Organic Plant Breeding: Achievements, Opportunities, and challenges

Økologisk planteforædling: Resultater, muligheder og udfordringer

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Crop plant varieties released from conventional breeding programs do not cover all requirements and demands of organic systems.

Sorter der er udviklet i konventionelle planteforædlingsprogrammer dækker ikke alle de krav og behov, der er i økologiske landbrugssystemer.

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Organizations were founded around 1980 to 1990 to
(Organisationer blev dannet omkring 1980 til 1990 for at)

1) safeguard genetic resources on farm and in garden, (beskytte genetiske ressourcer på landbrug og i haver)

2) produce and distribute organic seed, and (producere og distribuere økologiske frø, og)

3) start organic breeding programs. (starte økologiske forædlingsprogrammer)

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Aims that many of us agreed upon were (Mål, som mange af os var enige om, var)

1. the adaptation of varieties to organic growing conditions (tilpasning af sorter til økologiske dyrkningsbetingelser),

2. to (re-)establish farmers and gardeners as breeders (genetablere landmænd og gartnere som forædlere),

3. reduce external input (seed) into the farm organism (reducere eksterne input (udæd/frø) til gård-organismen,

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Aims that many of us agreed upon were (Mål, som mange af os var enige om, var

4. appreciate the holistic nature of the plant and its integrity (værdsætte planters holistiske natur og integritet),

5. create a cooperation between breeders, growers, and consumers (at skabe samarbejde mellem forædlere, avlere og forbrugere),

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Aims that many of us agreed upon were
(Mål, som mange af os var enige om, var)

6. increased varietal diversity, and
(øge sortsdiversitet, og)

7. high food quality
(høj fødevarekvalitet).

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Present achievements (Opnåede resultater):

Organic breeding projects have yielded encouraging results (Økologiske planteforædlingsprojekter har givet lovende resultater).

Academic working groups have investigated and improved organic breeding methods (Akademiske arbejdsgrupper har undersøgt og forbedret økologiske planteforædlingsmetoder).

The first academic textbook “Organic Plant Breeding” will appear soon (Den første akademiske undervisningsbog “Økologisk Planteforædling” udkommer snart).

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The need for organic breeding programs
Behovet for økologiske planteforædlingsprogrammer

Example 1: Winter wheat breeding in Northwest USA

Eksempel 1: Vinterhvedeforædling i det nordvestlige USA

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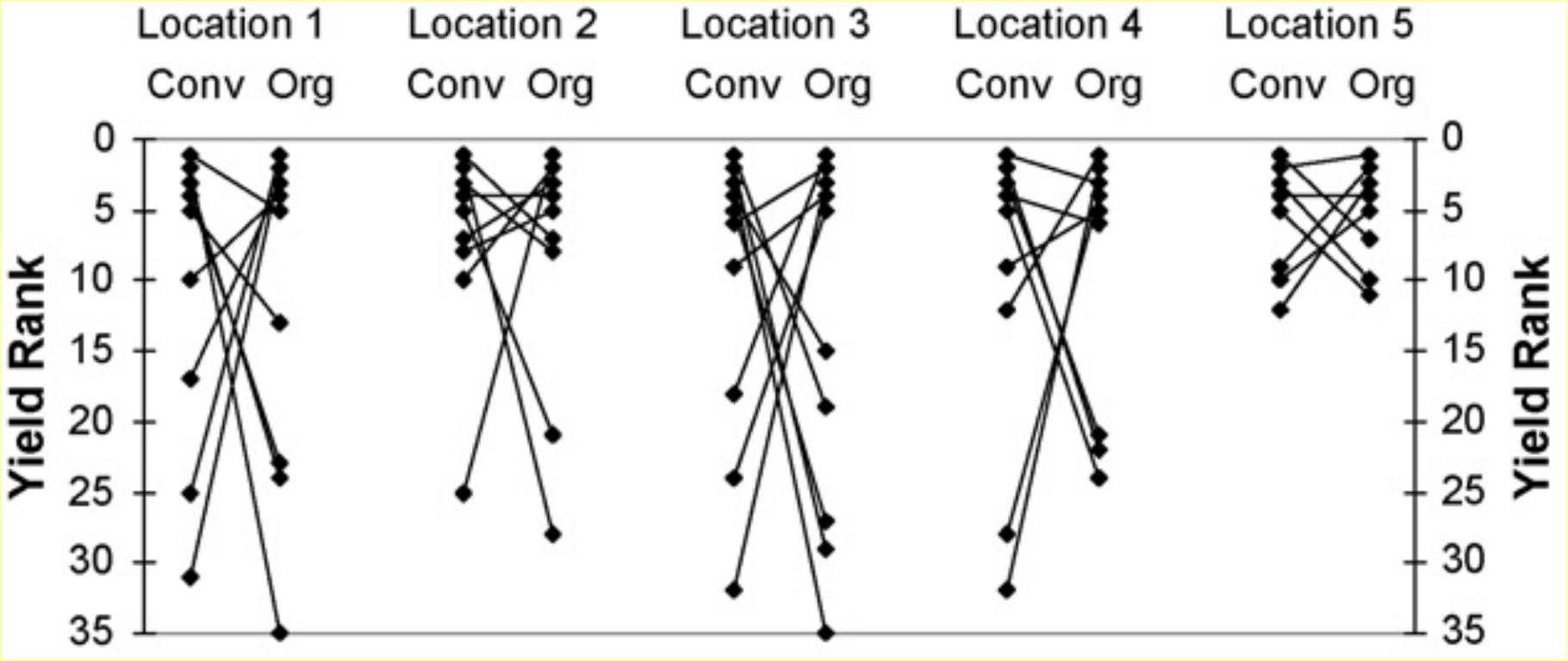
Behovet for økologiske forædlingsprogrammer



Genotypers forskellige udbytteplacering i økologiske og konventionelle hvedeafprøvninger. De fem højestplacerede genotyper blev sammenlignet på hver lokalitet (Murphy et al. 2007).

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The need for organic breeding programs

Direct selection in organic systems produced yields 15%, 7%, 31% and 5% higher than the yields resulting from indirect selection for locations 1–4, respectively. Differences observed at location 5 were not significant.

