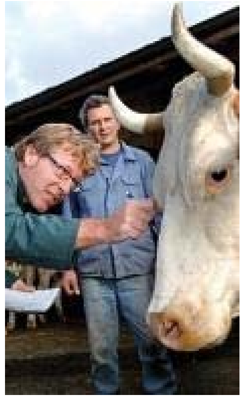
FiBL
EXCELLENCE FOR SUSTAINABILITY

Research Institute of Organic Agriculture
Forschungsinstitut für biologischen Landbau
Institut de recherche de l'agriculture biologique








Organic and Participatory Plant Breeding

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ETH Z L 751-3603-00G Plant Breeding II 20.11.2014

Outline

- **Characteristics of organic farming & special requirements**
- **Breeding strategies of FiBL**
  - Genotype x Management Interaction
  - Genotype x Microbe Interaction
  - Breeding for mixed cropping
- **Different concepts of breeding**
  - Organic plant breeding
  - Evolutionary participatory plant breeding

- **Participatory plant breeding (PPB)**
  - Concept of PPB
  - Examples from South & North
  - Challenges & Opportunities, Legal aspects
  - Participatory cotton breeding in India
- **Financing of breeding programs**

Research Institute of Organic Agriculture (FiBL)

- Founded in 1973 as private foundation
- Turnover of 20 M US$, 75% project funding
- 135 staff members plus 50 interns, B.A./Master/PhD students, apprentices
- Research on over 200 Swiss organic farms

- Dedicated to promote organic agriculture by applied science and to serve the organic farmers in all aspects of agriculture.
- Holistic approach from animal to soil science, arable crops to viniculture, politic impact and sustainability assessment with strong emphasis on stakeholder involvement

Departments of FiBL Switzerland

Soil Sciences
- Long term trials
- Soil quality & functions
- Plant Symbiosis
- Climate Impact

Crop Sciences
- Crop Production Systems
- Plant Breeding & Variety Testing
- Crop Protection
- Functional Agrobiodiversity
- Agroecology
- Input Assessment

Livestock Sciences
- Livestock Breeding
- Animal Welfare & Husbandry
- Animal Nutrition
- Animal Health
- Parasitology & Laboratory
- Aquaculture

Socio-Economic Sc.
- Agricultural Politics
- Consumer Research
- Food Quality
- Innovation in Agriculture
- Rural Sociology
- Sustainability Assessment
- Technology Assessment

Departments of FiBL Switzerland

Extension, Training & Communication

- Farmer Trainings & Workshops
- On farm Trials
- Dissemination
- Agricultural weekly journal
- Public relation

International Cooperation

- Agriculture in the Tropics
- Agroforestry Systems
- Market Development
- Policy & Sector Development

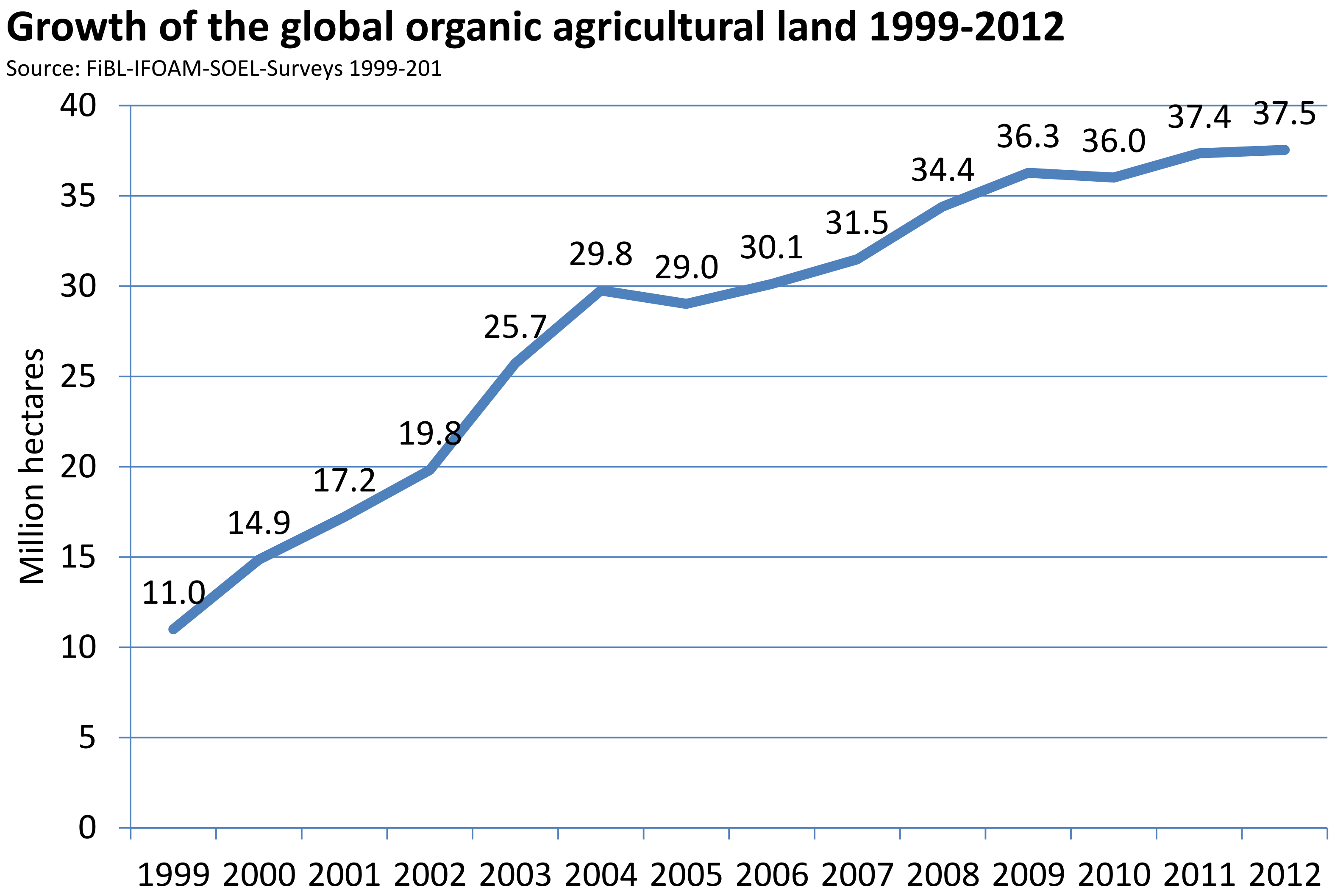
FiBL Offices:

- Kiev (Ukraine)
- Sikasso (Mali)

