Examples of breeding research for organic farming in the Netherlands

A cooperation between
Louis Bolk Instituut (LBI) and Plant Research International (PRI)
The Netherlands,
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OSA 2008

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Starting points for our breeding research (1)

- 4-year publicly funded pre-breeding program
- PRI and LBI as partners
- Users driven program (farmers and formal breeders)
- Main crops: carrot, onion, cabbage, wheat, potato

- Challenge to show that organic plant breeding is more than conventional breeding for another market.

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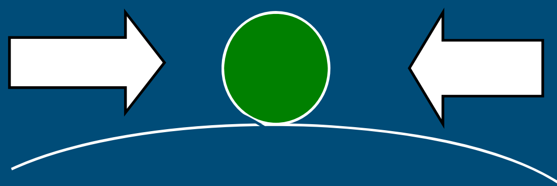
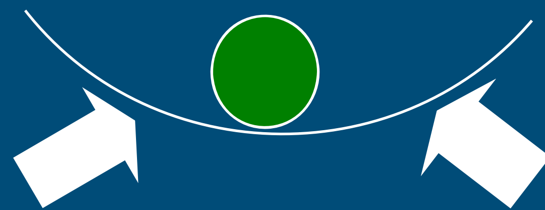
Control vs adaptation approach

<u>**Control model**</u>



- focus on the problem
- ruling out variation
- continuous monitoring
- direct interference
- static balance.

<u>**Adaptation model**</u>



- focus on the system
- exploiting variation
- stimulating self regulation
- indirect management
- dynamic balance.

(Ten Napel *et al*., 2006; WUR/LBI)

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Three areas of the breeding research (2)

1. Selection criteria for robust varieties: what's urgent?
   - direct and indirect factors for plant health (below and above soil)
   - Field selection methods and molecular markers
2. Selection strategies: what is added value?
   - Selection environment (org. vs conv., low vs high input)
   - Participatory selection
3. Socio-economic and legal conditions: how to make it feasible?

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Black spots – carrots

Problem:

1. At harvest time carrots look good, but during storage black spots increase.

2. No resistant varieties available

Diversity of fungi causing black spots

- Varietal differences known
- Literature: at least 5 different fungi involved!

Important in NL:

- Alternaria radicina (field infection, seed borne)
- Rhexcocercosporidium carotae (field infection, seed borne?)
- Thielaviodes basicola (infection during washing)

Result: simple selection method

5 weeks after inoculation

- Lab test for resistance screening
- Scoring in 4 classes
- Disease index (0-1) =

$$\frac{\text{average symptom class}}{\text{maximum symptom class}}$$

- but sensitive to environment
- not applicable on single carrots
- good correlation with field test

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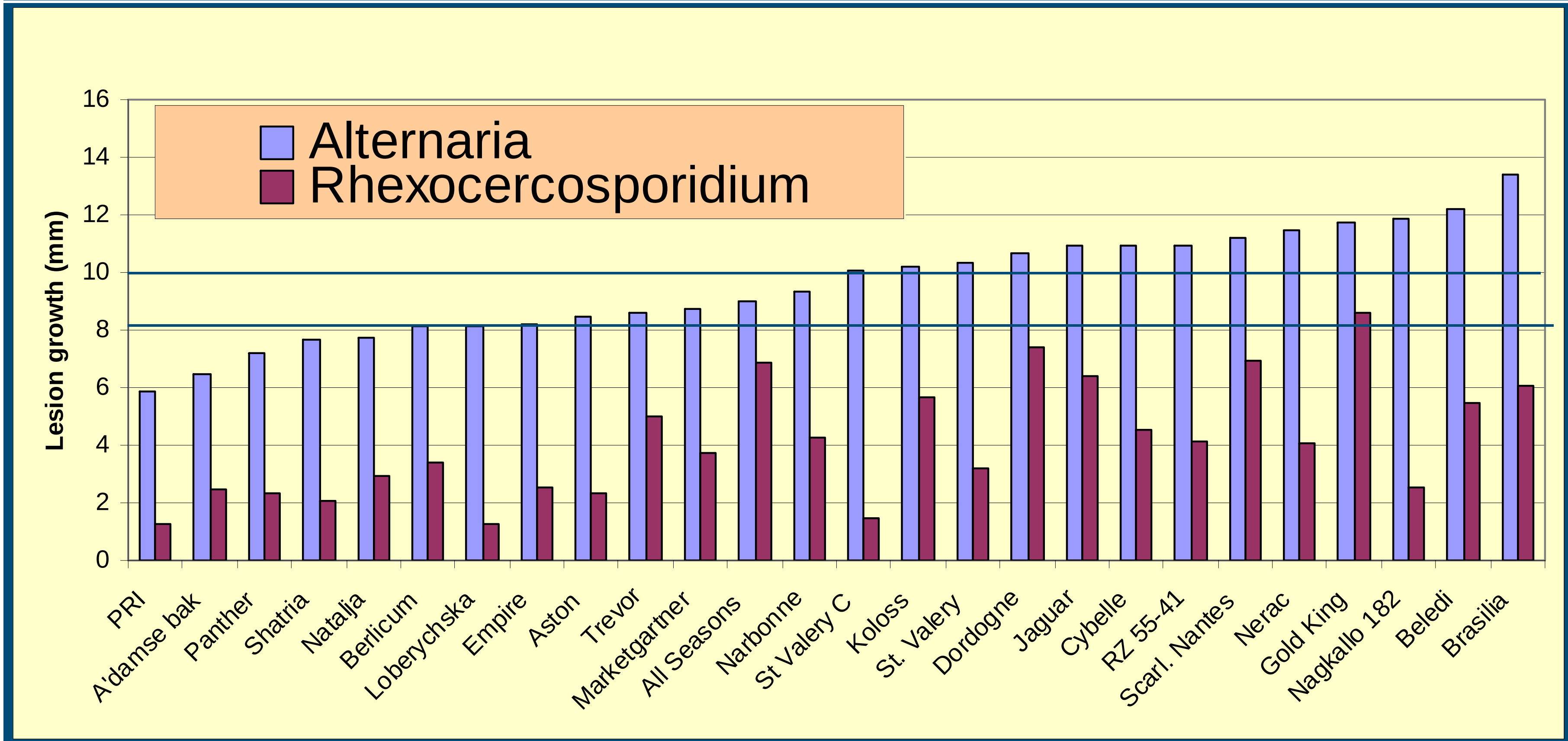
Variety trials with 26 varieties in 2005 and 2006



