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Plant Breeding for Organic and Low-input Agriculture

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Presence and Future for Plant Breeding

Hohenheim 29th March 2019

Outline

- Strategies and Approaches of organic plant breeding
- Breeding for mixed cropping systems: pea & barley
- Breeding for the holobiont: exploring relation of pea microbiom and tolerance towards soil fatigue

Global sales of certified organic foods (from 1999 to 2017)

In billion Euro
(Willer, 2018, FiBL Statistic

“If we want to sell and buy organic food, we need seeds that are system-adapted”.

Strategies for Organic Plant Breeding

Ecological instensification of organic production through

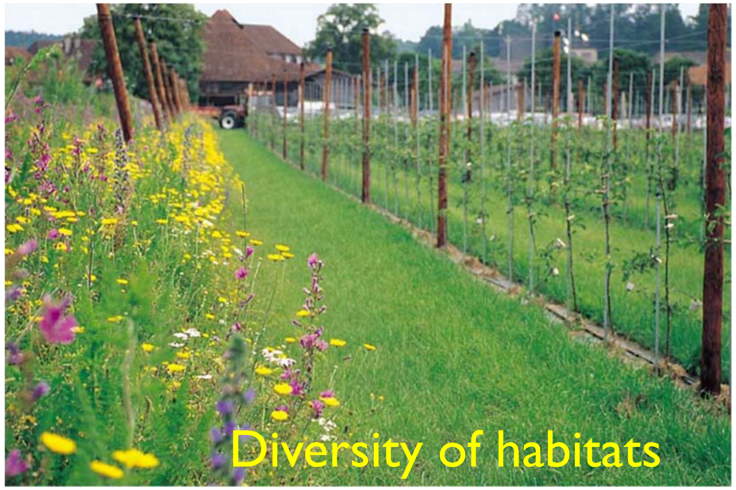
- Focused breeding for target environments with limited external inputs
- Selection for specific traits, like seed- borne diseases, weed competition
- Meeting market demand and expectation of farmers and consumer
- Alternative breeding programs refraining from genetic engineering and certain breeding techniques

Enabling more sustainable food production systems through

- Large portfolio of crops on farm level to mitigate risks of crop failure
- Functional biodiversity on field level to reach high level of self regulation and closed nutrient cycle
- Safeguarding and evolving genetic resources for future generations