Direkte selektion i økologiske systemer producerede udbytter, der var hhv 15%, 7%, 31% og 5% højere end de udbytter der blev opnået via indirekte selektion på lokaliteterne 1-4. Forskellen observeret på lokalitet 5 var ikke signifikante.

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The need for organic breeding programs

Example 2: Maize in Germany in 2 paired conventional / organic trials.

Eksemple 2: Majs i Tyskland i 2 parrede konventionelle / økologiske forsøg

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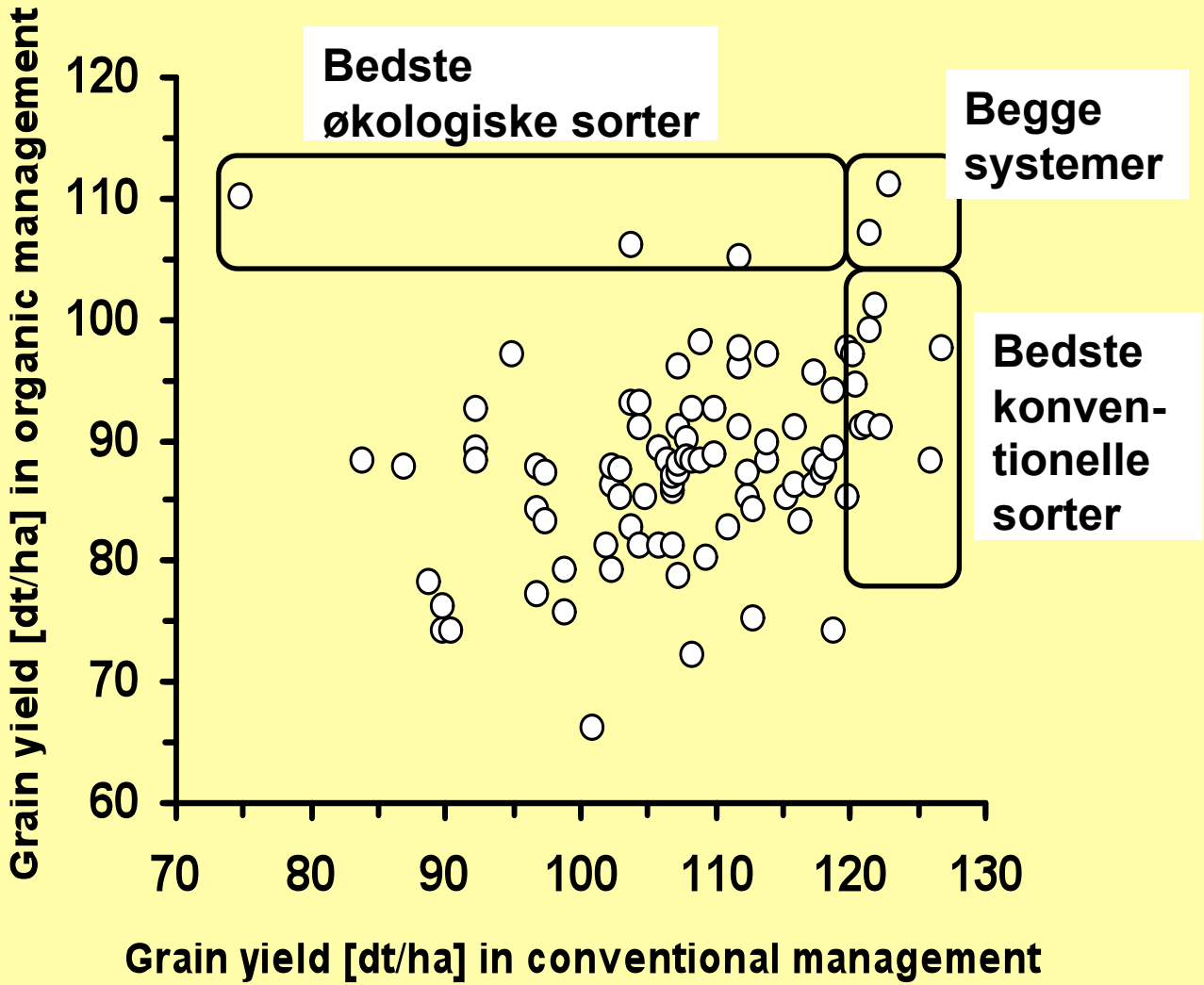

Udbytter i hybridmajs under økologisk og konventionel dyrkning (Burger et al. 2008, modified)

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Crucial traits (Nødvendige egenskaber)

Breeding within organic systems allows to select for individual traits like (Forædling i økologiske systemer tillader at selektere for individuelle egenskaber som)

- **weed tolerance (ukrudtstolerance),**
- **nutrient use efficiency / low input, and (næringsstofudnyttelseseffektivitet/lavt input, og)**
- **field resistance against pests and diseases, plus (mark resistens overfor skadedyr og sygdomme)**
- **the interactions among these traits (interaktionen mellem disse egenskaber).**

Crucial traits: Weed tolerance (Nødvendige egenskaber: Ukrudtstolerance)

Very complex trait (Meget kompleks egenskab).

Few experiments have investigated varietal differences (Få eksperimenter har undersøgt sortsforskelle).

No results from breeding programs for weed tolerance (Ingen resultater fra forædlingsprogrammer for ukrudtstolerance).

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Crucial traits: Weed tolerance

Most important aspect is the morphological weed suppression ability. (Det vigtigste aspekt er afgrødens morfologiske evne til at undertrykke ukrudt)

In cereal grains e.g. height, early season growth, tillering capacity, and leaf area index

I korn er det fx højde, tidlig vækst,

evne til at buske sig, og bladarealindeks

(Mason and Spaner 2006).

(Cereal Breeding Research Darzau)

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Crucial traits: Weed tolerance

Tolerance to mechanical weed control. (strength of the roots, root distribution, and leaf-arrangement). (Tolerance overfor mekanisk ukrudtsbehandling (røddernes styrke og distribution samt bladenes placering))

Generally competition in the root sphere is little investigated. (Generelt ved vi ikke meget om konkurrence i rodsfæren)

Allelopathic effects under field conditions (Allelopatiske effekter under markforhold).