Differences in resistance for Alternaria and Rhexocercosporidium, no absolute resistance !

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Perspectives for breeding (2004-2007)

Perspectives for breeding for black spot resistance in carrot:

- Test methods show different resistance results for different fungi: a need to combine resistances in breeding;
- No absolute resistance found;
- Test is not applicable on single carrots, problem for breeding;
- Future research: QTL's?

Onion: improved root system

- Onion needs high level of nutrients
- Root system of onion
  - lack of root hairs
  - shallow and scarcely branched
- Uptake improvement
  - Better root system
  - Higher mycorrhizal responsiveness

Picture from De Melo & Kik, 2003

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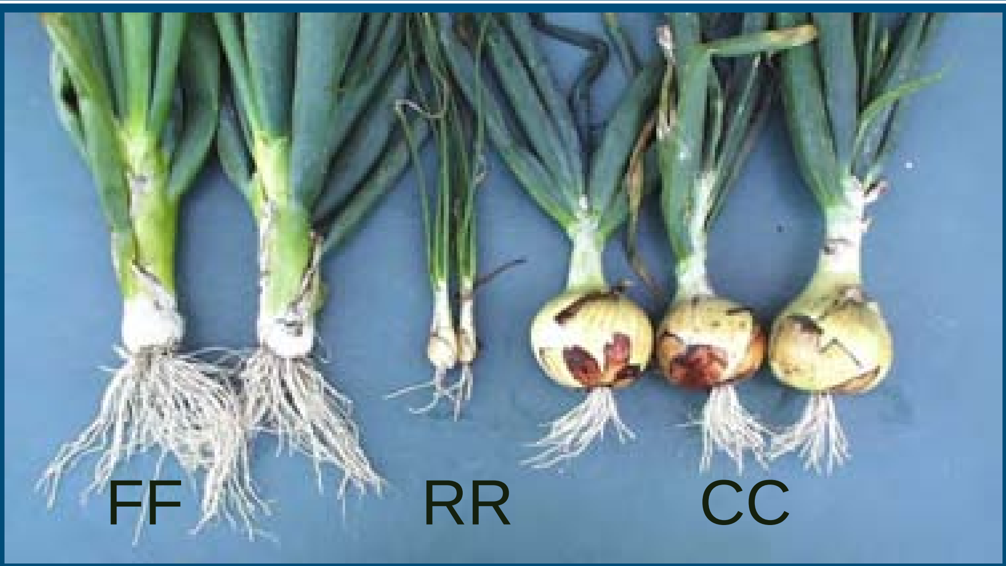
Improvement of the onion root system