Breeding for functional biodiversity

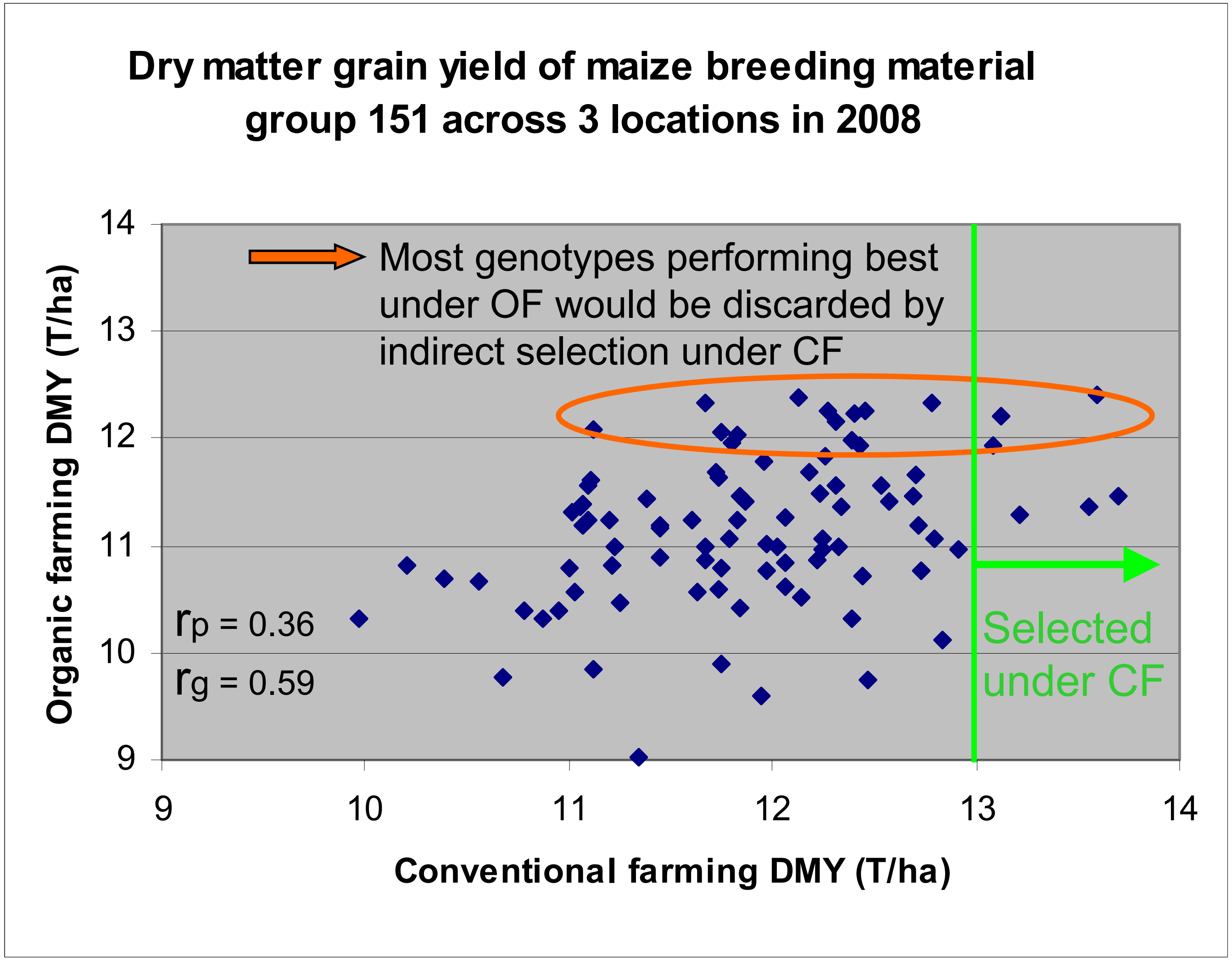

Diversity of landscapes


Diversity of habitats


Diversity of species


Diversity within species

Lost opportunities of indirect selection



Messmer et al. (2009)

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Importance of Selection environments

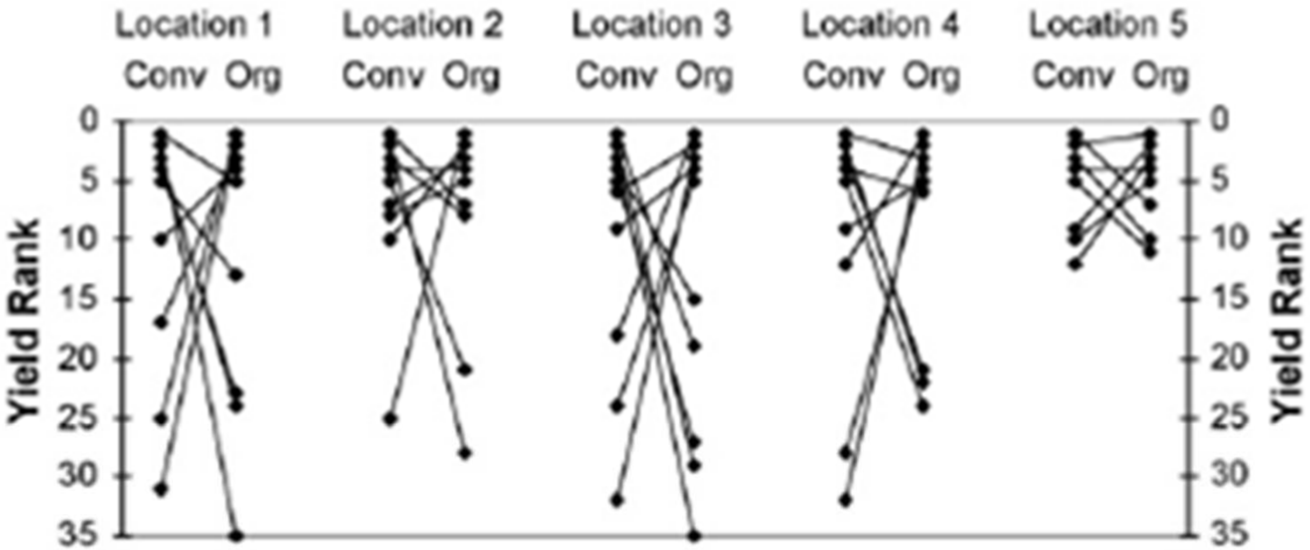


Fig. 1. Genotypic change in rank between organic and conventional wheat nurseries. The top five ranking genotypes for yield in both organic and conventional systems were compared at each location. Genotypes are ranked from 1 = highest yield to 35 = lowest yield.

Murphy et al. (2007)