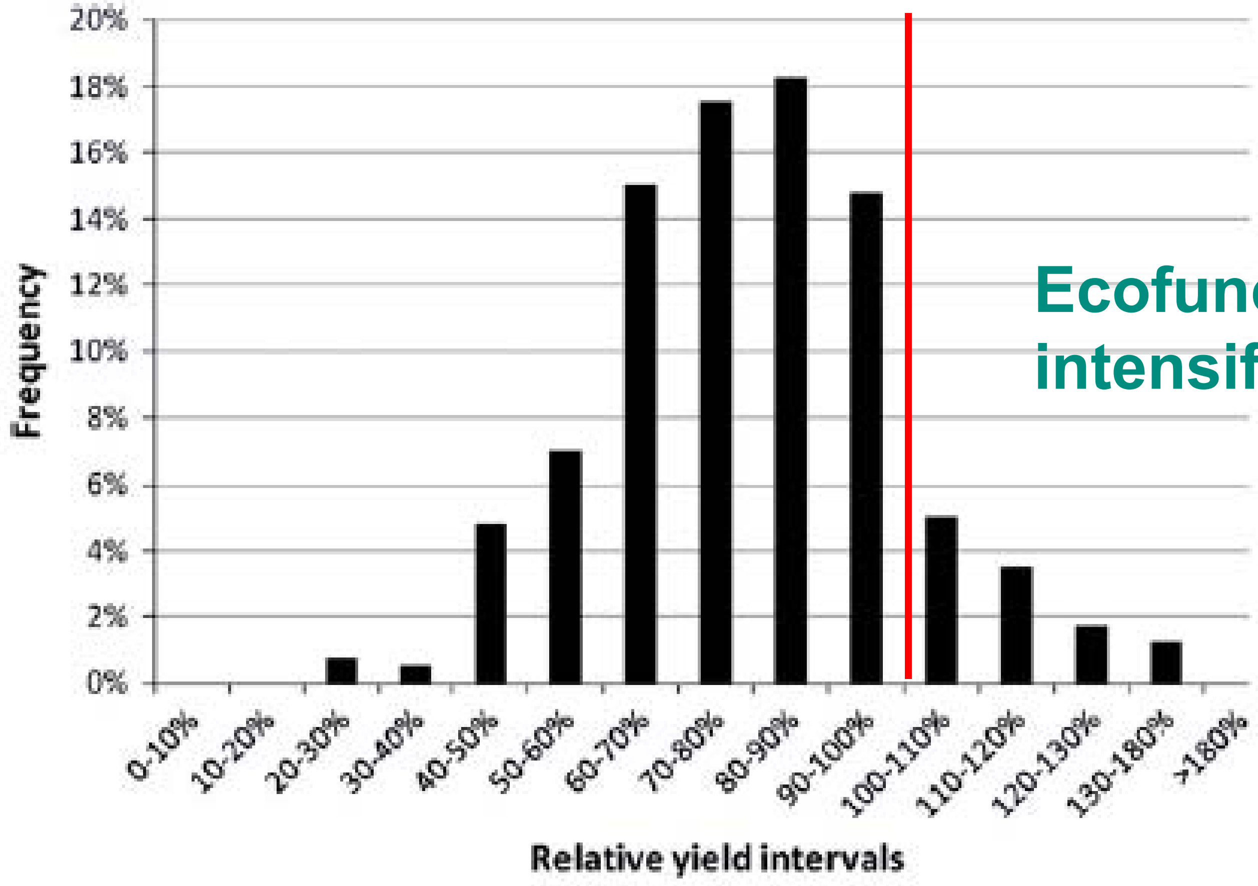
- Establishment of FiBL Germany, FiBL Austria as independent entities
- Establishment of organic Research Institute IBLA in Luxemburg, Bioinstitute in Czeck Republic, ÖMKI in Hungary and ICOA in India

On-farm research with 200 - 300 farmers

Growth of the organic farmland 1999-2012



Meta-analyis about relative yields of organic compared to conventionals systems (n=362)

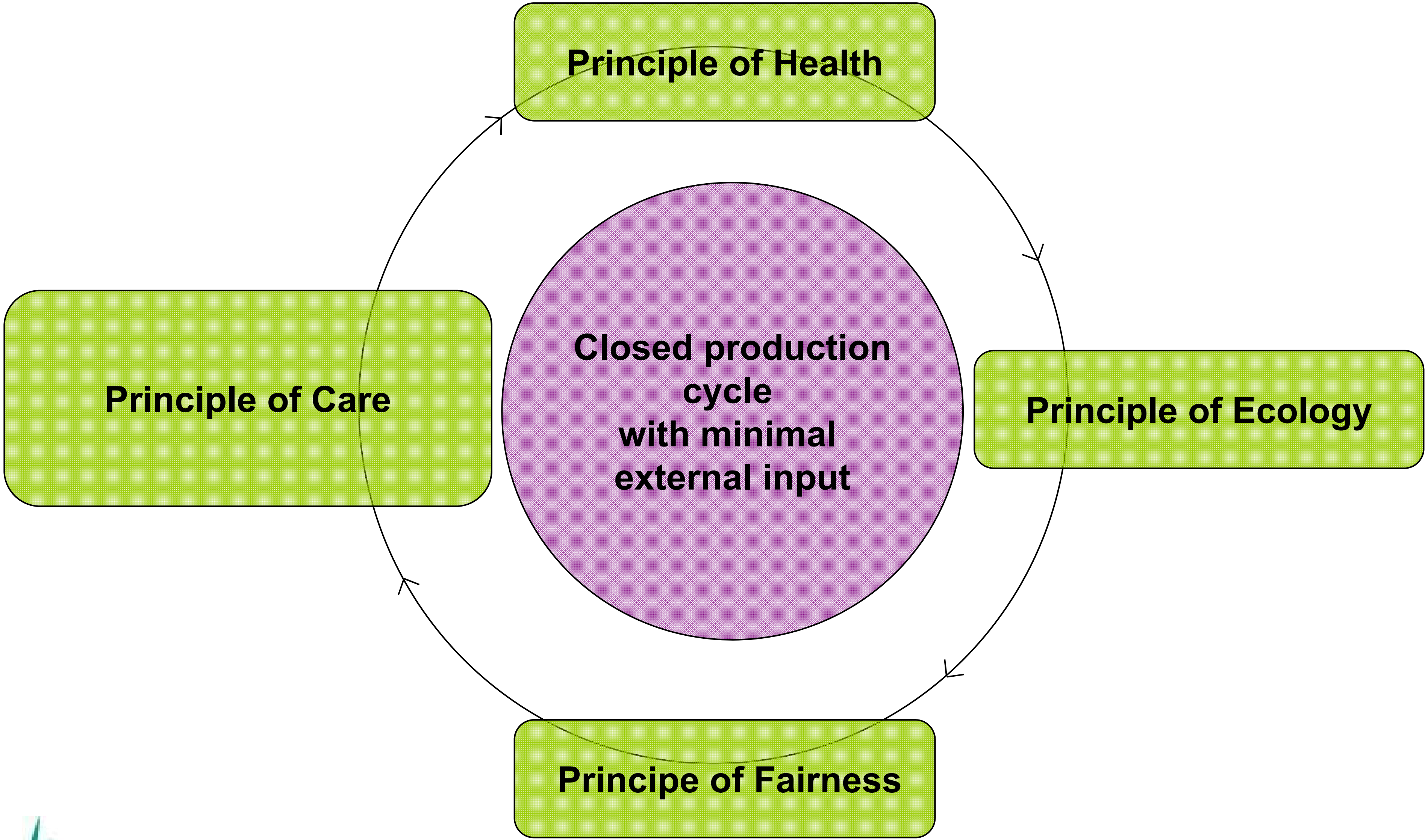


Ecofunctional intensification

Fig. 1. Frequency of occurrence of relative yields of organic vs. conventional agriculture, grouped in 10% intervals.