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Crucial traits: Weed tolerance

Intercropping with suitable cultivated plants of selected species can be used to simulate weed competition

(Samdyrkning med egnede kultiverede arter kan anvendes til at simulere konkurrenceevne overfor ukrudt)

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Crucial traits: Field resistance (Nødvendig egenskab: mark resistens)

Breeding for field resistance against diseases has been successful for e.g. barley and tomato (Forædling for mark resistens overfor sygdomme er lykkedes i fx byg og tomat).

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Crucial traits: Field resistance

An example for fungal pathogens restricted to organic agriculture are the smut fungi of cereals, e.g. loose smut (*Ustilago nuda*) and covered smut (*Ustilago hordei*) in barley.

Et eksempel på svampepatogener, der først og fremmest er problemer i økologisk landbrug, er nøgen og dækket bygbrand.

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Crucial traits: Field resistance

Seed borne spores can be controlled e. g. by hot water treatment. This method, however, is not efficient enough to meet the threshold given by the authorities for the production of certified seed. Screening for resistance within organic systems was successfully carried out by e.g. Lorenz et al. (2006).

Udsædsbårne sporer kan kontrolleres fx med varmvandsbehandling. Denne metode er dog ikke effektiv nok til at efterleve myndighedernes krav til certificeret udsæd. Screening for resistens i økologiske systemer blev gennemført med succes af fx Lorenz et al. (2006).

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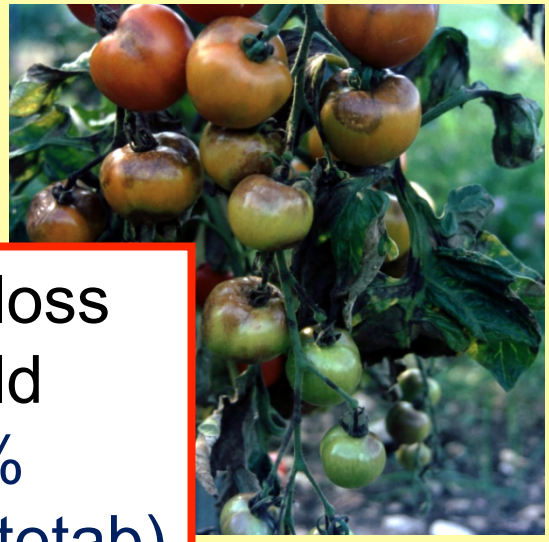
Crucial traits: Field resistance

The host – pathogen system Tomato – late blight (*Phytophthora infestans*) is rapidly evolving on the global scale. (Værts-patogen systemet for tomatskimmel udvikles hurtigt globalt)



Total loss of yield (100% udbyttetab)

Polygenetic field resistance (polygenetisk markresistens)

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Crucial traits: Field resistance

Host – pathogen system Tomato – late blight (Vært – patogen system tomat – skimmelsvamp)

Selection in the F_2 generation in organic low input environments (Selektion i F_2 generation i økologisk lavt input miljø)

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The Crucial traits (De nødvendige egenskaber)

nutrient use efficiency (næringsstofudnyttelseseffektivitet),

adaptation to nutrient dynamics (tilpasning til næringsstof dynamik),

abiotic stress (og abiotisk stress)

have only been investigated to a limited extend in organic agriculture and research results are barely used in breeding (er kun undersøgt i begrænset omfang i økologisk landbrug og forskningsresultater bruges næsten ikke I planteforædlingen).

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Crucial traits: Nitrogen use efficiency
(Nødvendig egenskab: effektiv udnyttelse af kvælstof)

Maize in Germany (Majs i Tyskland)

Conventional studies with varying nitrogen (N) supply. Experimental hybrids of European elite breeding lines selected at low N out yielded those selected at high N level

Konventionelle studier med varierende niveauer af kvælstoftildeling. Eksperimentielle hybrider af europæiske linjer selekteret ved lave N niveauer gav større udbytter end de linjer der var selekteret ved højt N niveau.
(Presterl et al. 2002).

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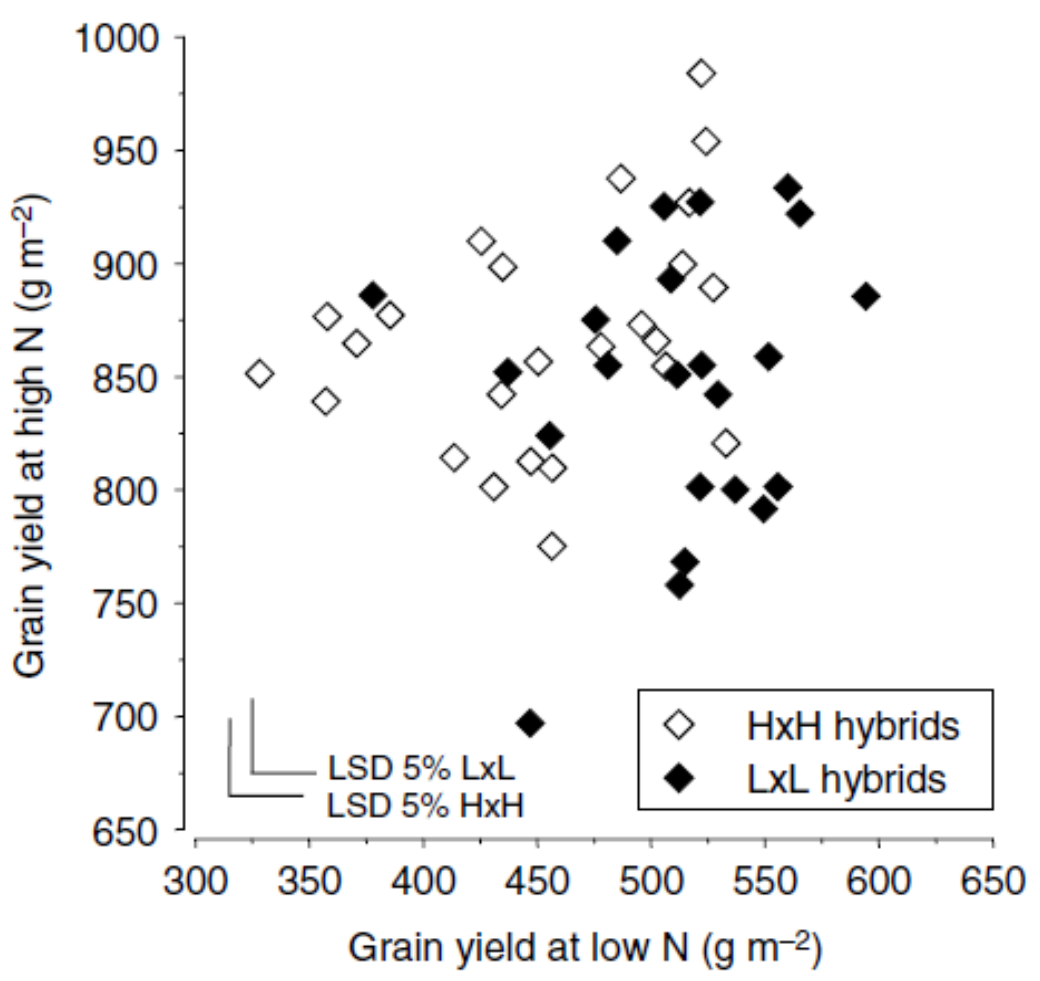
Nødvendig egenskab: effektiv udnyttelse af N