Approaches of Organic Plant Breeding

Combining breeding & agronomic innovations for Organic

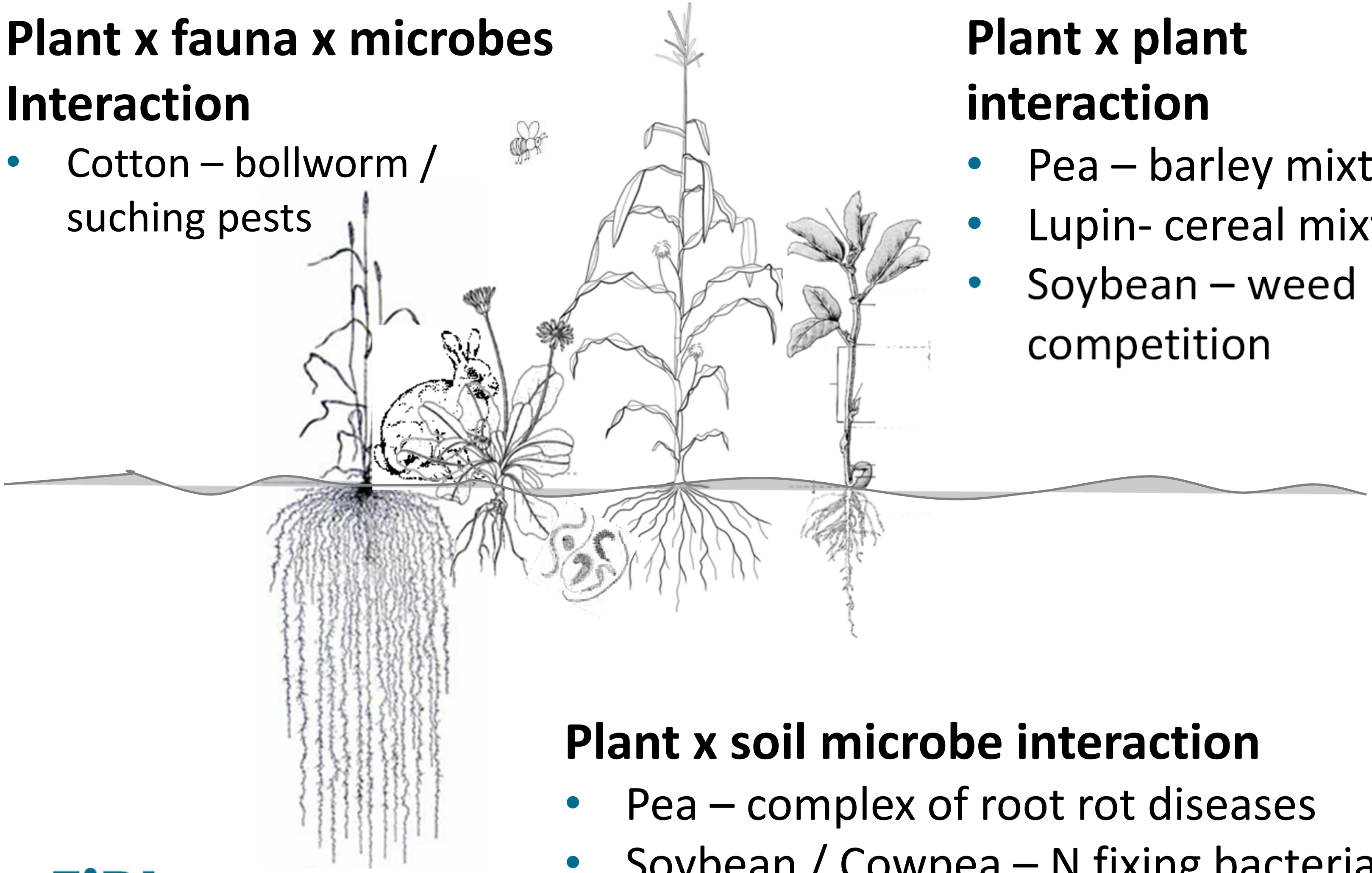
Breeding for increased diversity

- Breeding for diversity within cultivars
- Breeding for mixed cropping systems
- Breeding for improve diversity of associated soil microbes
- Decentralized participatory breeding for local conditions

Embedding diversity into markets

- Involving all stakeholders (farmer, value chain and community driven breeding)
- New concepts for the ownership of cultivars and their financing
- Changing regulatory framework to foster greater agrobiodiversity (official variety testing, seed regulation)
- Valorization of organic plant breeding along the value chain (www.bioverita.org)

Breeding for complex organic farming systems



Plant x fauna x microbes Interaction

- Cotton – bollworm / suching pests

Plant x plant interaction

- Pea – barley mixture
- Lupin- cereal mixture
- Soybean – weed competition

Plant x soil microbe interaction

- Pea – complex of root rot diseases
- Soybean / Cowpea – N fixing bacteria

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BREEDING STRATEGIES FOR A SPRING PEA-SPRING BARLEY MIXED CROPPING SYSTEM