De Ponti et al. 2011, Agricultural Systems

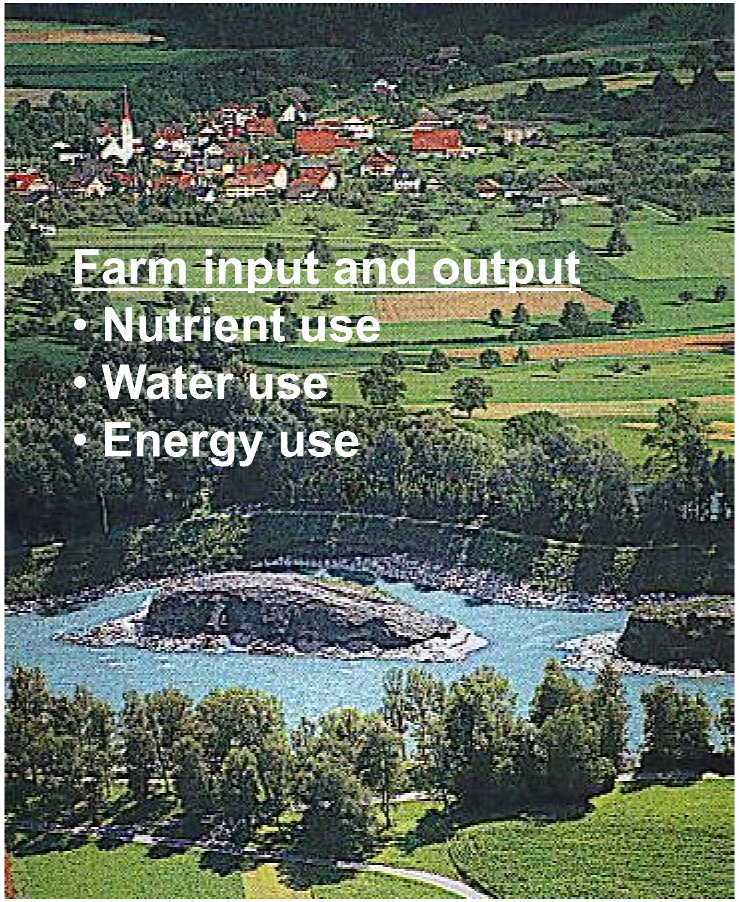
IFOAM Organic AgricultureFarming Principles



Environmental indicators for agriculture

Biodiversity and Landscape
- Floral diversity
- Faunal diversity
- Habitat diversity
- Landscape

Soil
- Soil organic matter
- Biological activity
- Soil Structure
- Soil erosion



Climate and air
- CO2
- N2O
- CH4
- NH3
- Pesticides

Ground and surface water
- Nitrate leaching
- Pesticides

Based on OECD-list 1997, Dabbert et al., 2000

Ecological performance of OF (400 studies)

Indicator	++	+	0	-	--
• Ecosystem		x			
• Soil		x			
• Ground & surface water		x			
• Climate & air			x		
• Farm input & output		x			
• Animal welfare & health			x		
• Food quality		x			

Legend: Organic farming performs:
++ much better, + better, 0 the same, - worse, -- much worse than conventional farming

x **Subjective confidence interval of the final assessment marked with x**

Source: Stolze *et al.* 2000

Special needs for organic farming

- **Organic farming (OF) is characterized by**
  - Closed production cycles with minimum external input
  - Diversity of animal and plant species on farm level
  - Special attention to soil fertility as basis for sustainable production
  - Efficient self-regulating system
- **Compared to conventional farming (CF)**
  - Weed control by optimized **crop rotation**, **mechanical treatments** and **competitive varieties** instead of herbizides
  - Pest and insect control by supporting **predators/parasitoids/symbionts** and **resistant varieties** instead of pestizides
  - Nutrition of plants by **animal or green manure** instead of fast releasing mineral fertilizer

Requirements for organic farming

- Varieties adapted to organic farms, which produce **high and stable** yields with a **high quality** even under low-external input conditions
- Special requirements to the species:
  - Fast youth development
  - Nutrient efficiency (slow releasing fertilizer)
  - Capability of weed suppression or tolerant against weeds/weeding
  - Resistant towards seed born diseases
  - Utilization of symbioses with soil organisms
- Possibility of farm saved seeds
- Genetic diversity
- Prohibition of GMO (incl. cell fusion)
- Preservation and free access to GMO free genetic resources

Specific requirements for organic farming

Refrainging from seed treatments:

- **Attack of the seedlings with seed- and soil borne fungi** (Tilletia, Fusarium, Stagonospora,..) → **resistant cultivars**, healthy seeds
- **Crow damage** → deeper sowing, **higher TKW**

Refraining from herbicides:

- **Weed pressure**→ competition advantage by **fast juvenile development, root growth**, shading by **tillers, leave biomass or plant height, tolerance** towards weeds or resistant towards thin weeder

Refraining fungicide, insecticides, etc.:

- **Pest and Diseases**→ **resistant/tolerant cultivars**, especially **quantitative inherited resistance**, utilizing morphological protecting mechanisms(plant height, ear morphology wax layer, …)

Specific requirements for organic farming

Refraining from growth regulators

- **Risk of lodging** → lodging and sprouting resistant cultivars

Refraining from fast- soluble mineral fertilizers:

- **Slow release of nutrients from farm yard manure do not always cover the needs of plants→ nutrient efficient cultivars** with a high and stable yield under limited fertilizer levels and temporarily occurring fertilizer deficit (clear-sighted planning of crop rotation and of organic fertilizers),

  → **good distinctive root system**

  → **symbioses with soil microorganism** (mycorrhiza, Plant growth promoting rhizobacteria,..)

Specific requirements for organic farming

Refraining from additives and artificial flavours:

- **Breeding of varieties with high content of essential amino acids** (corn, field bean, lupine), essential fatty acids (flax), low antinutritious substances (partly against herbivores!!!!), high content of secondary health relevant Ingredients (flavonoids, phenol, ….)