Forhold mellem kerneudbytte ved lavt (L) og højt (H) N niveau i jorden af henholdsvis 25 H x H og 24 L x L majshybrider (Presterl et al. 2002).

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The Crucial traits: Abiotic stress tolerance (Nødvendig egenskab: abiotisk stress tolerance)

Barley in Syria: In conventional studies in low input semi arid environments 64 breeding lines selected in low and high yielding environments, respectively, were compared in 21 environments covering a wide range of yield level (Ceccarelli 1996).
(I konventionelle studier i lavinput, nedbørsfattige miljøer blev 64 linjer selekteret i miljøer med lavt og højt udbytte. Disse blev sammenlignet på 21 forsøg.)

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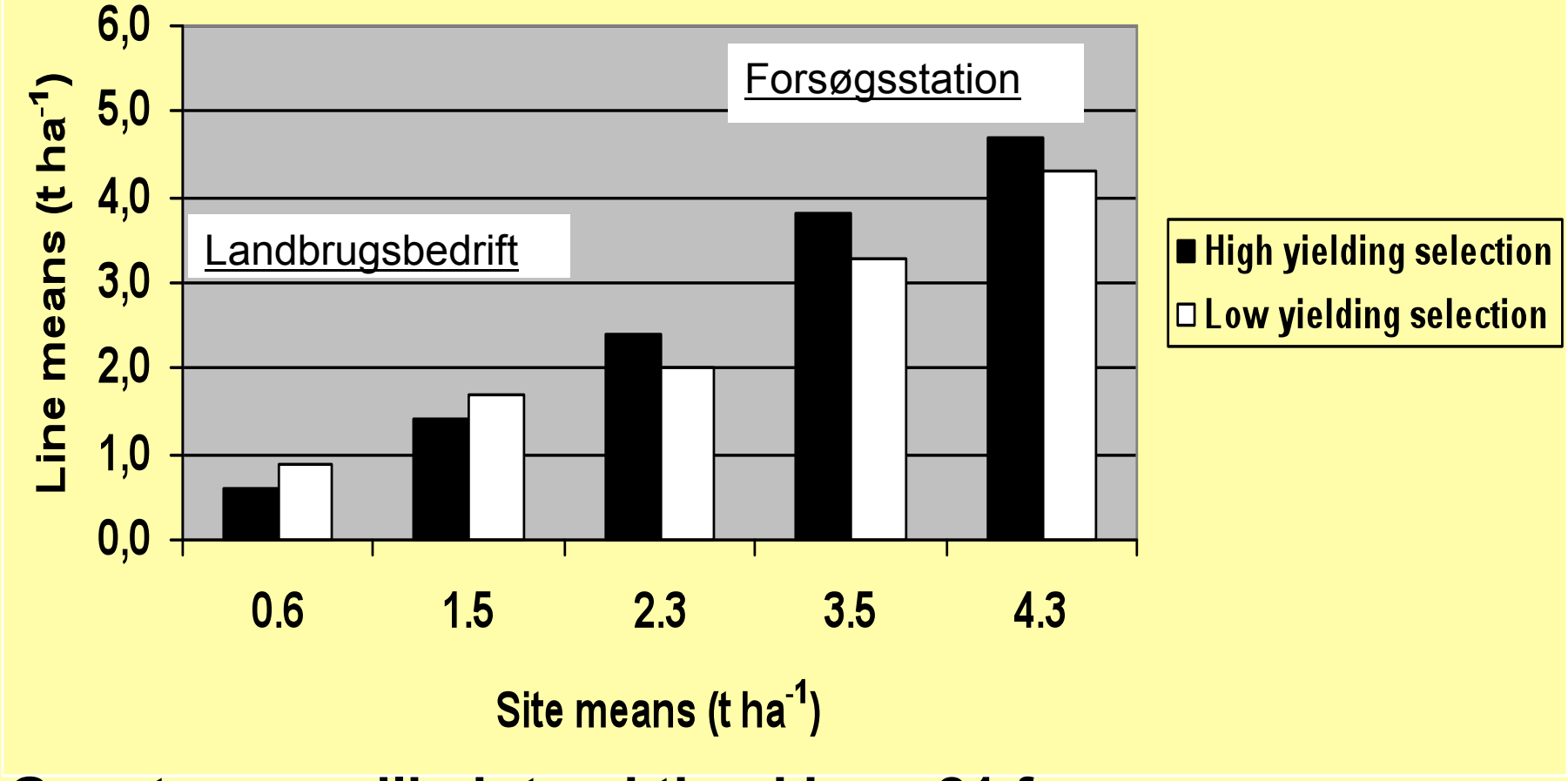
Nødvendig egenskab: abiotisk stress



Genotype x miljø interaktion i byg: 21 forsøg, kombinationer er puljet i 5 grupper i forhold til gennemsnitsudbyttet (Ceccarelli 1996)

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Other areas of excellence of organic breeding (Andre områder der udmærker økologisk forædling)

- Participation in the breeding process (Deltagelse i forædlingsprocessen)
- Organoleptic quality (Organoleptisk kvalitet)
- Site-specific adaptation (Lokal/sted-specifik tilpasning)
- Responsibility for biodiversity and genetic resources (Ansvar for biodiversitet og genetiske ressourcer).