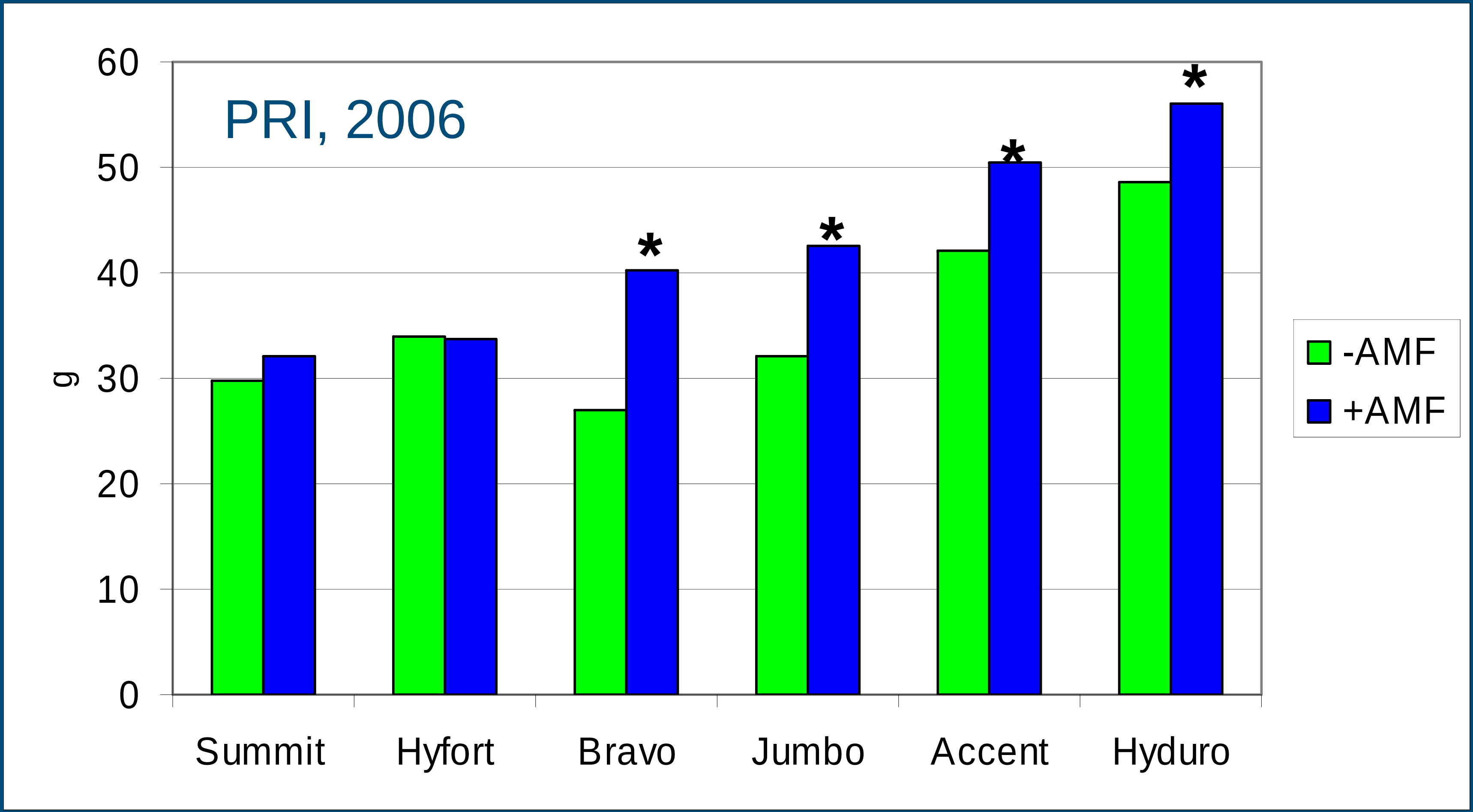


A. roylei x A. fistulosum
↓
A. cepa x RF hybrid
↓
CC x RF population
(tri-hybrid cross)

Picture from De Melo & Kik, 2003

- *A. fistulosum* has more and longer roots than *A. cepa* > possibilities for breeding (De Melo, 2003)
- *A. fistulosum* has interesting mycorrhizal responsiveness and resistance against Fusarium bulb rot
- Through tri-hybrid cross introgression is possible

Cultivar pot trials with and without AMF



* = significant differences

Breeding for mycorrhizal responsiveness?