ReMIX
Species mixtures for redesigning European cropping systems

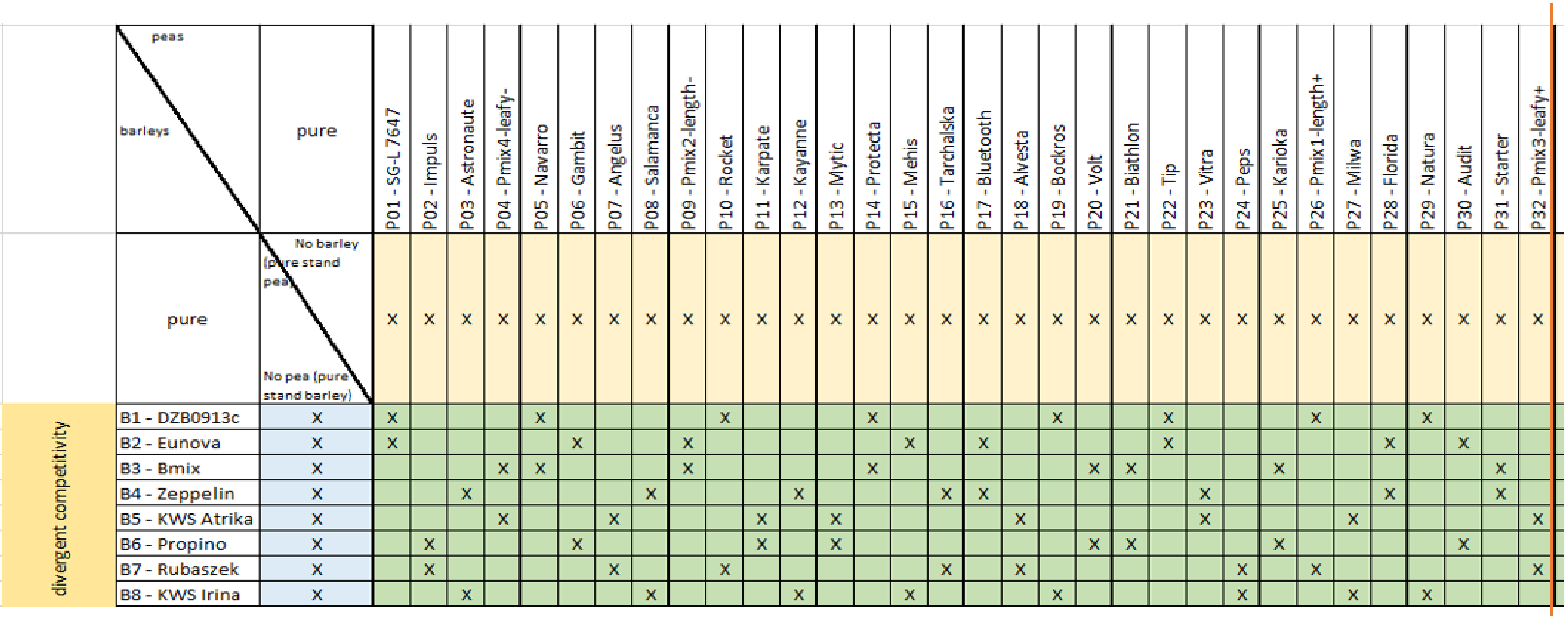
Benedikt Haug

Supervisors: M. Messmer, P. Hohmann (FiBL), I. Goldringer, J. Enjalbert (INRA)

Presentation UE course modélisation

Frick, 01.03.2019

Experimental design



	peas barleys	pure	P01 - SG-L 7647	P02 - Impuls	P03 - Astronaute	P04 - Pmix4-leafy-	P05 - Navarro	P06 - Gambit	P07 - Angelus	P08 - Salamanca	P09 - Pmix2-length-	P10 - Rocket	P11 - Karpate	P12 - Kayanne	P13 - Mytic	P14 - Protecta	P15 - Mehis	P16 - Tarchalska	P17 - Bluetooth	P18 - Alvesta	P19 - Bockros	P20 - Volt	P21 - Biathlon	P22 - Tip	P23 - Vitra	P24 - Peps	P25 - Karioka	P26 - Pmix1-length+	P27 - Milwa	P28 - Florida	P29 - Natura	P30 - Audit	P31 - Starter	P32 - Pmix3-leafy+
	pure	No barley (pure stand pea) No pea (pure stand barley)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
divergent competitivity	B1 - DZB0913c	x	x				x					x				x					x			x				x			x			
	B2 - Eunova	x	x					x			x						x		x					x						x		x		
	B3 - Bmix	x				x	x				x					x						x	x				x						x	
	B4 - Zeppelin	x			x					x				x				x	x						x					x			x	
	B5 - KWS Atrika	x				x			x				x		x					x					x				x					x
	B6 - Propino	x		x				x					x		x							x	x				x					x		
	B7 - Rubaszek	x		x					x			x						x		x						x		x						x
	B8 - KWS Irina	x			x					x				x			x				x					x			x		x			

- Trial design: Incomplete factorial 8 barleys pure, 32 peas pure, 64 mixtures
- 2 locations (Fislisbach + Uster) x 2 replications
- Sown as an alpha design with a block size of 5 (20 blocks per replication)
- Seed densities in mixtures: 80% pea, 40% barley (no row intercropping – plants mixed within rows)
- Plot size 7 m^2 each; 2 x 2 x 112 = 448 micro plots in total

GMA - SMA models derived from GCA and SCCA

Model 1

$$Y_{rbp} = \mu + \alpha_r + GMA_b + GMA_p + SMA_{bp} + e$$

With Y_{rbp} the mixture yield of the b-th barly variety and the p-th pea varietiy in repetition r,

