Practical examples of vegetable breeding

BREEDING FOR NUTRITIONAL QUALITY IN OPEN POLLINATED VEGETABLE CROPS

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Kultursaat at a glance

- Approx. 300 spons. members, of those 30 breeders
- Financing via membership fees, contributions from foundations, public subsidies
- Annual budget approx. 1.4 Mio. €


GEMÜSE

Hybrid-Saatgut passt nicht zu Bio – und ist trotzdem weit verbreitet

What are our approaches?

- *on-farm breeding, OP varieties,*
- *seed saving must be possible (no F1-hybrids),*
- *some heterogeneity to allow crops to cope with climate variability and other stresses,*
- *maximise plant-soil cooperation,*
- *disease tolerance instead of monogenic resistances,*
- *face the challenges of daily farmer practices (yield, harvest efficiency, plant health, shelf life etc.),*
- *meet trade requirements (nitrate content, shape, colour),*
- *and focus on food with high quality (taste and nutrition).*

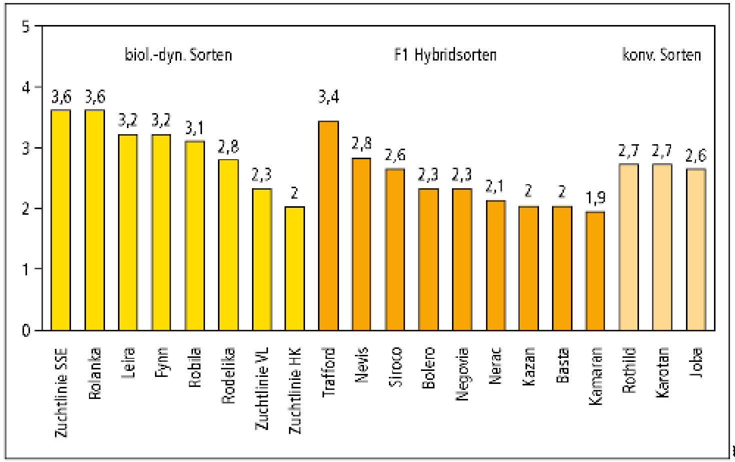

Abbildung 2: Frische Möhren: Ausprägung des Merkmals „Süß"
(5 = Merkmal sehr stark ausgeprägt, 0 = keine Ausprägung)

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another glance

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GLS Treuhand Zukunftsstiftung Landwirtschaft

BÖLN

Gefördert durch: Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz aufgrund eines Beschlusses des Deutschen Bundestages

European Commission

- training of junior breeders: maintaining open access to knowledge on breeding
- actively seeking cooperation with the value chain (Völkel, Naturata, etc)
- in order to tackle biggest gaps in a broad range of crops:

broccoli, cauliflower, chicory, eggplant, fennel, turnip, carrot, pepper, radicchio, cucumber, lettuce, tomato, zucchini…


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Breeding projects together with the value chain

Naturata funds breeding in OP cauliflower:

- 9 projects
- direct distribution preferred
- harvest period, uniformity in size, taste

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Conducting Research projects with universities

Example *‚Brokkoli-Pop‘*

Development of open pollinating broccoli for organic farming
with good agronomic traits and sensory quality

in co-operation with

UNIVERSITÄT HOHENHEIM 1818

Possible solution: Different registration procedure for organic varieties

Gefördert durch:
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aufgrund eines Beschlusses des Deutschen Bundestages

Replacement of „old“ hybrids with protoplast fusion CMS hybrids: very uniform

OP varieties: cannot meet current uniformity standards without inbreeding

Selection in ‘OP’ populations
by single plant progeny selection and
accompanied by analytics and a ‘Sensortool‘

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- ✓100 % daughter company of Odin cooperative
- ✓20 hectares in Oostelbeers, NL
- ✓Production of biodynamic seeds for Bingenheimer Saatgut and Sativa
- ✓Biodynamic vegetable breeding, of a.o. pumpkin, red beet, onion, spinach, chinese cabbage, curly kale, cauliflower
- ✓Only open pollinated: no hybrids, no patents, no genetic modifcation and laboratory techniques
- ✓More variation on the field and in the shop
- ✓Collaboration with the whole food system

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Focus on taste and nutritional value in vegetable breeding

- Improving nutritional quality is becoming more important in plant breeding
- For biodynamic breeding, a holistic perspective is needed

Many questions:

- How to breed for nutritional quality and taste?
  - There is a trade off between yield and quality
  - Hence, a balance is needed
- What is the impact of traits related to efficiency (ease of harvesting, storabillity) on quality?
- How to select for quality in the field using indirect methods?
- Is it possible to look for a balance in yield and nutritional quality for vegetable crops?