-AMF + AMF

High AMF response

-AMF + AMF

Low AMF response

Effect of AMF on CC x RF population

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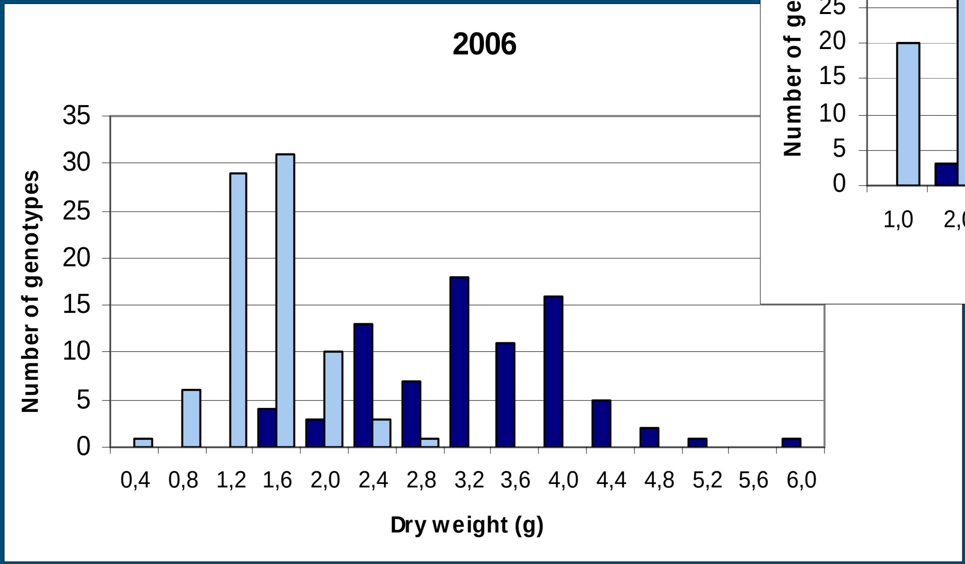
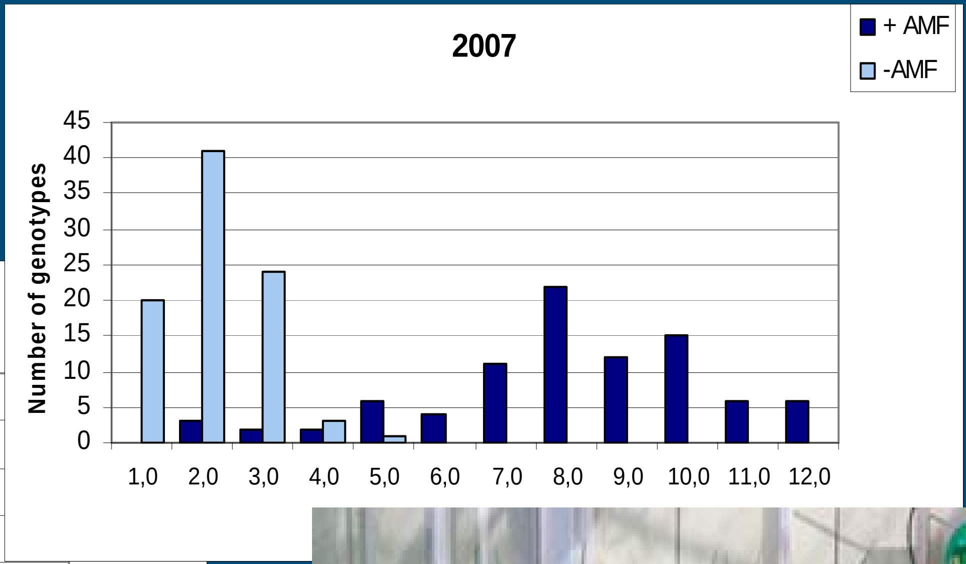
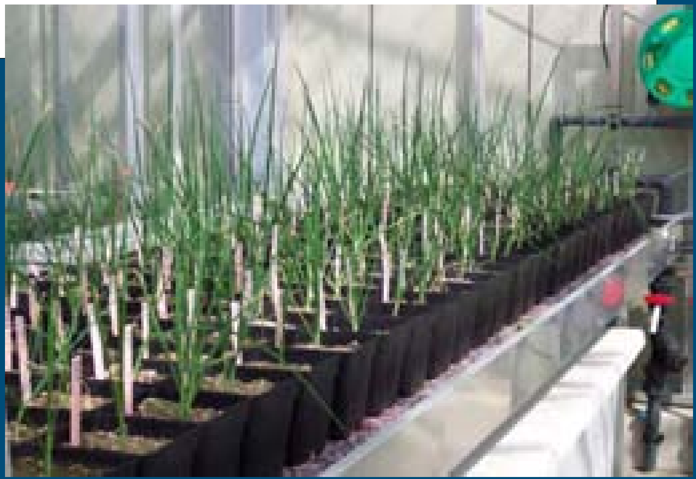
Effect of AMF on CC x RF population







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2008 -2011

Aim: development of genitors for organic agriculture

Mycorrhizal - response and early colonization

2008

Resistance against Fusarium

2009

Improvement of the root system

2009, 2010

Thrips in white cabbage (2004-2007)

'sand paper'

'warts'

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Aim & Methods

Aims:

- Identification of plant traits related with reduced thrips damage (resistance or tolerance)
- Inheritance of resistance or tolerance

Methods:

- Literature (limited), interviews with organic growers, cooperation with cabbage breeders
- Variety trials for plant traits: developmental stage, openness, firmness, leaf thickness, leaf wax, brix (sugar content)