μ the intercept,

α_r the effect of the rth repetition/block,

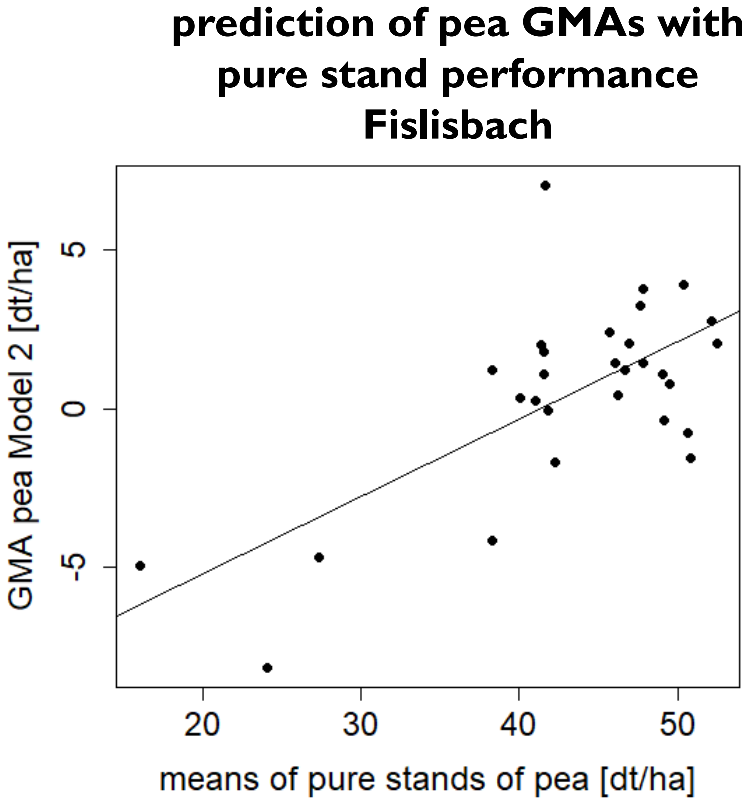
GMA_b the general mixing ability of the bth barley cultivar,

GMA_p the general mixing ability of the pth pea variety,

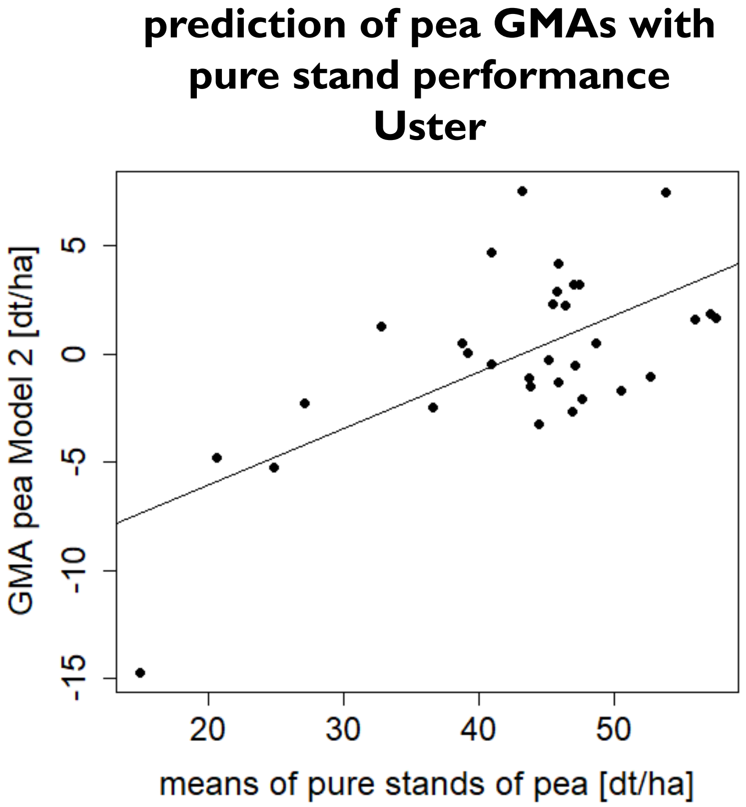
SMA_{bp} the specific mixing ability of the bth barley cultivar with the pth pea cultivar (interaction),

e the error term

Results Model 2 – prediction of pea GMAs with pure stand performance



r = 0.46



r = 0.41

Analysis methodology II – Producer Associate when separating pea and barley yield in mixtures

Separated harvest data available for mixtures (yield pea $Y_{p(b)}$ and yield barley $Y_{p(b)}$ component)

$$\mathrm{Y}_{bp} = Y_{b(p)} + Y_{p(b)}$$

→ Posibility to decompose GMA into its producer and associate effects (*Pr* and *As*, respectively).

→ The producer effect *Pr* is the contribution of a variety to its own component yield in a mixture and its associate effect *As* is the effect that this variety exhibits on the fraction yield of its mixing partner

→ Pr(oducer) and As(sociate) effects (Forst, 2018; Goldringer 1994) can be calculated in the same manner as one calculates GMA/SMA using the component yields as dependent variable

$$Y_{b(p)r} = \mu_b + \frac{1}{2}\alpha_r + Pr_b + As_p + SMA_{b(p)} + e_{bpr}$$

$$Y_{p(b)r} = \mu_b + \frac{1}{2}\alpha_r + Pr_p + As_b + SMA_{p(b)} + e_{bpr}$$

With $Y_{b(p)}$is the component yield of barley variety b when combined with pea variety p,