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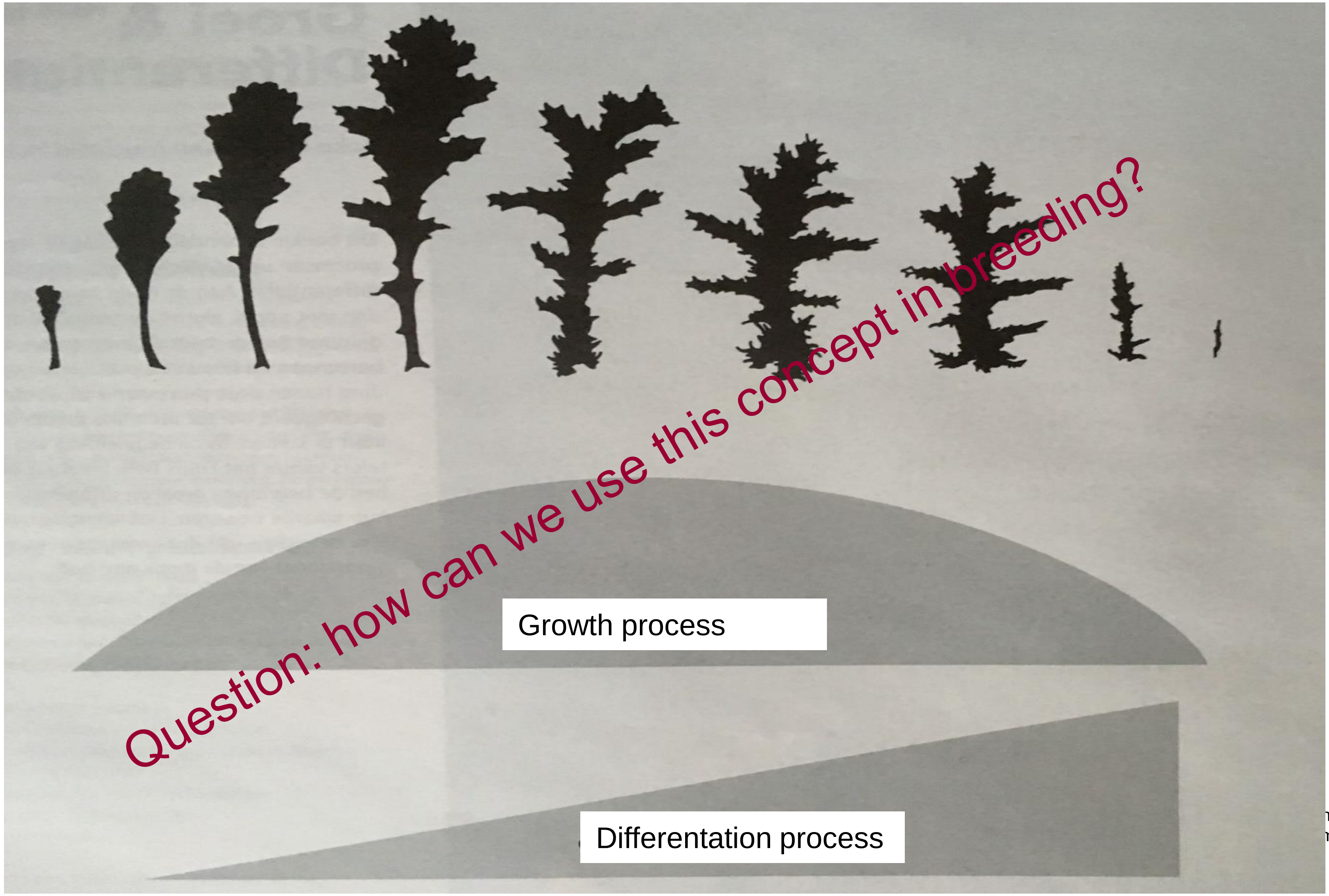
Growth and Differentiation concept:
better tolerance against pests and diseases (Loomis, 1932)