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Firmness

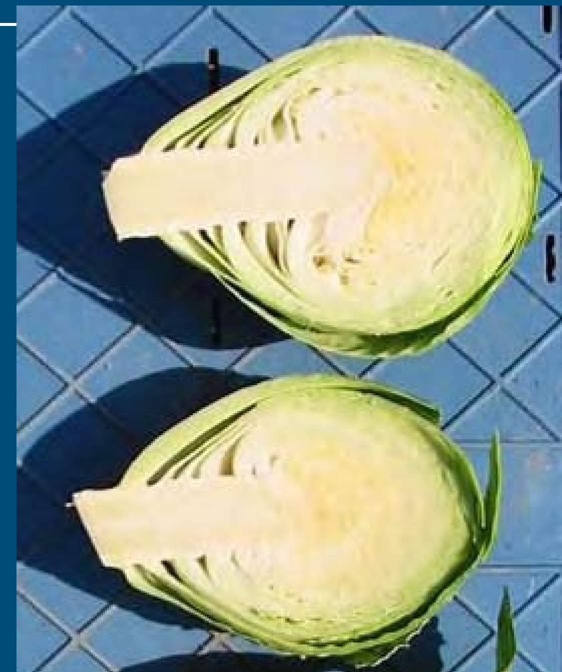
3

4

5

7

8



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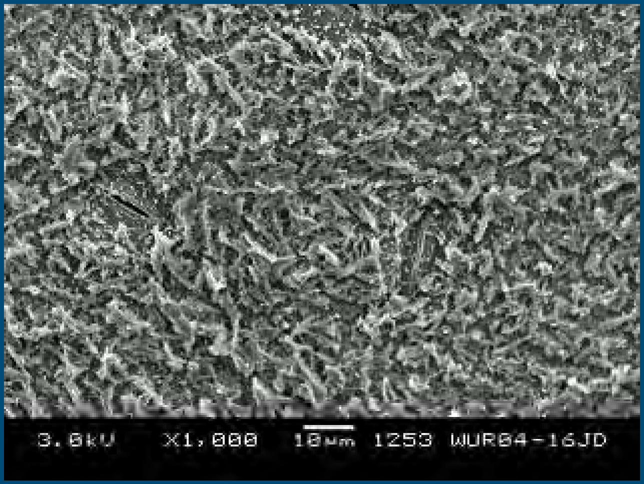
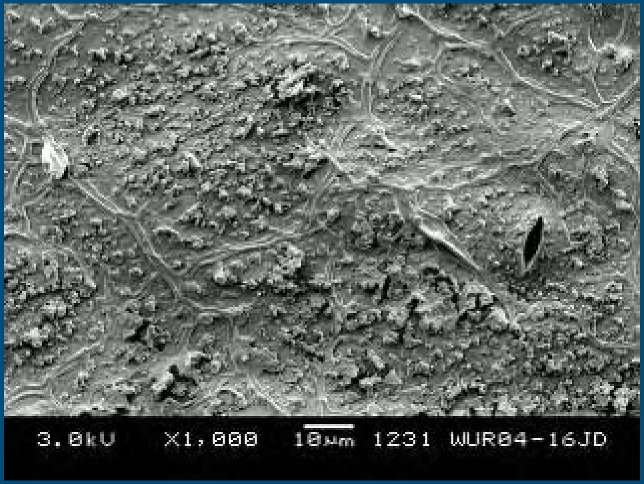
Leaf surface wax





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Ripeness

- Late planting reduces thrips damage ($P<0.05$) (except in early August when no damage is observed)
- Later in the season, the effect is only observed on the more susceptible, earlier ripening varieties
- Probably early development of the head enhances thrips damage

Damage vs. thrips population

- Damage and population are significantly correlated
- Correlation increases from early to late harvest
- No varieties with remarkably low damage with respect to thrips population
  - -> differences in damage caused by resistance, rather than tolerance

Predicting damage from plant traits

Aim: predicting thrips damage at final harvest (mid-October)

- Many potential explanatory variables
  (all measured traits, in all 4 harvests)

- Correlations of individual variables with thrips damage are generally low: $R^2 < 0.45$;
  strongest (negative) correlations with leaf surface wax
  in last 2 harvests (end September- mid October)

- Find predictive models involving more than one parameter:
  - Different plant traits are often highly correlated
  - Avoid overfitting
  - Method: All-subsets regression,
    model selection criterion: Mallows' Cp

Predicting damage from plant traits

- Several models more or less equivalent
- Common elements:
  - Brix, end September-mid October: positive
  - Head development, mid-end August: positive
    - Traits indicating development: stage, circumference, firmness
  - Leaf wax, end September-mid October: negative
  - Brix is not correlated with stage or leaf wax; stage and leaf wax are negatively correlated
    - i.e. early maturing varieties have less wax than later varieties
- Some models include leaf thickness; positive or negative

Possible role of plant traits

- Developmental stage in August
  - A more developed, more compact head may offer a safer environment, more conducive to reproduction
- Brix in September-October
  - More sugar means richer food
  - Perhaps: reflection of different physiological condition that also may affect symptom development
- Leaf wax in September-October
  - Mobility or feeding may be reduced by leaf wax ?
- Leaf thickness
  - The observed effect in different models is not consistent and may be an artefact

Conclusions

- Late planting reduces damage in susceptible varieties, but not to the level of resistant varieties
- Individual plant traits are not sufficient to predict thrips damage
- Combinations including Brix and Leaf Wax late in the season, and Development mid-end August explain up to 75% of variance for damage

Future work on thrips tolerance (2008-2011)

- Field test 2007 included new combinations of earliness and leaf wax to better separate effects
- Role of secondary metabolites in resistance
- Cross population between late, high-wax, resistant and earlier, low wax, susceptible variety:
  - Validation of relations traits – damage
  - Genetics of damage and related traits