μ_b the intercept of barley component yields,

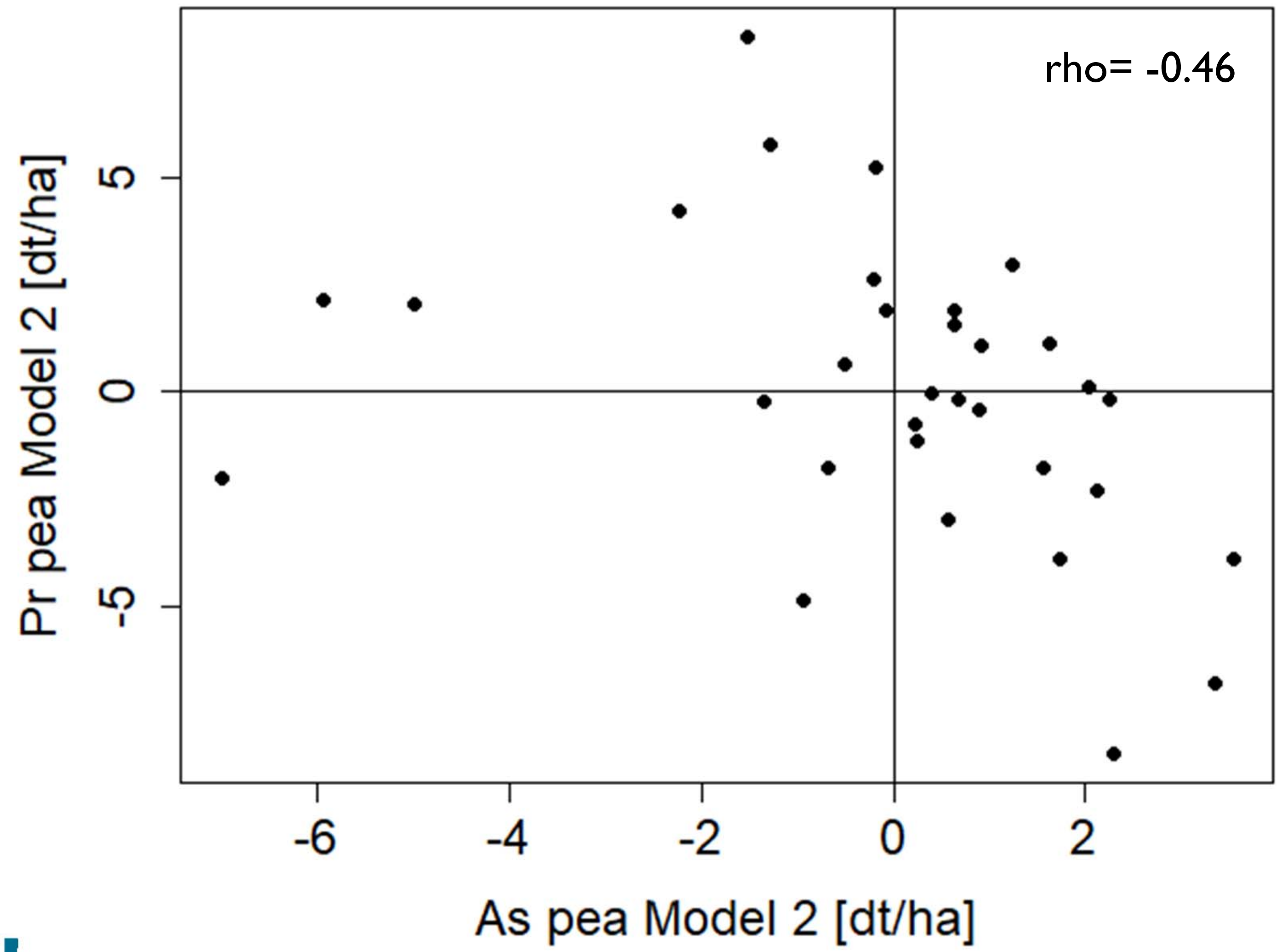
$Pr_b$is the Producer effect of barley variety b (the positive or negative performance of variety b due to its innate productivity when combined with the other species),

As_p is the Associate effect of variety p (the positive or negative impact of variety p on its associated mixing partners) and

$SMA_{b(p)}$is the interaction of the two mixing partners

e_{bpr} the error

Producer effect of pea on pea yield and Associate effect of pea on barley yield



Analysis methodology III

Genetic correlations between…

… Mixture yield and pure stand yield

… Mixture yield and key traits (e.g. plant length, leaf area)

→ Multivariate model (several dependent variables)

- → e.g. pure stand yield and mixture yield
- → e.g. pea $Y_{p(b)}$ and yield barley $Y_{p(b)}$ component yield

→ Calculating **inirect gain of selection** via genetic correlations, e.g. predicting mixture yield via pure stand yield, key traits, predicting or As/Pr effects via key traits

→ **Suggest new breeding schemes for breeding for mixed cropping**

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Resistance screening of pea against a complex of root-rot pathogens

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11 FiBL

2 ETH Zürich

Schweizerische Eidgenossenschaft
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Confederaziun svizra

LIVESEED

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Pea Resistance Screening – Our Approach