(scheme: Bloksma en Huber, 2002)

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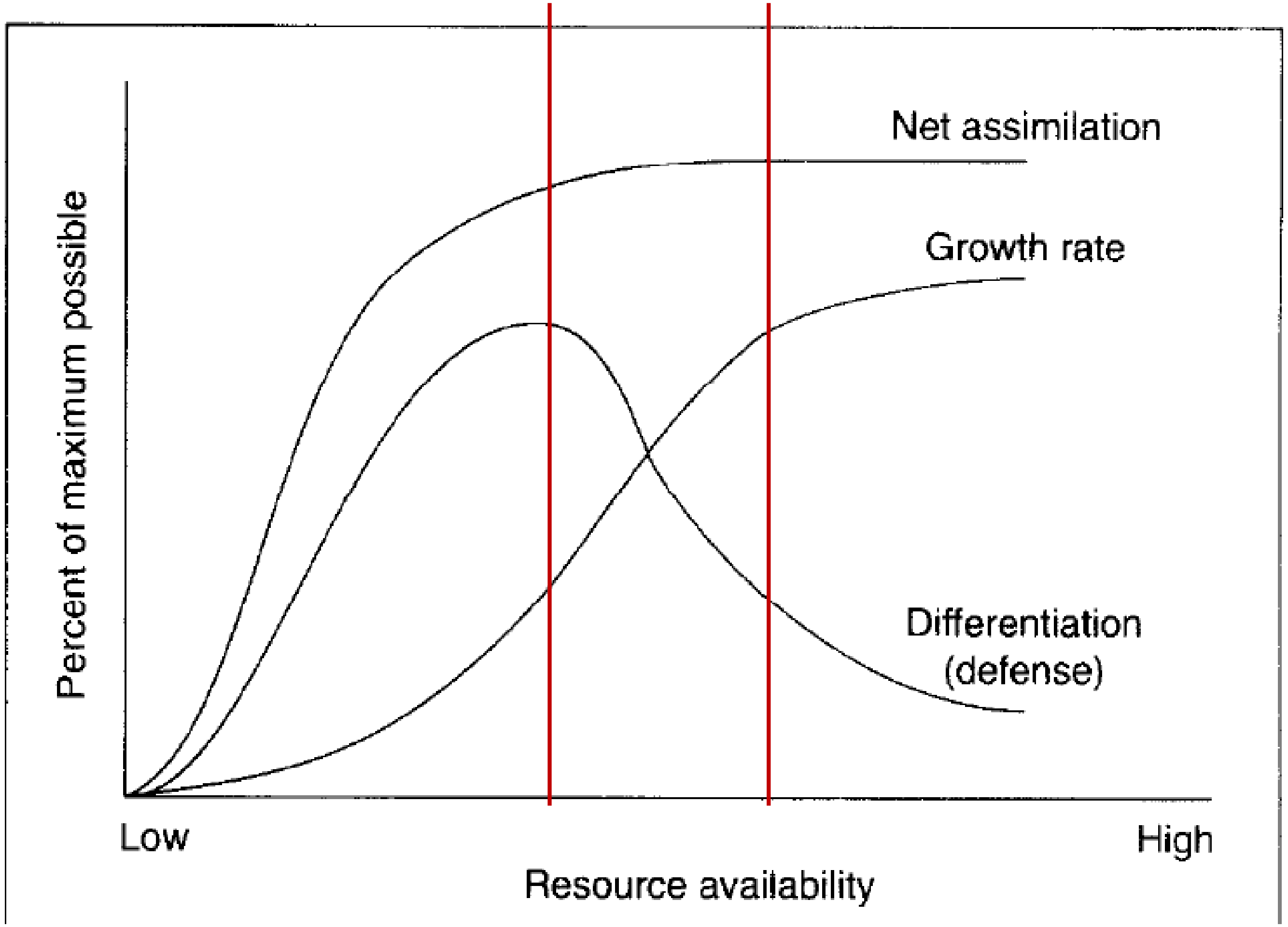
Growth and Differentiation concept: Lerdau et al. 1994