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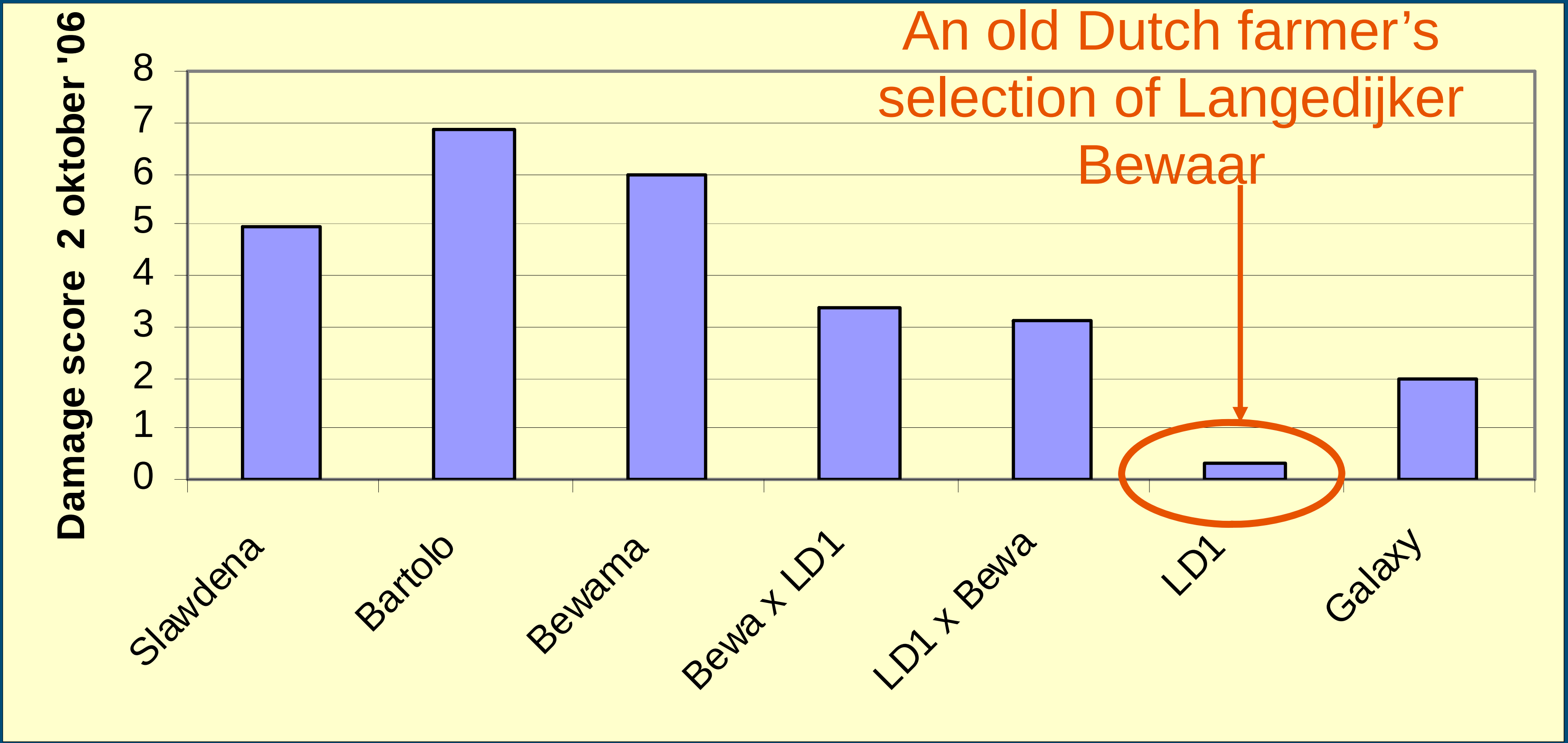
F1 population results



Susceptible x resistant crosses are intermediary

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Fusarium or scab: symptoms and fungi

- bleached ears
- orange/pink spikelets

Fusarium or scab: effects

- Yield loss (30-70%) > shrunken kernels
- Low quality of seed > poor germination
- Quality loss > mycotoxins (DON)

Picture MSU, Montana, USA

Fusarium complex:

F. culmorum

→ *F. graminearum*

F. avenaceum

F. poae

M. nivale

Results

Cultivars differ in:

- level of resistance against fusarium;
- mycotoxin accumulation over time.
- tolerance for yield loss

Cultivars	DON		"Increase"
	Before rain	After rain	
Baldus	130	770	5.9
Thasos	230	530	**2.3**
Anemos	260	2310	**8.9**
Monsun	310	2020	6.5
Lavett	490	4790	**9.8**
LP 340-2-00	490	2110	4.3
Minaret	570	1780	3.1
Pasteur	570	3300	5.8
Taifun	590	1230	**2.1**
LP 590-3-98	670	2530	3.8
Zirrus	720	1800	**2.5**
Melon	890	2270	**2.6**
SCHW 41-91-54	960	8950	**9.3**
Quattro	1260	11400	**9.0**
Paragon	1910	10400	5.4
Tybalt	2010	12400	6.2