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Other areas of excellence of organic breeding

Participatory rice breeding was developed in the Philippines by MASIPAG since 1987 (Kollektiv risforædling er udviklet på Filippinerne af MASIPAG siden 1987 (Medina 2009, Vicente et al. 2009).

The objective was the creation of a seed system as an alternative to high input varieties propagated by the Green Revolution (Formålet er at skabe et frø-system, der udgør et alternativ til højt input sorter, der blev udviklet under den Grønne Revolution).

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Other areas of excellence of organic breeding

Farmers identify the breeding objectives, are involved in producing crosses, select in segregating generations, evaluate and maintain the best populations

Landmænd fastsætter forædlingsmål, er involveret i at lave krydsninger, selekterer i det segregerende materiale, evaluerer og vedligeholder de bedste populationer.

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Masipag Rice Conservation and Breeding Support system

>35,000 farmers in 47 provinces use regionally adapted selections
(>35.000 landmænd I 47 provinser bruger regionalt tilpassede selektioner).
(Courtesy P. Medina + L. Bachmann)

Nationale 'back-up' landbrug

2,060 rice varieties & Selections

Regionale (2) og provinsielle (9) 'back-up' landbrug)

300 to **1,200** rice varieties & selections

Forsøgslandbrug (223)

At least **50** varieties per TF

Verifikationslandbrug

6 to 24 varieties

Landbrugsproduktion

At least 3 varieties

Other areas of excellence of organic breeding

Present and future sources for organic breeding (Nuværende og fremtidige kilder til økologisk planteforædling)

Example 1: In the Central European Organic Outdoor Tomato Project the origin of genetic resources was investigated (Eksempel 1: I det centraleuropæiske udendørs tomatprojekt blev blev det undersøgt hvor de genetiske ressourcer stammede fra).
(Horneburg and Becker 2008a).

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Evaluation of genetic resources (Evaluering af genetiske ressourcer)

Selection from 3,500 accessions from (Selektion fra 3.500 accessioner)

1. **Seed trade (Frøvirksomheder)**
2. **Genebanks (Genbanker)**
3. **NGO (NGO)**
4. **Seed savers (Frøsamlere)**

Field trials at 3 organic farms 2003-2005 (Markforsøg på tre økologiske gårde i 2003-2005)

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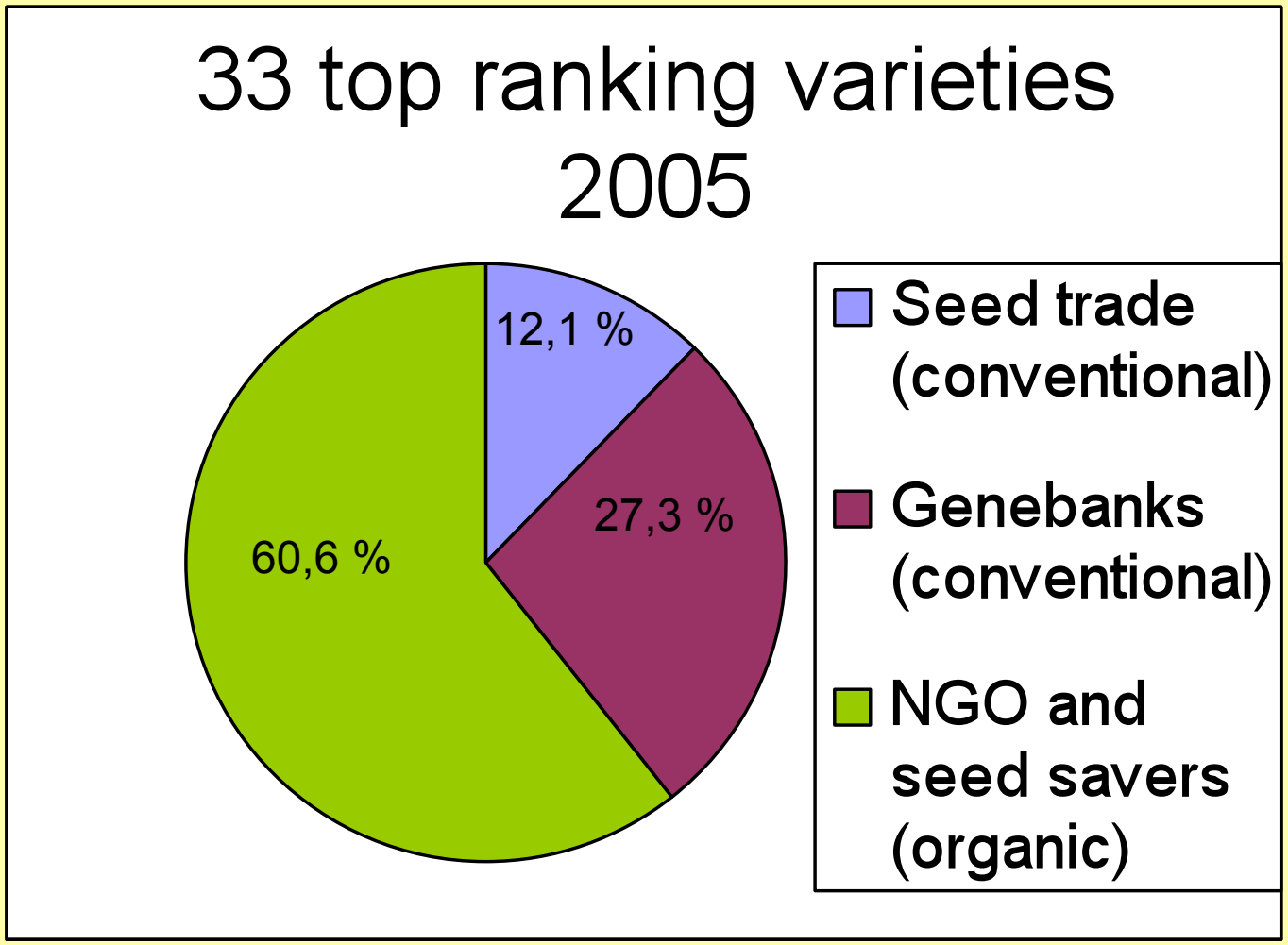
Origin of the most suitable varieties (Kilder til de mest egnede sorter)



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Other areas of excellence of organic breeding

Present and future sources for organic breeding (Eksisterende og fremtidige kilder for økologisk forædling)

Example 2: “Dehybridizing the hybrids” sweetcorn breeding in Switzerland.
Aim: An open pollinated supersweet sweetcorn variety.