- **Breeding of varieties with high optical and sensory quality** (high-priced segment)

- **Breeding towards high storage capability:** high content of antioxidants

Specific requirements for organic farming

Intercropping:

- **Breeding of varieties optimized for intercropping (**Rheintaler-Ribbelmais & Schwefelbohne, pea & barley)

Legume plants (biological N fixation, protein rich food):

- Decrease of grain legumes in Europe of 50% in the last 10 years because of low economical value, fewer breeding programs, less cost efficient than corn and wheat → **breeding of different legume species** (long cultivation phases) and other small crops

Heterogeneity of organic farming:

- **High diversity in farm management: differences in number of animals, crop rotation, site, access to market → broad choice locally adapted plants with high tolerance against biotic and abiotic stress** (nutrient-,water deficit, heat)

Specific requirements for organic farming

Excluding genetic engineering and cell fusion:

- **Limited choice of cultivars** especially severe for broccoli and cauliflower→ parallel **GMO-free breeding efforts** to compete with breeding success of conventional breeders (e.g. open pollinated varieties instead of CMS hybrids)

  →breeding for **quantitative inherited insect resistance** (instead of Bt-Corn)

FiBL Plant Breeding Strategy

- **Science based breeding research**
  - Information about new breeding techniques
  - Combine participatory breeding with marker assisted selection
  - Develop efficient screening methods for plant breeding for improved symbiosis

- **Fast implementation of new cultivars**
  - Independent cultivar testing under organic and low input growing conditions under farmers' condition (on farm testing)
  - Development of marketing strategies for improved cultivars (FP7 HealthyMinorCereals)
  - Cultivar recommendations combined with management guideline

FiBL Plant Breeding Strategy

- **Focus on traits that have not been addressed in plant breeding so far**
  - Improved nutrient use efficiency and plant health by breeding for improved Plant – Microbe Symbioses
  - Breeding for mixed cropping (Plant – Plant Interaction)
  - Utilizing Genotype x Management Interaction (low input, organic)
  - Seed born diseases, weed competition

- **Focus on crops where availability or choice of cultivars is limited for organic farmers**
  - GM free plant breeding programs (soybean, cotton, brassica)
  - Neglected local crops and legumes (biological N fixation)
  - Demand of farmers for improved varieties (rape seed, potato)

FiBL Plant Breeding Strategy

- **Networking & Transdisciplinary Research to start and enforce local seed and breeding activities**
  - Involvement of all stakeholders and politcal lobbying
  - Capacity building of smallholders to improve their seed supply
  - Training in seed multiplication, seed processing, seed testing and storage
  - Development of local seed chain and cultivar testing
  - Establishment of decentralized participatory breeding activities with smallholders (including farmers, breeders, researchers, processors and retailers)

→ **seed sovereignty, local seed production**

→ **increase diversity on field, farm, landscale level as well as on stakeholder level**

Genotype x management interaction

- **Projects**
  - **Importance of selection environment for breeding gain in maize (comparison of direct and indirect selection for organic farming) (publication in preparation)**
  - Assessment of nutrient use efficiency of different wheat varieties under organic and conventional farming systems (COST 860, NUE-CROPS)
  - Establishment of HPTLC for the quantification of amino acids of different wheat varieties cultivated in distinct farming systems as well as Proteomic analysis (Detmold)
  - Genotype x management interactions of maize cultivars under reduced and conventional tillage and organic and synthetic fertilization

Importance of appropriate selection environments for breeding maize adapted to organic farming systems

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Breeding goals of maize:

Conventional farming

- **DM yield**
- Resistance against green snapping
- Resistance against early lodging
- Disease resistance
- Nutrient use efficiency
- Water use efficiency
- Insect resistance
- Cold tolerance
- Early vigor

Do we need special breeding programs for organic farming?

Organic farming

- **DM yield**
- Resistance against green snapping
- Resistance against early lodging
- Disease resistance
- **Nutrient use efficiency**
- Water use efficiency
- **Insect resistance**
- Cold tolerance
- **Early vigor**
- **Weed competition / tolerance**
- **Seed health and vigor**

Objectives:

- **Compare performance of segregating maize populations under Organic (OF) and Conventional (CF) Farming systems**
- **Determine quantitative genetic paremeters decisive for selection response under OF *versus* CF** (Heritability, genetic correlation, indirect selection gain)
- **Determine breeding strategy to maximize selection gain of maize breeding for OF**

Plant material:

- **Four different material groups:**
  - **151:** **Testcrosses of Flint lines x dent tester**
  - **152:** **Testcrosses of Flint lines x dent tester**
  - **153:** **Testcrosses of Dent lines x flint tester**
  - **154:** **Testcrosses of Dent lines x flint tester**

  90 TC each + 10 standard hybrid varieties

  All lines were derived from F1 crosses of early maturing European elite breeding material of KWS AG by in vivo haploid induction and preselected for their line *per se* performance

Field design:

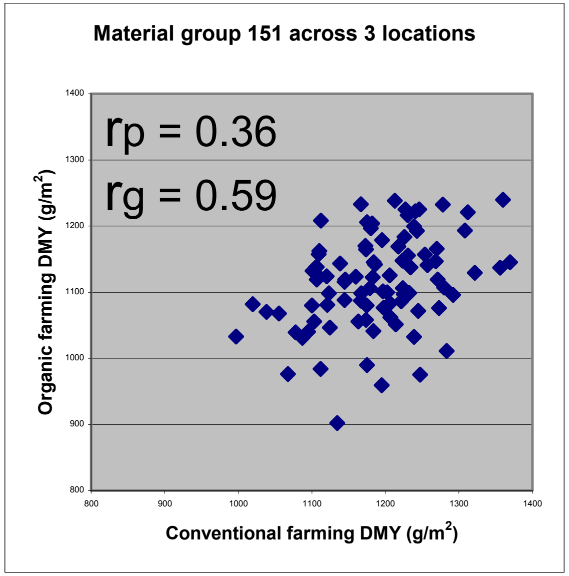
- **Field trials were performed in 2008 in three geographic regions of Germany on an organic and conventional farm closeby**
  - Einbeck (EIN)
  - Stuttgart Hohenheim (HOH)
  - Kaufering (KAUF)
- **lattice design (10 x 10) with 2 replications**

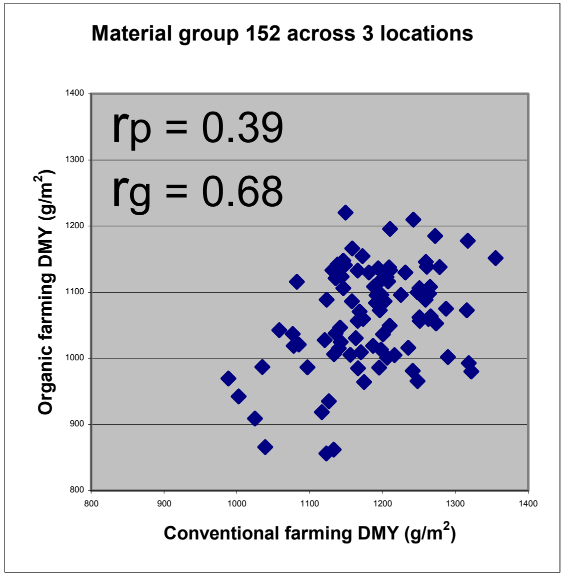
Field trials:

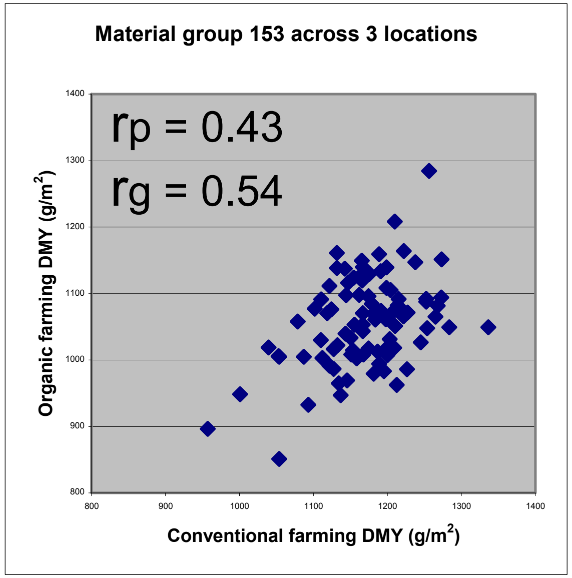
Conventional farming CF

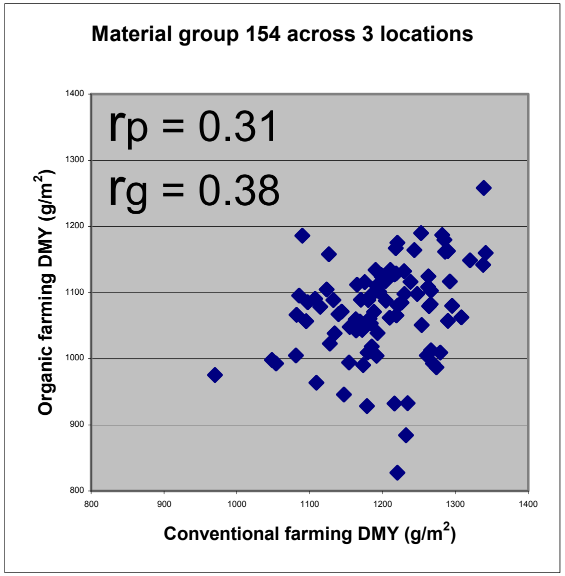
Organic farming OF

Testcross DMY under OF versus CF:









Results of the four material sets averaged across the 3 regions:

Traits	DMY (g m²)	DMY (g m²)	DMC (%)	DMC (%)	DMY (g m²)	DMC (%)
Material	**OF**	**CF**	**OF**	**CF**	**Gen. corr.**	**Gen. corr.**
Heritability	h^2	h^2	h^2	h^2	r_g	r_g
151 Flint x D	49%	54%	95%	95%	0.56	0.96
152 Flint x D	54%	68%	90%	92%	0.68	0.94
153 Dent x F	72%	75%	92%	91%	0.54	0.97
154 Dent x F	67%	78%	92%	93%	0.38	0.94

Selection gain & Effectiveness of indirect selection:

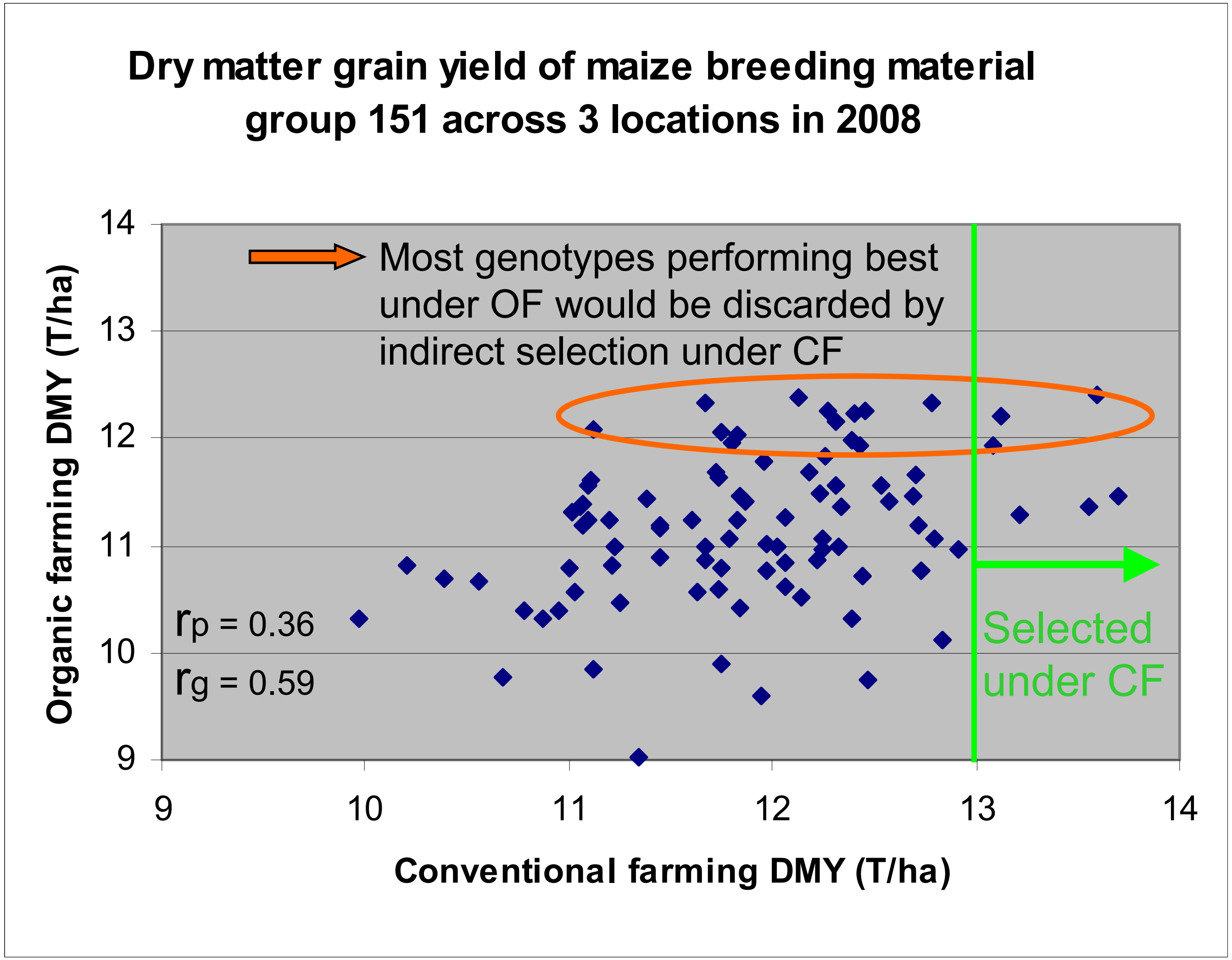
i =	Selection intensity
h =	square root of heritability
r_g =	Genetic correlation
σ_g =	Square root of genetic variance