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Relationship FHB and plant morphology

- Cultivars with a compact ears are always susceptible;

Other traits of influence:

- Flowering period
- Openness spikelets
- Openness flowers
- Length ear- flag leaf

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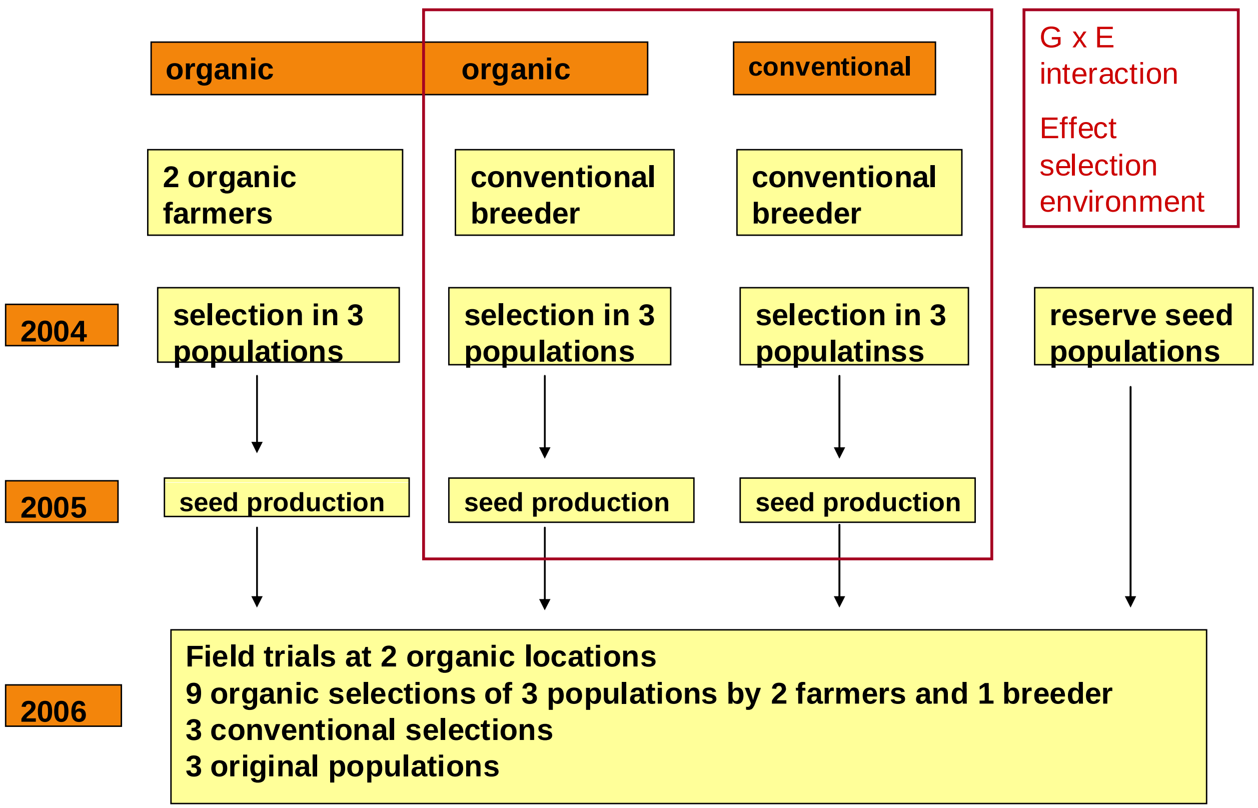
Selection environment: onion



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Data analysis

- Most traits were characterized according to UPOV standards
- Progress: Selection response R = µ1-µ2
- We record of each trait the mean of the original population and the selection; the difference between these (if significant) is the Selection differential
- We will express the selection differential in standard deviation units, to allow comparison of selections among populations with different amounts or types of variation.

  (S = (µ1-µ2)/sed1)
- T-test (lsd) to find significant differences

Effect of selection environment on onion roots

Selection	Number of roots	Number of branched roots	Length longest root	Number >50% longest	*Dry weight roots*
Original population	55.1 b	9.26 b	18.36 a	19.8 b	*0.217 b*
Organic	56.9 b	6.77 ab	20.14 a	16.8 ab	*0.225 b*
Conventional	*36.8 a*	*4.03 a*	*16.87 a*	*12.7 a*	*0.127 a*

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Socio-economic conditions

- Organic farmers depend on conventional VCU testing system (value for cultivation and use)
- Yield most important for recommended list for wheat varieties
- Need to adapt the protocol for testing
  - low-input, organic growing conditions
  - extra traits: e.g. early covering, baking quality, straw length
- Area OA is too small for specific organic breeding program for spring wheat

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Organic spring wheat variety trials

Results of 3 years of spring wheat variety trials for organic farming

	Spring wheat varieties in the Dutch conv. variety list			Promising spring wheat varieties in organic trials		
	Lavett	Pasteur	Tybalt	Thasos	Quattro	Epos
Early soil coverage[1]	6.7	5.5	6.4	6.8	6.8	5.8
Straw length (rel.)	106	97	93	105	106	106
Grain yield (rel.)	96	98	109	99	99	99
Baking quality [1]	8.2	5.0	6.3	7.2	7.0	7.5

