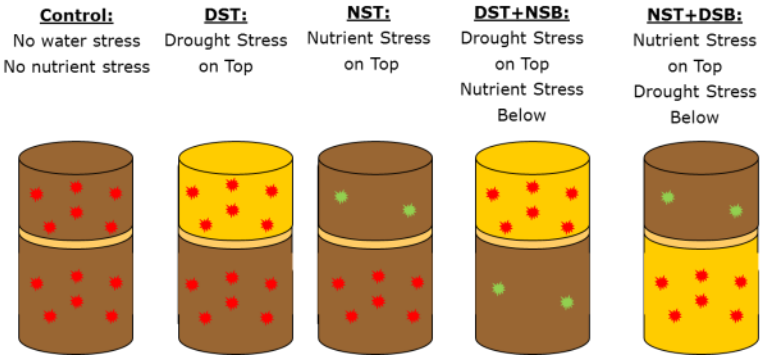
Step 5

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

Step 1: Root "Morpho/physiology" of Resource Capture *in Time and Space*

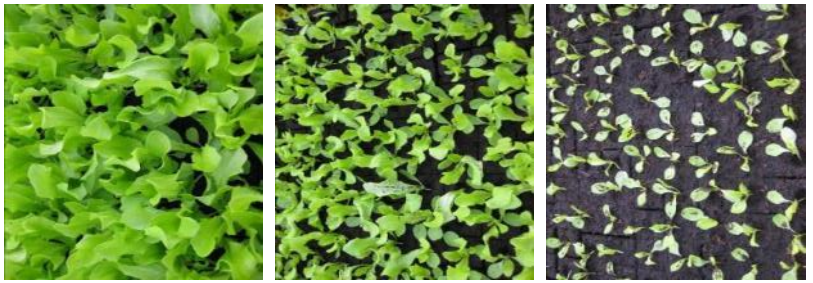
Greenhouse trials

- 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

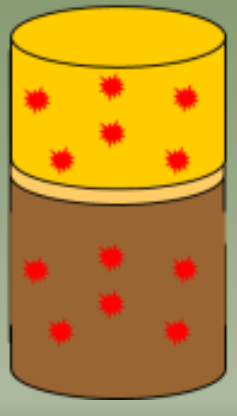
- 4 cultivars
- Application of two types of transplanting stress
- Measurement of shoot & root growth, and resource capture in time and space