- **Direct selection gain under OF:**
  - $R_{OF} = i_{OF} \times h_{OF} \times \sigma_{g\ OF}$
- **Indirect selection gain under CF to improve performance in OF:**
  - $CR_{OF} = i_{CF} \times h_{CF} \times r_{g\ (OF:CF)} \times \sigma_{g\ OF}$
- **Efficiency of indirect selection under CF versus direct selection to improve performance in OF (Falconer & Mackay 1996) assuming same intensity:**
  - $CR_{OF}/R_{OF} = (h_{CF} / h_{OF}) \times r_{g\ (OF:CF)}$

Effectiveness of indirect selection under CF for performance under OF:

Traits	DMY (g m^2)	DMC (%)
Efficiency	CR_{OF} / R_{OF}	CR_{OF} / R_{OF}
151 Flint x D	59%	96%
152 Flint x D	76%	95%
153 Dent x F	55%	97%
154 Dent x F	41%	95%

Lost opportunities of indirect selection



Conclusions:

- To realize the maximum selection gain for quantitative traits with medium heritability selection needs to be done under OF as the limiting environmental factors are different for both systems
  - Grain yield in OF depends also on weed competition, limited N-supply, insect attack and other parameters that can be controlled under CF

- Highly heritable traits can be preselected under CF
  - Dry matter content, flowering time, plant height, oligogenic inherited resistance traits

Plant genotype x microbe interaction

Projects

- Winter wheat varieties x mycorrhiza under different farming systems in DOK long term trial (COST 860)
- Maize varieties x mycorrhiza colonization rate and mycorrhiza species composition under different tillage and fertilization management (NUE-Crops, ETHZ)
- Maize varieties derived from landraces and elite lines inoculated with mycorrhiza (KWS, NUE-Crops)
- **Improved nitrogen fixation and protein content of soybean by cold adapted Bradyrhizobia, Mycorrhiza and PGPR (BLE-Soybean, Mahle, ISCB, BioSuisse)**
  - Soybean varieties x Bradyrhizobia strains under different temperture regimes
  - Soybean x Bradyrhizobia x Mycorrhiza (ISCB)
- Selection of improved Cowpea x Bradyrhizobia strains under different growing conditions in Kenya

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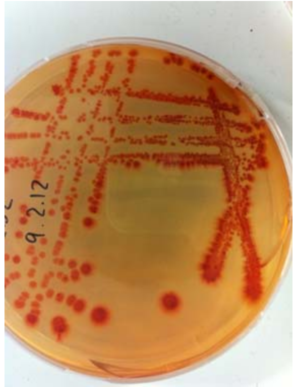


Breeding for improved N fixation by optimizing Soybean x *Bradyrhizobium* Interaction

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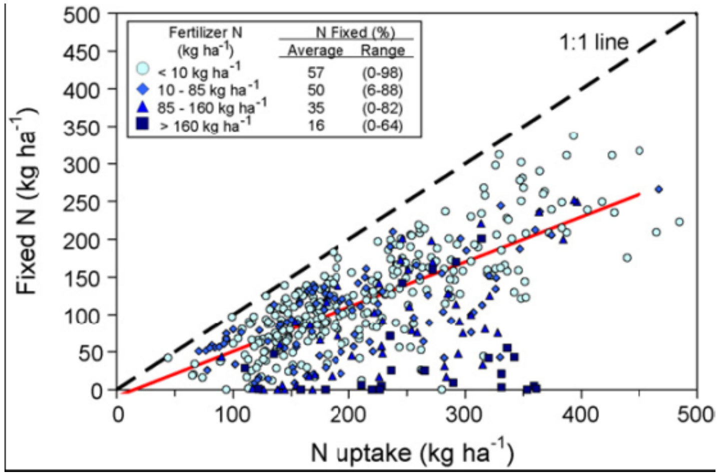
Selection for improved Nitrogen fixation by optimizing interaction of early soybean enotypes, bradyrhizobia strains and soil conditions

Breeding for better symbiosis (Regel, 2002):

- Root exudates of soybean
- Nos Gene of Bradyrhizobia (Nod-Factor)
- Nod-factor Rezeptor of soybean inducing inodulation etc.
- Synergistic effekte mit Mycorrhiza fungi and PGPR
- **Soil temperature**
- Soil parameter: pH, P, Ca, Al, Mn content
- Mobility of Bradyrhizobia



Salvagioti et al. 2008

Biological N fixation ranges from 0 – 337 kg pro ha und Jahr (Salvagioti et al. 2008)

Why breeding for improved symbiosis?

- **Background:** Soybean is not yet adapted to cool climatic conditions of Germany and Switzerland. Natural symbiontic N fixing soil bacteria are missing. Therefore inoculation is neccessary. Most commercially available inocula have been developed for USA and are limited to few strains
- **Hypothesis:**

  In order to have a very efficient biological nitrogen fixation we do not only need cold tolerant soybean genotypes but also cold tolerant Bradyrhizobia strains
- **Research Question:**

  Can the biological nitrogen fixation be improved by selecting for adjusted symbionts?

  Should different soybean genotypes be inoculated with different strains?

Soybean breeding for cool growing conditions

funded by BLE 2011-2013

Establishment of test system:

- Inoculation of different soybean varieties with differnt bradyrhizobia strains at different temperature regime
- Harvest after 6 weeks cultivation at 14/12° or 22/18° C

Variety: Gallec , inoculum: Force 48 (Strain G49) substrat: soil Buus & quarz sand (1:1 v/v%) autoclaved