[1] Assessed on a scale from 1-9

(Osman et al., 2005)

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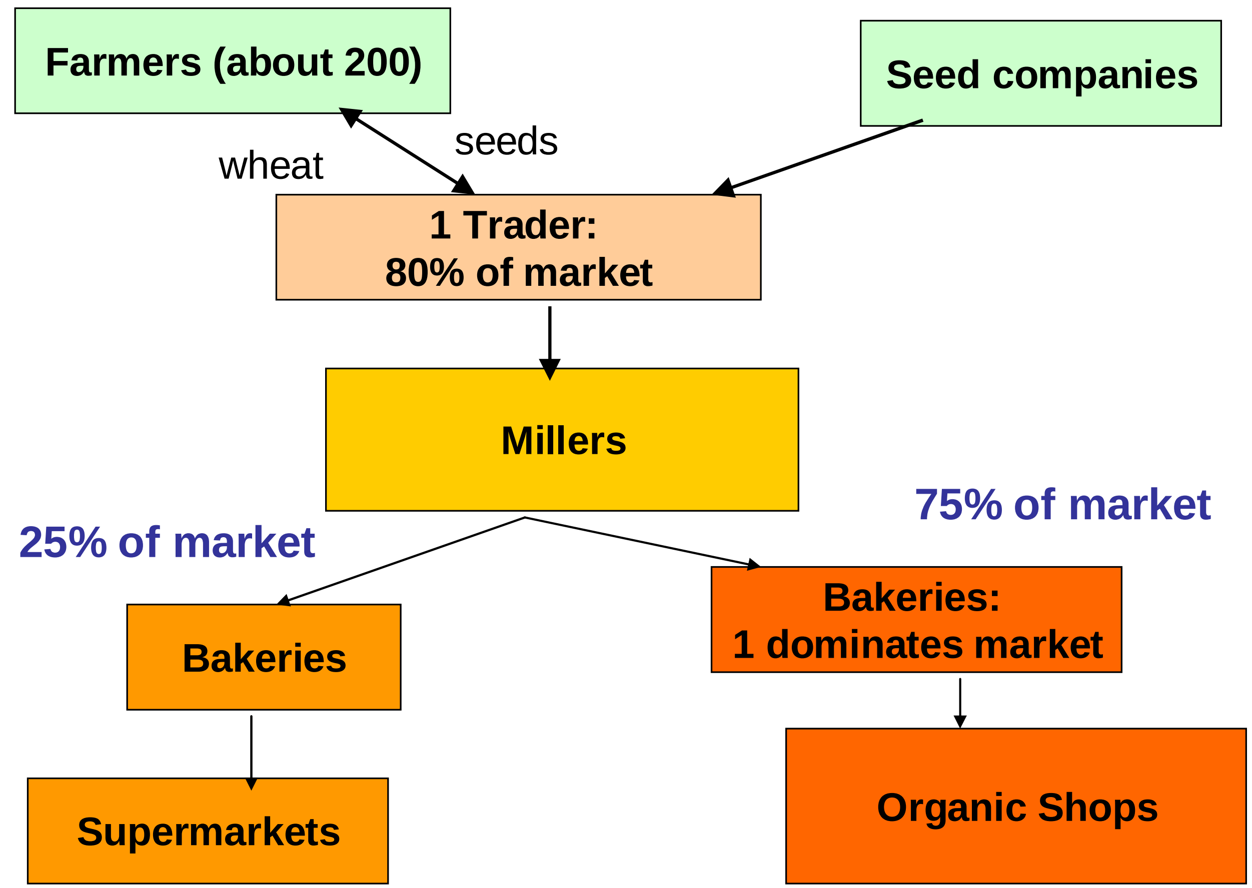
Need for commitment of the chain partners

- If possible link up with existing breeding expertise and infrastructure
- A spring wheat program costs 45.000 euros
- Cannot be earned by seed sales
- By chain partners?



Alternative financing sources

Alternatives:

- Raise the Licence fee, Acreage Levy, Levy on meal/flour?
- Levy on bread (Levy of 2¼ cent on 25% of all organic bread loaves 45.000 Euro)
- Next steps: setting up a collaboration with chain partners and breeders

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Conclusions

How different is OPB from CPB?

- CA: able to adapt the environment to genotypes,
  OA: need to adapt genotypes to the environment.
- Also indirect traits can contribute to plant health;
- OA also needs to adapt the socio-economic and legal ‘environment’!

Partners 2004-2007 and 2008-2011

Thanks to:

- Plant Research International:

Olga Scholten
Roeland Voorrips
Karin Burger
Greet Steenhuis-Broers
(Sierd Zijlstra, pensionated)

- Louis Bolk Instituut:

Edith Lammerts van Bueren
Aart Osman
Marjolein Tiemens-Hulscher
Bart Timmermans

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