Eksempel 2: ”Dehybridisering af hybrider” af sukkermajs forædling i Schweiz.
Mål: en fremmedbestøvende, meget sød sukkermajs sort.

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Andre områder der udmærker økologisk forædling

Source: Ca. 30 commercial hybrid varieties in multiple crosses and subsequent pedigree and mass selection. An additional variety had to be deleted due to contamination with GMO (personal communication F. Ebner / Sativa).

Kilde: Ca. 30 kommercielle hybridsorter i mange krydsninger efterfulgt af pedigree og masseselektion. En sort måtte udgå pga. forurening med GMO.

(Personlig kommunikation F. Ebner / Sativa).

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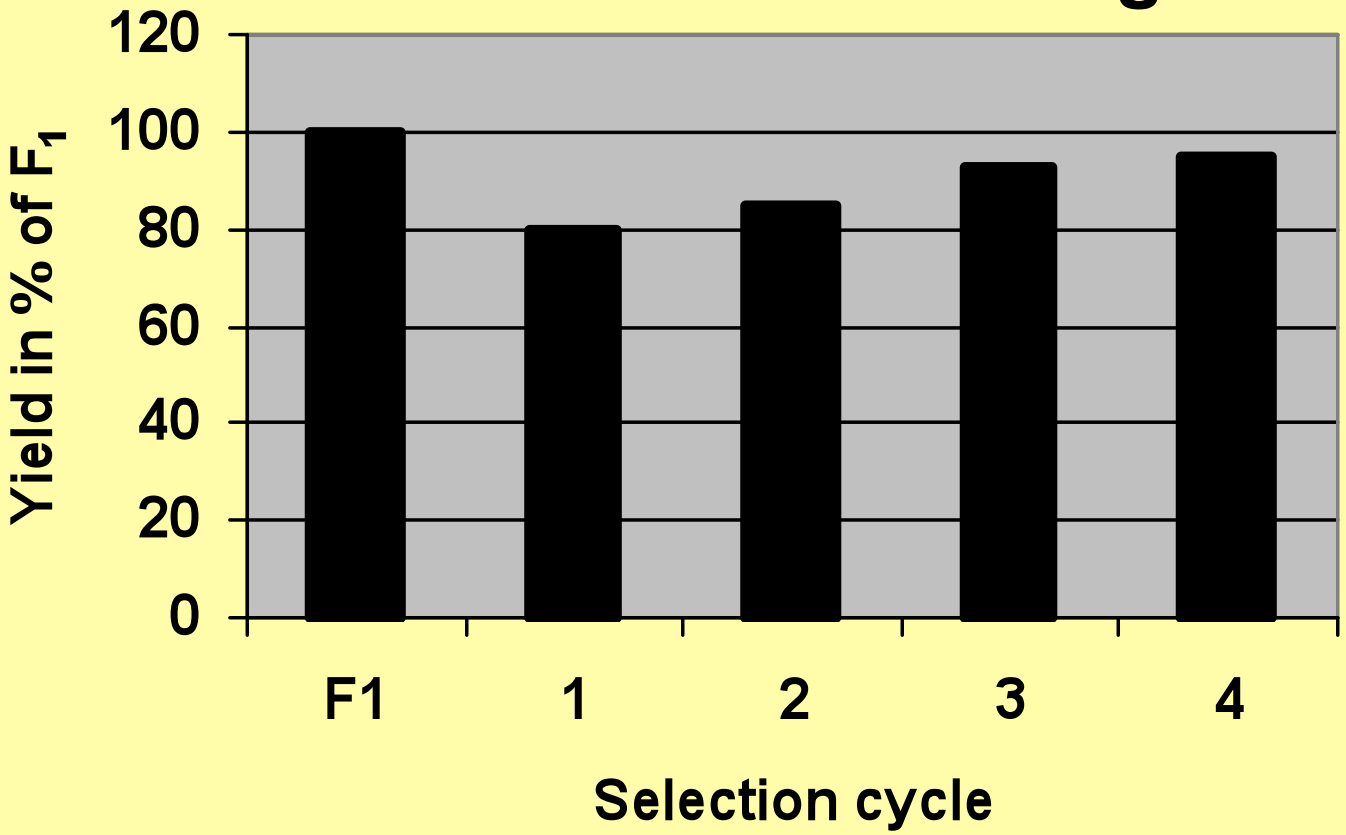
Present and future sources for organic breeding



Yield development during the selection for an open pollinated sweetcorn variety compared to the performance of hybrid varieties (F_1) (Udbytteudvikling i forløbet, hvor der selekteres for en fremmedbestøvende sukkermajs sammenlignet med F_1 hybridernes udbytter) (personal communication Sativa).

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Other areas of excellence of organic breeding

Present and future sources for organic breeding

Open pollinated varieties create an open access source for further development
(Fremmedbestøvende sorter udgør en 'open access' kilde til yderligere udvikling.

Hybrid varieties are only in exceptional cases stored in genebanks or taken into dynamic management on farm
(Hybrider er kun i enkelte tilfælde opbevaret i genbanker og anvendt i dynamisk dyrkning på landbrug).

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Other areas of excellence of organic breeding

Present and future sources for organic breeding

Patenting, non restored cytoplasmatic male sterility, gene technology incl. terminator technology, etc. further reduce the availability of future genetic resources

Patentering, CMS, genteknologi inkl. Terminatorteknologi osv. reducerer tilgængeligheden af fremtidige genetiske ressourcer.