14/12° C

22/18° C

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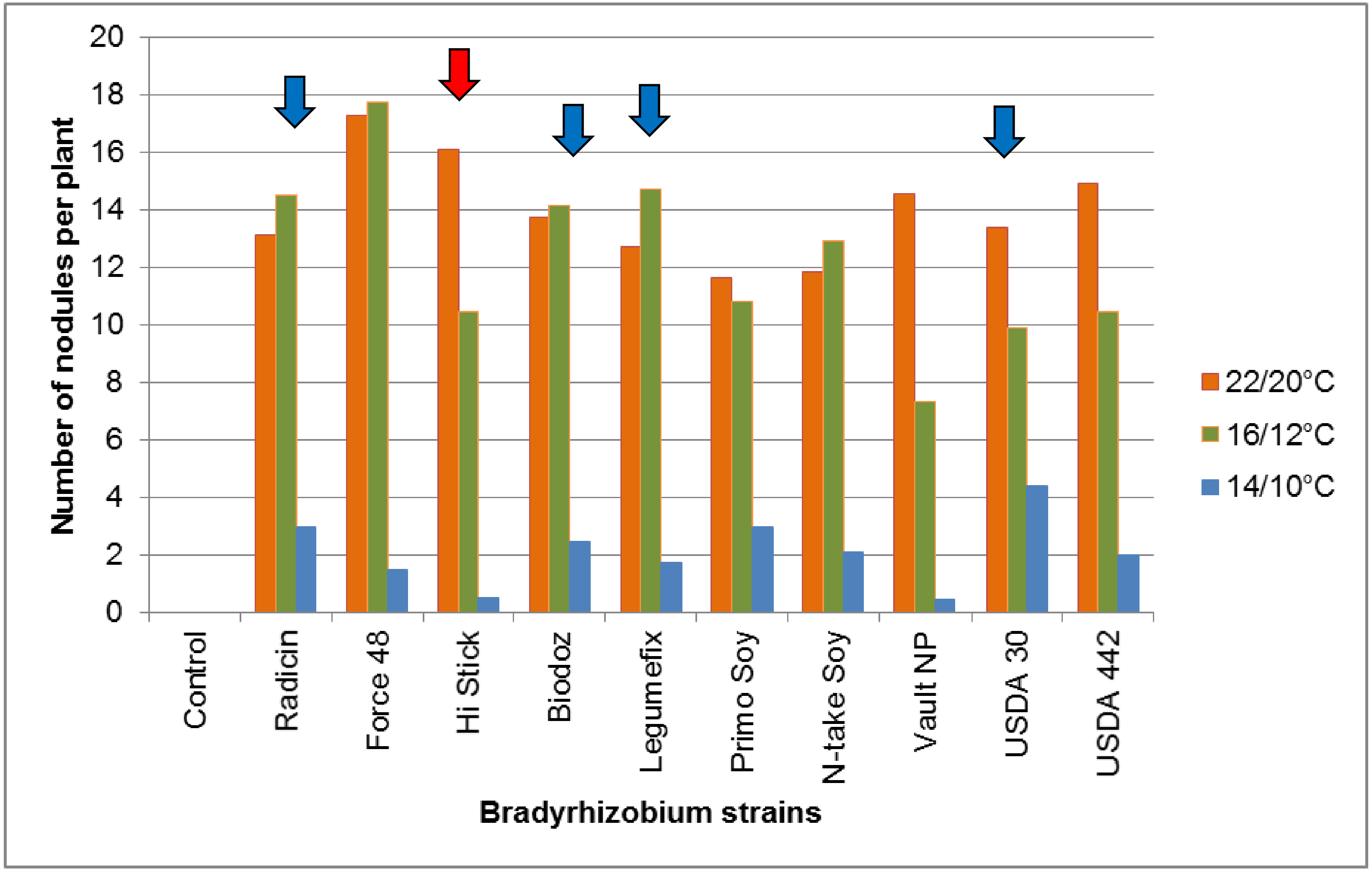
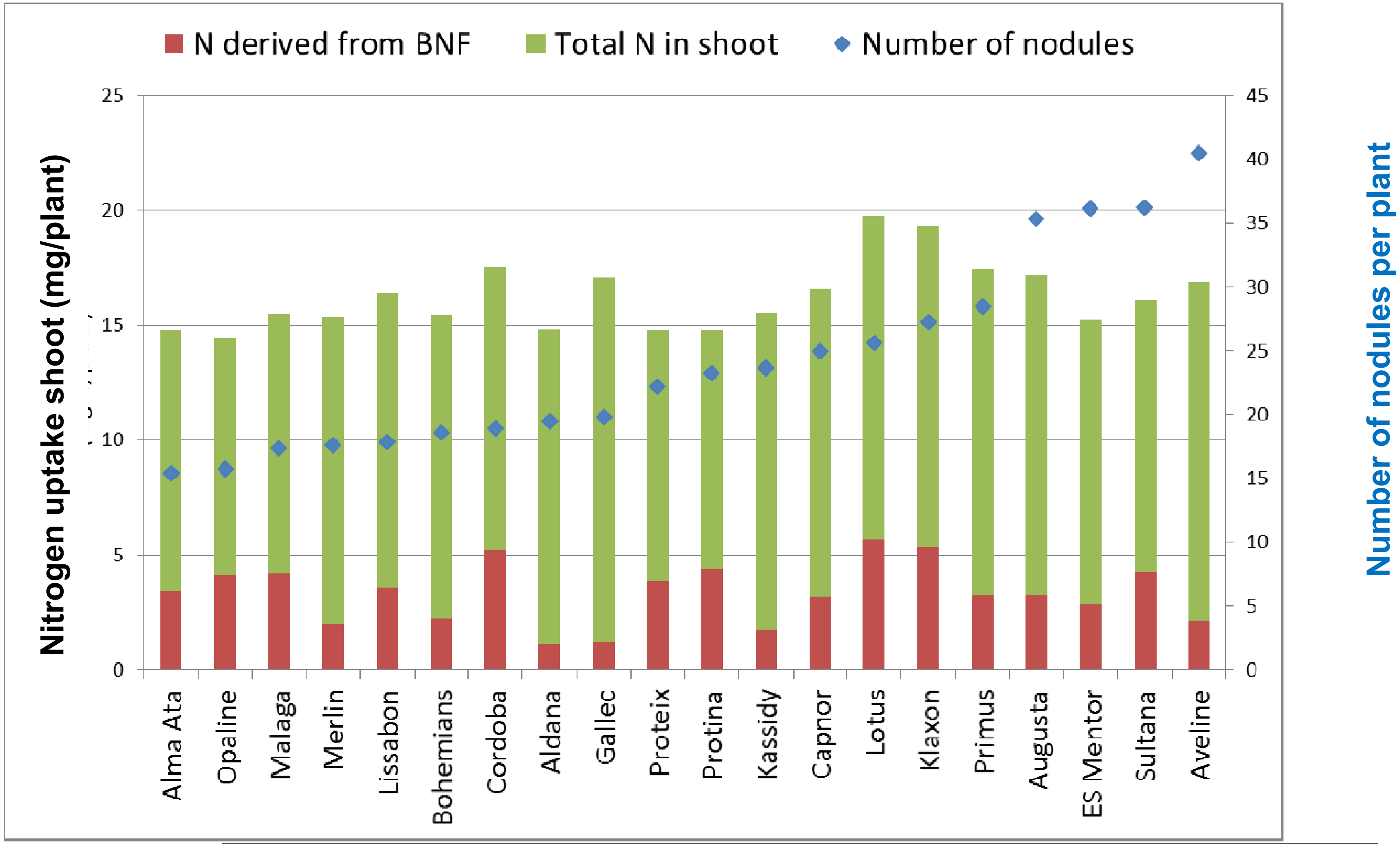
Number of nodules per plant at different temperature