- Identify pea lines resistant against pathogen complexes

  → **Controlled conditions screening systems**

- Elucidate the genetic basis of polygenic resistances

  → **Genome-Wide Association Study (GWAS)**

- Understand resistance-related plant-microbe interactions

  → **qPCR and high-throughput amplicon sequencing**

Resistance against root rot pathogens – a complex problem

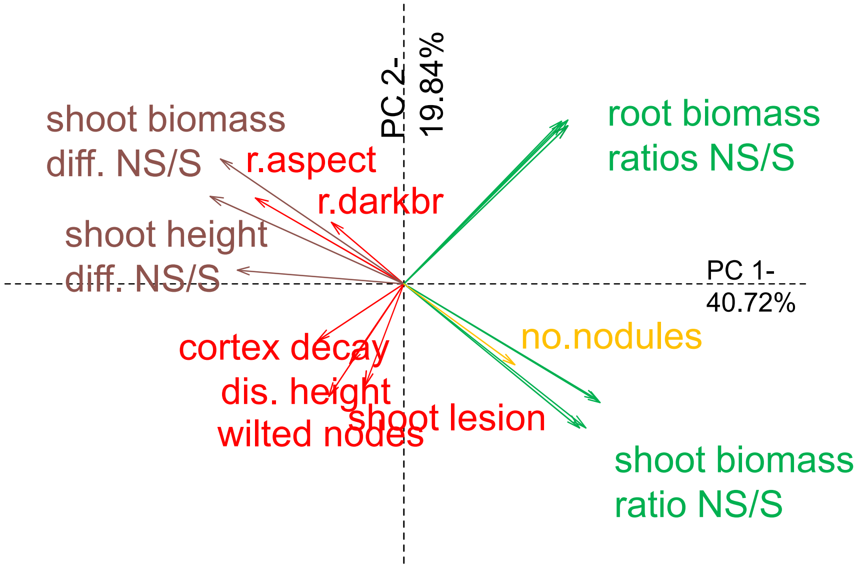
Aphanomyces euteiches

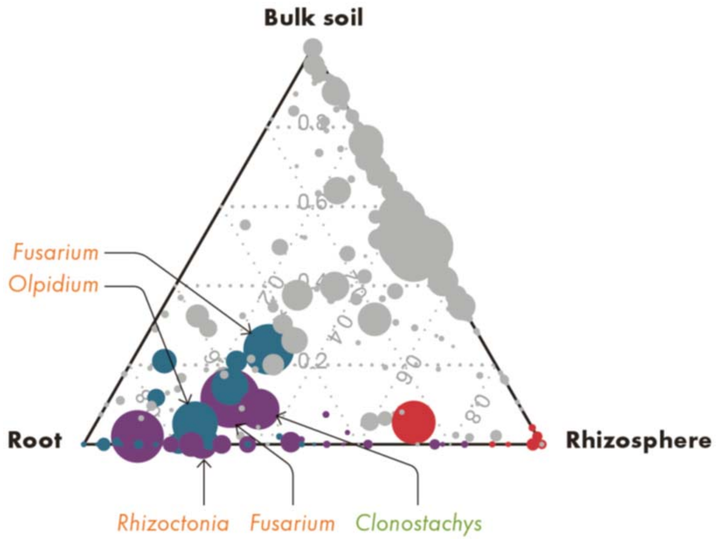
Pythium ultimum

Fusarium solani

Rhizoctonia solani

Pea Resistance Screening - Results

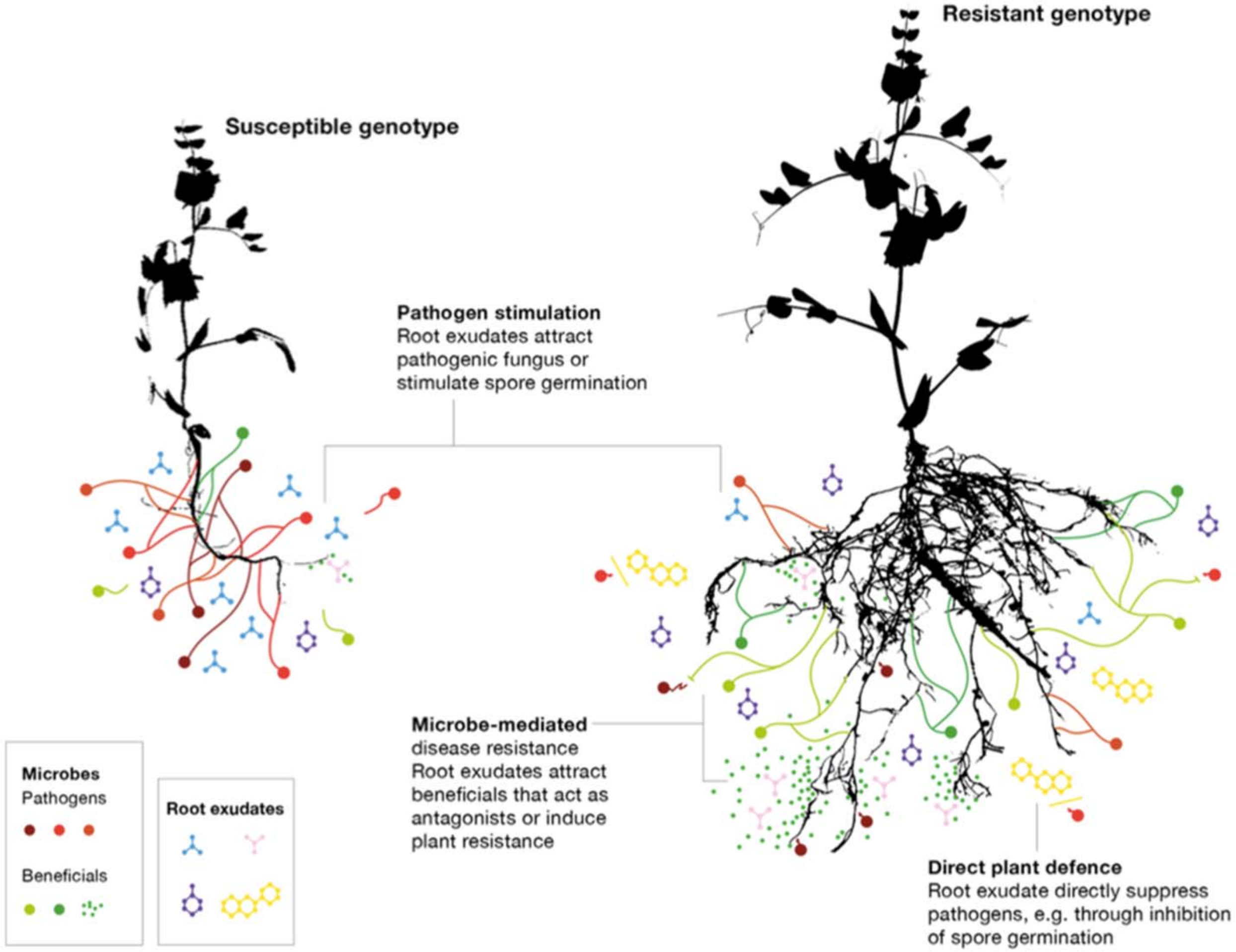




<u>Resistance assays</u>: Variation in different disease parameters

<u>Microbiome analysis</u>: putative pathogens and beneficials in the rhizosphere

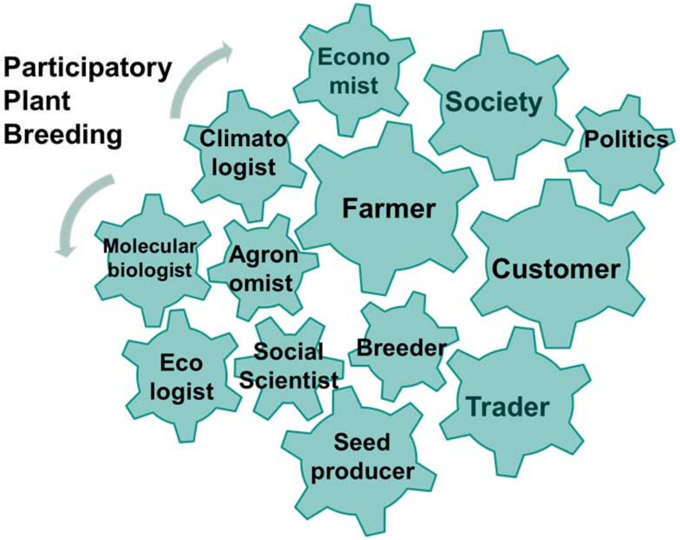
Pea Resistance Screening

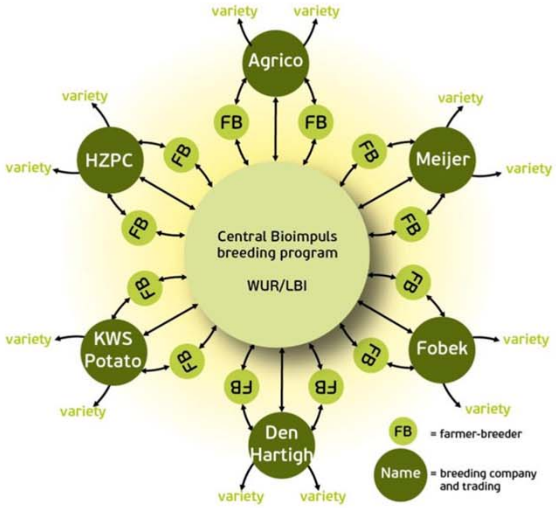


Include plant-microbe interactions in breeding programmes

Wille et al. 2018. *Plant Cell Environ 2019*

Decentralized Participatory Plant Breeding





- Seeding the Green Future – participatory non-GM cotton breeding in India (2013-2022)
- Participatory soybean breeding in Switzerland

Swiss and European projects to promote Organic Plant Breeding

- Swiss FOAG: Promoting organic breeding 2016 -2021
- Green Cotton: participatory cotton breeding 2013-2022
- Horizon 2020 DIVERSIFOOD: Embedding crop diversity and networking for local high quality food systems, www.diversifood.eu 2015-2019
- Horizon 2020 LIVESEED : Improve performance of organic agriculture by boosting organic seed and plant breeding efforts across Europe 2017-2021
- Horizon 2020 ReMIX: Redesigning European cropping systems based on species MIXtures 2017-2021
- Horizon 2020 BRESOV: Breeding for Resilient, Efficient and Sustainable Organic Vegetable production 2018 - 2022
- Horizon 2020 ECOBREED: Increasing the efficiency and competitiveness of organic crop breeding 2018 - 2023

Thanks for your attention

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www.liveseed.eu

www.diversifood.org

www.remix.eu

www.bresov.eu

www.sgf-cotton.org

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