Optimal circumstances: mostly growth, little differentation
Average circumstances: both growth and differentation
Suboptimal condtions: little growth, little differentation

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Data collection on various crops conducted in various projects in several locations and years

Project	Location*	Year	Crop	Main results
Divers en Dichtbij	GAOS	2014/15	Red Cabbage	Relationships between leaf development, nutritional quality and picture forming methods were observed
Breeding for quality	GAOS, DBH	20`17-2018	Carrot, Red Cabbage, Pumpkin	Relationships between yield, storability, taste and nutritional quality
LIVESEED	DBH	2019	Cauliflower	Leaf formation and taste
Zaadvast en Zeker	DBH	2020	Chinese Cabbage	Leaf formation and taste
Zaadvast en Zeker	GAOS	2020	Onion	Yield, storability and nutritional quality
Zaadvast en Zeker	DBH	2020	Pumpkin	Relationships between yield, storability, taste and nutritional quality
Zaadvast en Zeker	DBH	2020	Rucola	Yield, leaf development, taste and nutritional quality
Zaadvast en Zeker	DBH	2020	Spinach	Yield, leaf development, and nutritional quality
Zaadvast en Zeker	DBH	2020	Red Beet	Yield, leaf development, and betacyanin levels

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GAOS: located on clay soil in Swifterbant
DBH: De Beersche Hoeve has sandy soil

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2014: first studies on cabbage
Growth and Differentiation: Leaf series

Langedijker bewaar

Rodynda

Rodima F1

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Growth and Differentation:
Which plants have the preffered leaf development?

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Follow-up in 2015: how is leaf development related to quality based on picture forming methods?

- Cabbages were sent to Paul Doesburg for analysis with crystallisations
  - 2 white cabbage varieties, 6 cabbages per variety
  - 2 red cabbage varieties, 6 cabbages per variety

- These cabbages were also analysed for head size and shape, dry matter content, Brix, EC, pH, minerals and with a self decomposing test (SDT)



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Correlations between Crystallisations by Paul Doesburg and other measurements on white and red cabbage

		conventional parameters				*Self Decomposing Test*		*combinations*		
		Brix	**dry matter content**	**pH**	**EC mS/cm**	**loss dry matter weight during SDT (in %)**	**loss fresh weight during SDT (in %)**	**loss dry weight x loss fresh weight during SDT**	**loss dry weight x loss fresh weight during SDT x dry matter content**	**loss dry weight x loss fresh weight during SDT x Brix**
red and white	*all cabbages*	*0,18*	*0,31*	*-0,09*	*0,08*	*0,40*	*0,45*	0,60	0,55	*0,54*
white	*all white*	*0,19*	*0,06*	*-0,69*	*-0,25*	*0,62*	*0,33*	*0,69*	*0,64*	*0,65*
white	Dowinda	0,45	0,25	-0,85	0,54	0,26	0,82	0,44	0,41	0,46
white	L. bewaar	0,05	0,00	-0,62	-0,76	0,99	-0,08	0,99	0,95	0,91
red	*all red*	*0,11*	*0,37*	*0,03*	*0,16*	*0,19*	*0,39*	*0,42*	*0,78*	*0,72*
red	Granat	0,20	0,74	-0,08	0,44	0,60	-0,13	0,73	0,83	0,68
red	Rodynda	-0,09	0,02	0,18	-0,09	0,08	0,90	0,61	0,95	0,82
# correlations < 0		1	1	5	3	0	2	0	0	0
# correlations > 0		6	6	2	4	7	5	7	7	7
st. deviation		0,15	0,24	0,38	0,41	0,29	0,37	0,18	0,19	0,14

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Results on red cabbage

- Leaf shape and development can be an indicator for nutritional quality
  - Only effective when differences are large
  - Leaf shape is also influenced by environmental factors