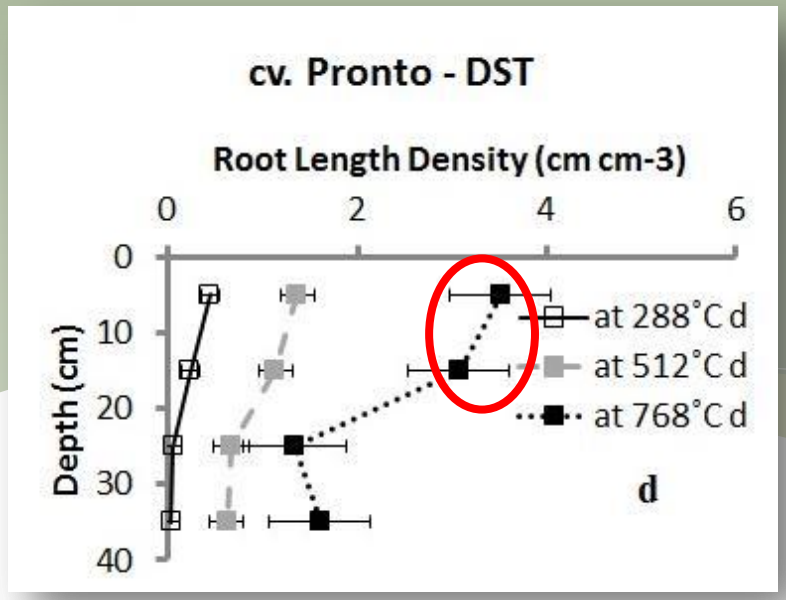


Drought

Root expansion was stimulated in the **stress compartment**

DST:
Drought Stress on Top

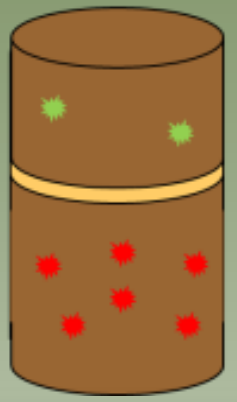


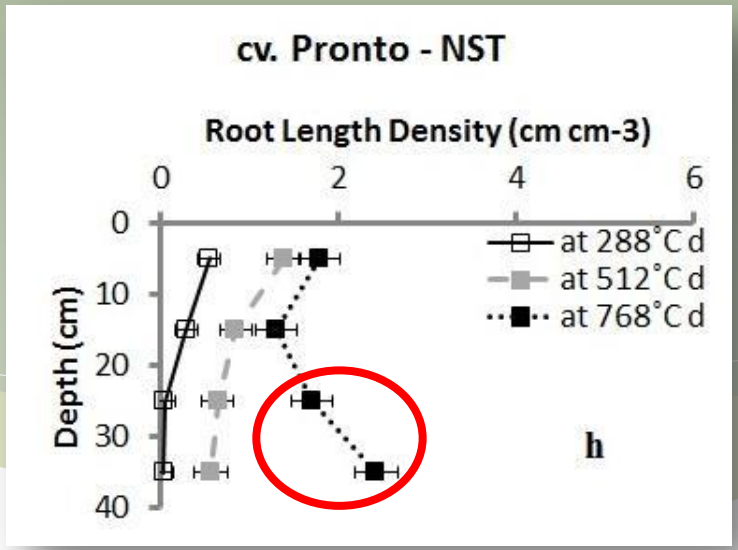


N-Shortage

Root expansion was stimulated in the **optimal compartment**

NST:
Nutrient Stress on Top

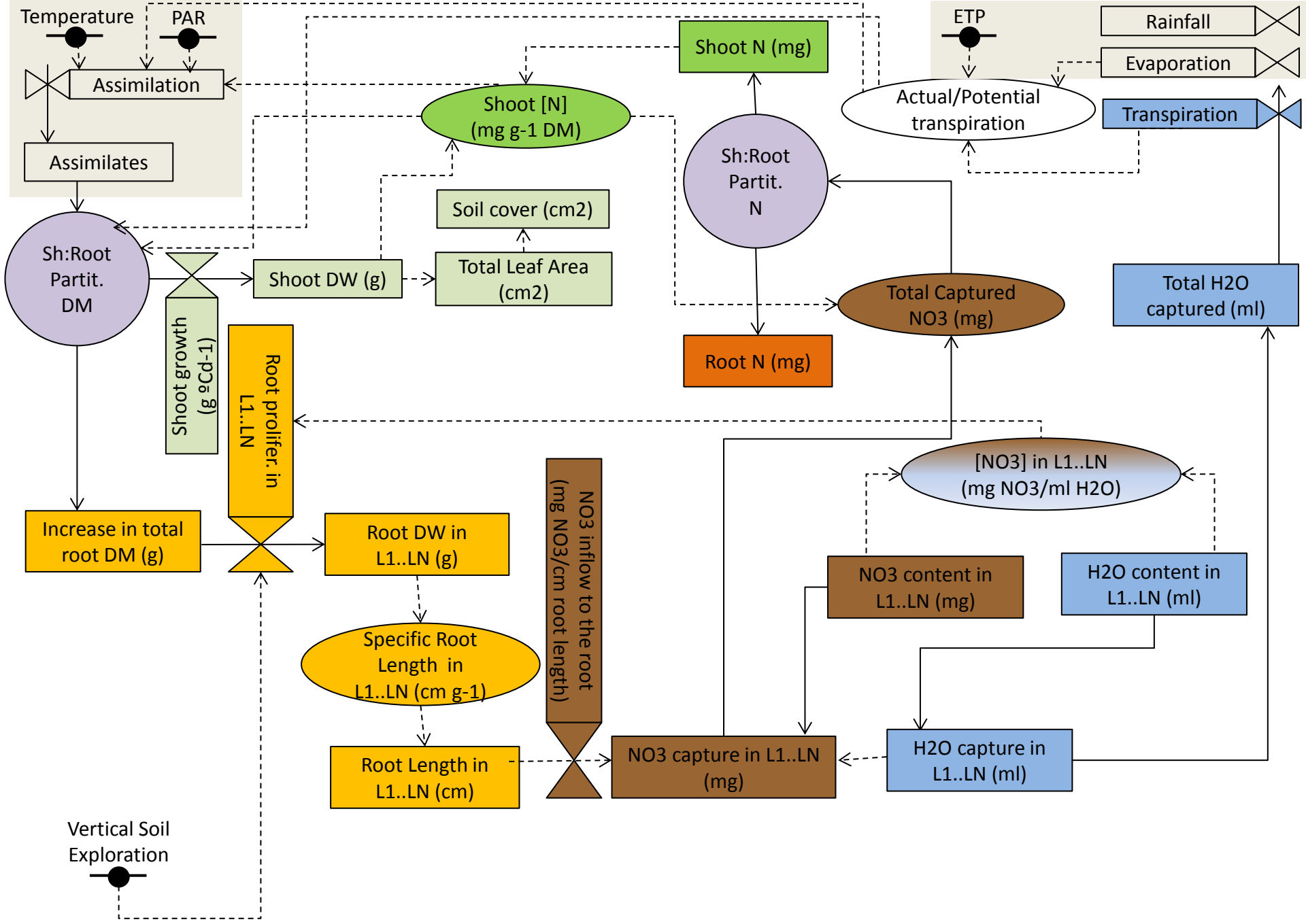




Step 2: Designing an eco-physiological model correlating Resource Capture and Root Development *in Time and Space*

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)*
- **Kerbiriou et al. 2013.** Influence of transplant size on the above- and below-ground performance of four contrasting field-grown lettuce cultivars. *Frontiers in Plant Sciences* (*in press)*


Temperature
PAR
Assimilation
Assimilates
Sh:Root Partit. DM
Shoot growth (g ºCd-1)
Root prolifer. in L1..LN
Increase in total root DM (g)
Root DW in L1..LN (g)
Specific Root Length in L1..LN (cm g-1)
Root Length in L1..LN (cm)
Vertical Soil Exploration
Shoot DW (g)
Total Leaf Area (cm2)
Soil cover (cm2)
Shoot [N] (mg g-1 DM)
Shoot N (mg)
Sh:Root Partit. N
Root N (mg)
ETP
Rainfall
Evaporation
Actual/Potential transpiration
Transpiration
Total Captured NO3 (mg)
Total H2O captured (ml)
[NO3] in L1..LN (mg NO3/ml H2O)
NO3 content in L1..LN (mg)
H2O content in L1..LN (ml)
NO3 inflow to the root (mg NO3/cm root length)
NO3 capture in L1..LN (mg)
H2O capture in L1..LN (ml)

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.*

	Wageningen				Voorst			
Trial #	1		2		1		2	
Conditions	Dry & Cool		Moist & Warm		Dry & Cold		Humid & Cool	
Sampling #	Inter	Final	Inter	Final	Inter	Final	Inter	Final
All NO3 in profile		32				**~ 80** 135		**~80**
[NO3] in L1								
[NO3] in L2			**42-46** 69					146
[NO3] in L3				**~ 80**				**~ 80**
[NO3] in L4				**42**				**~ 80** 130
All H2O in profile								88 144

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!