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Outlook 1

A controversial issue is the use of hybrid varieties and special techniques involved in hybrid breeding. (Et kontroversielt emne er anvendelsen af hybridsorter og specielle teknikker, der anvendes i forædling af hybrider)

The IFOAM General Assembly 2008 at Vignola / Italy carried motion 15.3 **"to encourage the use of seeds within organic systems that are bred and maintained using open pollination and natural pollination techniques"** and

IFOAM's generalforsamling 2008 i Italien: "at fremme anvendelsen af frø, i økologiske landbrugssystemer, der er forædlet og vedligeholdt ved hjælp af fremmedbestøvning og naturlige bestøvningsteknikker" og

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Outlook 1

motion 26.1 “**that cell fusion, including protoplast and/or cytoplast fusion breeding techniques, do not comply with the principles of Organic Agriculture.** Therefore we urge the IFOAM World Board to **develop clear guidelines on how to deal with varieties derived from cell fusion** [...] (IFOAM 2008)”.

”cellefusion, inklusiv protoplast og cytoplast fusion teknikker, er ikke i overensstemmelse med de økologiske principper. Derfor anmoder vi IFOAMs bestyrelse om at udvikle klare retningslinjer for hvordan sorter, der stammer fra cellefusion, skal håndteres…”

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Outlook 2

It is an open question whether (Det er et åbent spørgsmål om)

- **breeding for organics (varieties bred in conventional agriculture tested in organics) or (forædling for økologiske systemer (sorter forædlet i konventionelt landbrug og afprøvet under økologiske forhold))**
- **breeding within organics will be the main approach of the future (forædling i økologiske systemer bliver den primære tilgang til forædling for økologisk landbrug i fremtiden).**

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Outlook 2

The first and only certification system for organic varieties was established by Demeter Germany (abdp 2011) and is in use. The breeding process becomes transparent to the public.

(Det første og eneste certificeringssystem for økologiske sorter blev etableret af Demeter Tyskland (abdp 2011) og er i brug. Forædlingsprocessen bliver gennemskuelig for offentligheden).

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Organic Plant Breeding: Achievements, Opportunities, and challenges

For the next 3 years and to the OWC 2014 I want to propose

- **sessions for the exchange between organic plant breeders, and the**
- **creation of new cooperative projects in organic breeding and breeding research.**




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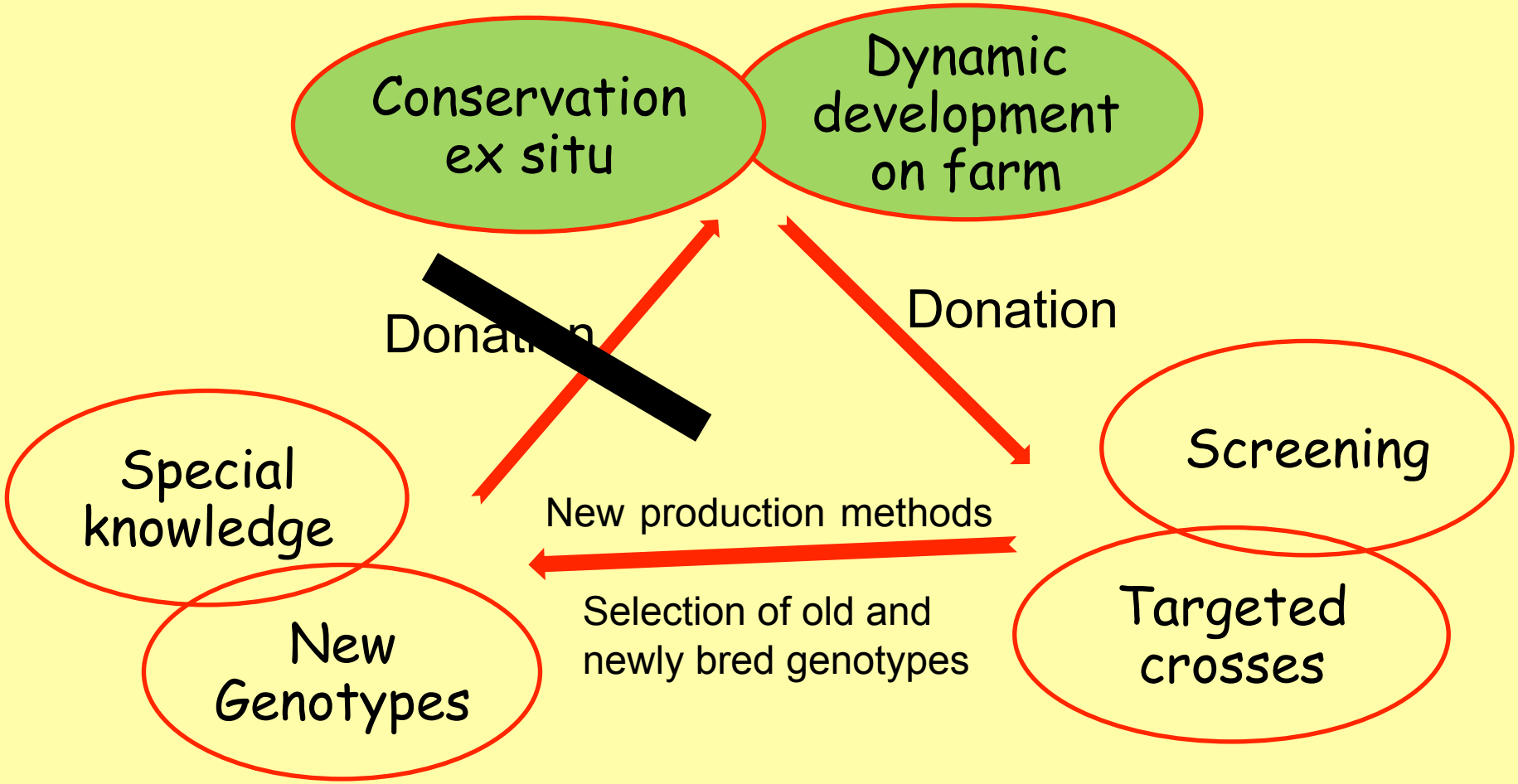

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"Once a year the Bundessortenamt passes the seed samples of varieties deleted from the national list on to the genebank. (...) This agreement covers all field crops and vegetables **except** potatoes, **hybrid varieties**, **and inbred lines**."