- First results for cauliflower and chinese cabbage suggest similar relationships exist for taste
  - However: there are also genotype and environment effects

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Comparison based on 4 onion varieties on 2 biodynamic farms (2019/20): effect of location and manure level on yield, storability and quality

	November		April	April / November		April		
	Bulbs/ meter	Marketable yield	Marketable yield	Marketable yield after storage	% bulb weight	Brix	Marketable yield November x Brix	Marketable yield after storage x Brix
		Ton/ha	**Ton/ha**	**in %**	**in %**			
Location 1: average manuring level	*19,1*	*33,0*	*24,6*	74,7	90,6	*9,6*	*316,5*	*235,7*
Location 2: high manuring level	*28,5*	*44,4*	*28,3*	63,6	82,0	*8,1*	*360,2*	*229,3*
Location 1/ Location 2 (in %)	***67***	***74***	***87***	***117***	***110***	***119***	***88***	***103***

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Correlations between various traits of rucola, measured spring 2020 (N = 16)

	Yield	Taste	Dry matter content	Brix	EC	pH	K+
Taste	-.264						
Dry matter content	-.804**	.000					
Brix	-.480	-.123	.704**				
EC	.638**	-.270	-.469	-.282			
pH	-.234	.150	-.018	-.278	-.676**		
K+	-.421	.435	.421	.385	.000	-.123	
$Ca^{2}+$	.343	-.109	-.410	-.548*	.025	.364	-.425

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Correlations between various traits of spinach, measured spring 2020 (N = 20)

N = 20	Yield	Dry matter content	Brix	EC	K+
Dry matter content	**-.718****				
Brix	**-.456***	**.781****			
EC	-.195	-.164	-.391		
K+	-.360	-.159	-.317	**.726****	
pH	.385	-.261	.047	.028	-.233

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Breeding for quality

- Louis Bolk Institute and the two farms DBH and GAOS

- Trial set-up:
  - Three crops: carrot, pumpkin and red cabbage, per crop 5 cultivars (3 open pollinated, 2 F1-hybrids)
  - Two bio-dynamic farms with different soils: clay and sandy soil
  - Two seasons: 2017 and 2018
  - Two harvests per season
  - Three replications per variety per location (RCBD)
  - Sowing, plant spacing, farm management and harvesting as similar as possible
  - Measurement of yield, storability and taste with farmers involved
  - Measurement of dry matter content, Brix, EC and pH at Louis Bolk Institute
  - Measurement of minerals by Eurofins: P, K, Mg, Ca, S, Na, Zn, Fe, Cu, Mn
  - Statistical analysis: ANOVA and correlations

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Correlations of fresh yield with storability, taste and nutritional quality

Trait	Carrot avg. correlations	st. dev.	Pumpkin avg. correlations	st. dev.	Red cabbage avg. correlations	st. dev.
N	8x5		8x5		4x5	
Storability (%)	0,00	0,52	-0,27	0,54	-0,40	0,18
Taste (1-9)	-0,26	0,35	-0,13	0,48	0,35	0,45
Dry matter content (%)	-0,77	0,16	-0,52	0,25	-0,36	0,18
Brix (%)	-0,71	0,16	-0,69	0,35	-0,27	0,33
EC (mS/cm)	-0,20	0,63	-0,89	0,07	0,21	0,35
pH	-0,28	0,31	0,07	0,63	0,52	0,22

Carrot: clear negative correlations between yield with dry matter content and Brix
Pumpkin: clear negative correlations between yield and EC
- also negative correlations between yield with dry matter content and Brix

Red cabbage: no consistent pattern with strong positive or negative correlations
- positive correlation between yield with pH
- Tendency for negative correlations between yield with storability, dry matter content, and Brix

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Possibilities for indirect selection for mineral content

	Pumpkin				Red cabbage				Carrot			
	EC	Brix	pH	Dry matter	EC	Brix	pH	Dry matter	EC	Brix	pH	Dry matter
P		+		+	+*				+*			
K	++	+		+*	++			+*	++			
Mg		+		+					+*			
Ca				-*						+*		+
S	+	++		+		+*		+	+*			
Na						+*		+*				
Zn		+		+				+*	+*			
Fe												
Cu									+*			
Mn												

\+ positive relation (double: strong relation)
\- negative relation
* relation not consistent through all treatments

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Average mineral content, on the basis of 12 probes per variety

	Variety	Amoro F1		Bright Summer F1		Orange Summer F1		Fictor		Red Kuri		Uchiki Kuri	
Mineral	(in)	Average	index on the basis of Uchiki Kuri	Average	index on the basis of Uchiki Kuri	Average	index on the basis of Uchiki Kuri	Average	index on the basis of Uchiki Kuri	Average	index on the basis of Uchiki Kuri	Average	index on the basis of Uchiki Kuri
Calcium	g	0,30	171	0,23	132	0,18	101	0,18	106	0,17	98	0,17	100
Fosfor	g	0,30	51	0,39	67	0,46	77	0,55	93	0,52	88	0,59	100
Potassium	g	2,32	54	3,59	83	3,80	88	4,34	101	3,85	89	4,31	100
Magnesium	g	0,12	59	0,16	78	0,16	80	0,20	98	0,18	86	0,20	100
Sulphur	g	0,17	57	0,24	79	0,27	88	0,31	99	0,29	94	0,31	100
Iron	mg	5,47	71	7,10	92	6,86	89	7,48	97	6,85	88	7,75	100
Copper	mg	0,50	55	0,87	95	0,79	86	0,80	88	0,97	106	0,92	100
Zinc	mg	2,17	49	2,42	54	3,70	83	4,08	91	4,25	95	4,48	100
Total			71		85		86		96		93		100

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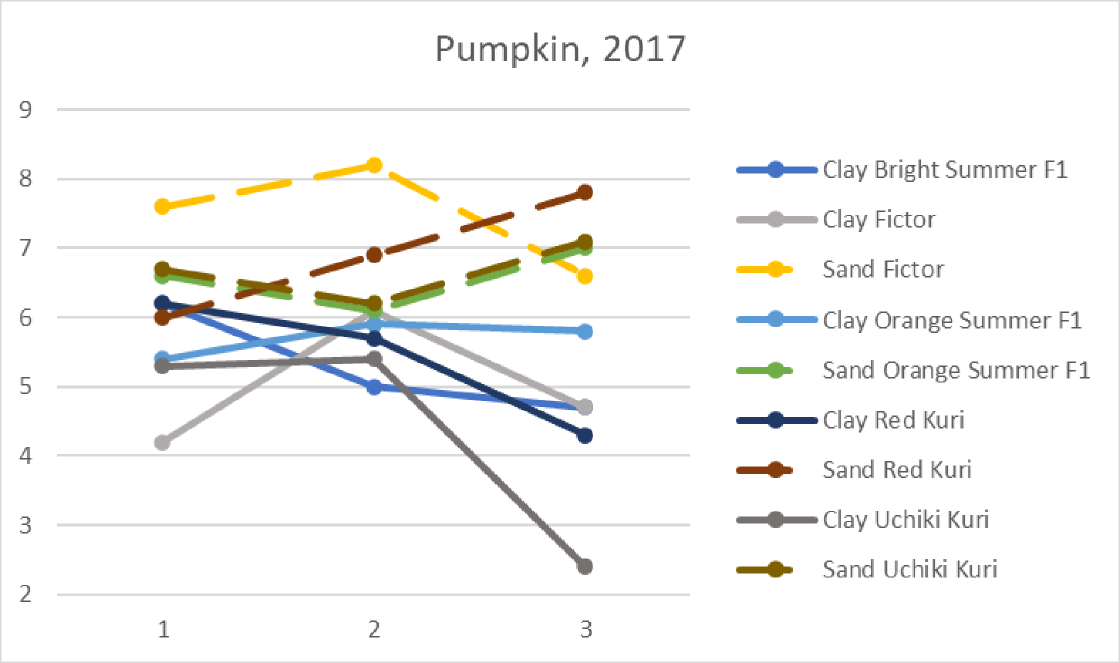
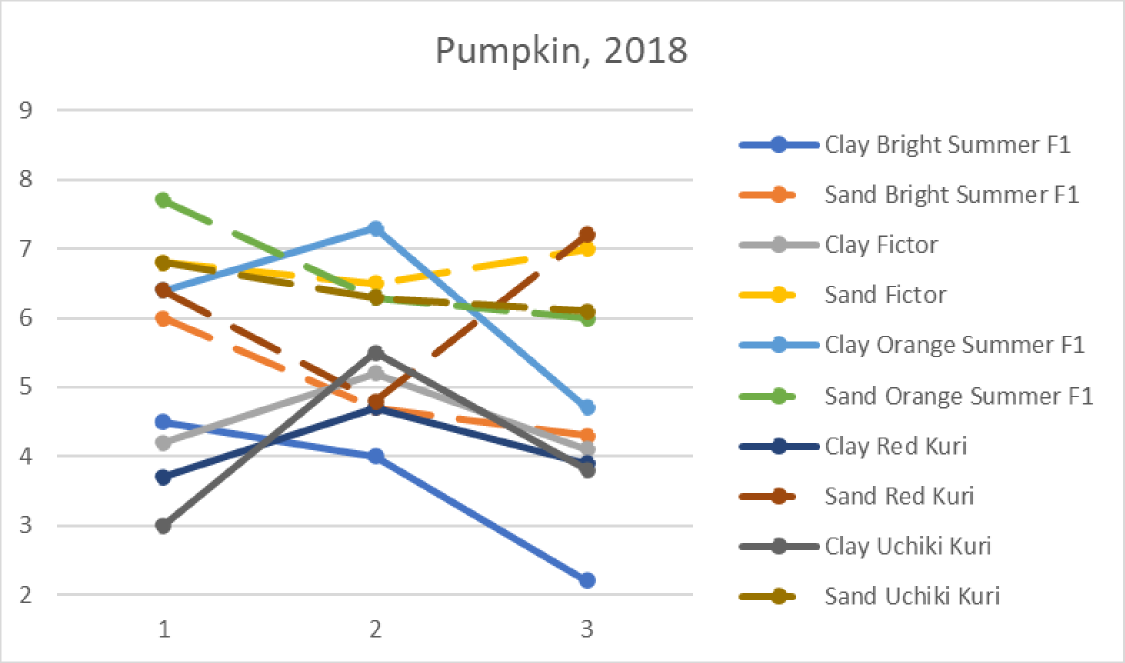
Change in taste of pumpkin during storage in seasons 2017 and 2018