The genebank of the Centre for Genetic Resources, the Netherlands, does **not hold hybrid varieties**. In the Netherlands all fruit vegetables produced by the breeding companies since the early eighties are hybrids.

in crops like tomato for two to three decades the publicly available genepool has not been replenished with genotypes representing the breeding progress.

Patenting further reduces the use of important traits in the long run.

How can we assess the amount of genetic resources that has been privatized?

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Other areas of excellence of organic breeding

Food quality was the aim in a small organic breeding program with parsnip (*Pastinaca sativa* L.), a neglected root vegetable of temperate regions (Horneburg et al. 2009).

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Selection of individuals

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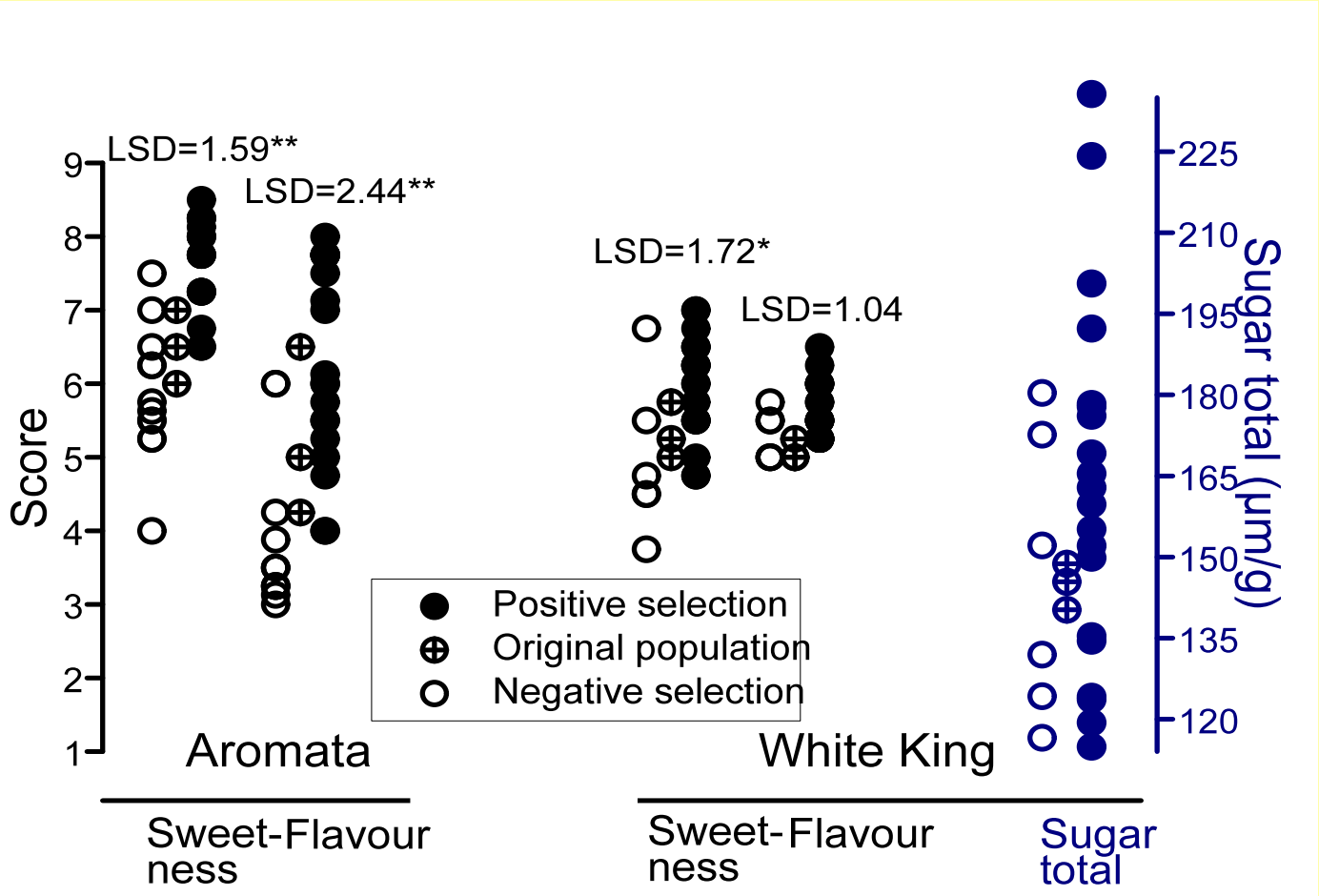

Each circle represents one progeny.
Differences between progenies * significant at p<0.05, ** significant at p<0.01
Sugar total = Glucose, fructose and sucrose

Quality improvement of parsnip by one generation of organoleptic selection (Horneburg et al. 2009, modified).

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Other areas of excellence of organic breeding

Site-specific adaptation:

A populations selected at a specific location is at this location superior in yield to populations selected at other locations.

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Site-specific adaptation

Yield (kg/ha) of five farmer selected bean populations at all five selection sites in Nicaragua (Almekinders et al. 2007, modified).
One line represents one test site. The highest yielding selection is indicated in red.

Test site		Selection site						*Mean*
	Altitude	Santa Rosa	Paso Hondo	La Lima	El Rosario	Rio Abajo	Test variety	
Santa Rosa	850 m	2005	1551	**2717**	2069	2127	1875	*2057*
Paso Hondo	630 m	969	**2522**	2134	2134	2263	1616	*1940*
La Lima	1000 m	969	839	**1948**	1098	1164	1551	*1262*
El Rosario	650 m	1035	1016	1180	**1722**	1275	1057	*1214*
Rio Abajo	600 m	2328	1616	1357	1482	**2522**	2269	*1929*
Mean		*1461*	*1509*	*1867*	*1701*	*1870*	*1674*	

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Other areas of excellence of organic breeding

Intrinsic value of plants

The organic movement values the plant as an integral being. Its integrity exists aside from the economic value of the species. Organic plant breeding respects the integrity of plants by respecting their natural reproductive ability and barriers, and their relationship with the living soil (Lammerts van Bueren et al. 2003).

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Wild tomatoes in privat gardens

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Wild tomatoes in a market garden

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Wide crosses

X

=

Wild tomato Golden Currant **Matina** **(Golden Currant x Matina) F8**

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