Differences between:

- Locations
- Seasons
- Varieties

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General conclusions project Breeding for quality

- Large season and location effects
- For all three crops, negative correlations between yield with dry matter content and Brix
- No consistent patterns for correlations of yield with storability and taste for all three crops

	Carrot						Pumpkin						Red cabbage					
	Yield	*Storability*	*Taste*	*Dry matter*	*Brix*	*EC*	*Yield*	*Storability*	*Taste*	*Dry matter*	*Brix*	*EC*	*Yield*	*Storability*	*Taste*	*Dry matter*	*Brix*	*EC*
Yield			(-)	--	--			(-)		-	-	--		(-)	(+)	(-)	(-)	
Storability									var	var	var	var			(-)	+*	+*	var
Taste				(+)	(+)					(+)	var	var				var	var	var

- Crop specific breeding with a good balance in yield, storability, taste and nutritional quality should be possible
  - Balance likely to be different for each crop

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Relationships in red beet phenology and betacyanin content

Possible indirect selection parameters:

- Change in leaf colour
- Leaf shape
- Leaf size

- Work-in-progress

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General conclusions

- For many crops, there is a trade off between yield and dry matter content
- Relationship between storability and quality is crop specific
- Crop phenology may be used as an indicator for nutritional quality and taste
- Indirect selection for mineral content may be different for different types of plant organs (fruit, root and leaves)

- Crop specific approaches are needed for a good balance in yield, storability, taste, and nutritional quality
- Soil, weather and farm management also have large effects on the growth process, and hence on all these traits

➢ "Kwaliteit kost tijd": Quality costs time, Janneke Benschop

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Thank you for your attention!

Time for questions?

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