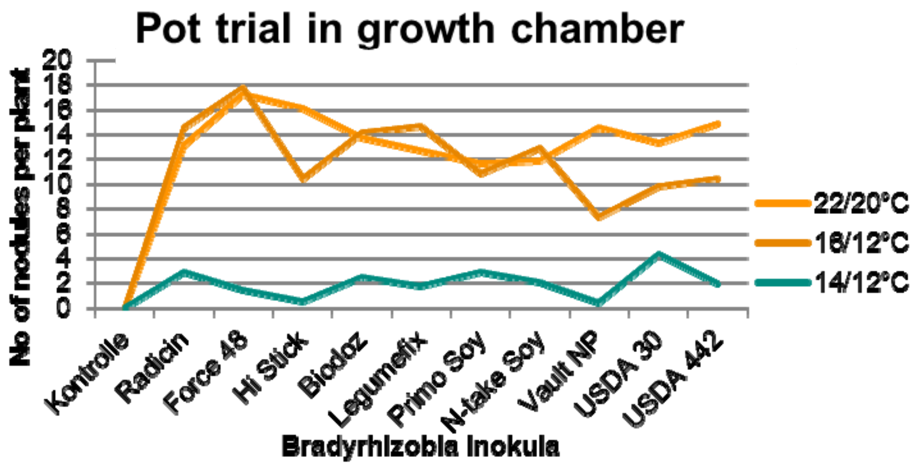


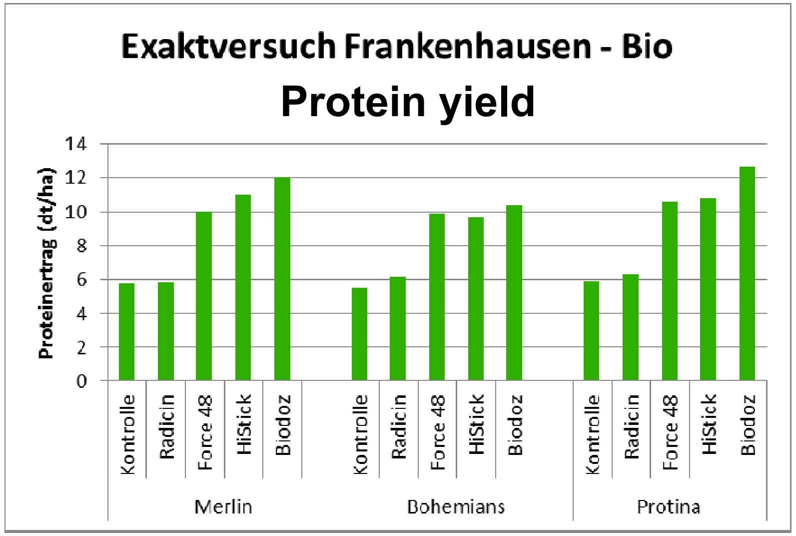
N uptake of 6 week old shoots across inocula

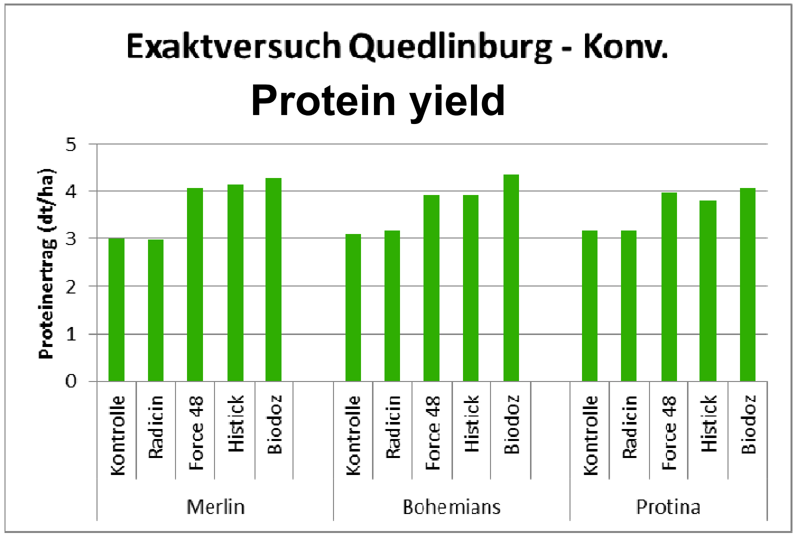


$$\%Ndfa = \frac{\delta^{15}N \text{ of reference plant} - \delta^{15}N \text{ of } N_2\text{-fixing legume}}{\delta^{15}N \text{ of reference plant} - \delta^{15}N \text{ of } N_2} \times \frac{100}{1}$$

Pot trial and verification in field trials





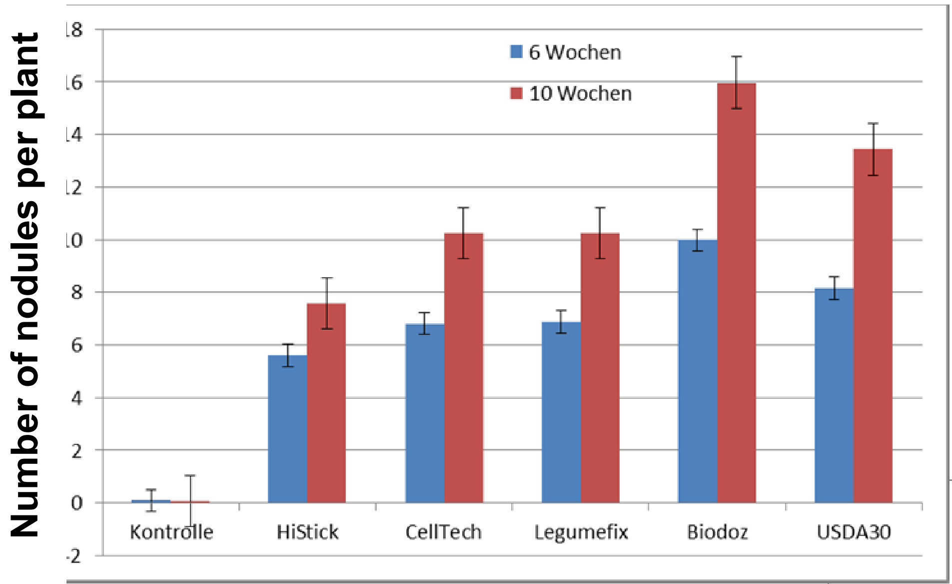


Tab. 1: Results of ANOVA of Field trial in Frankenhausen organic farm in 2011 and 2012

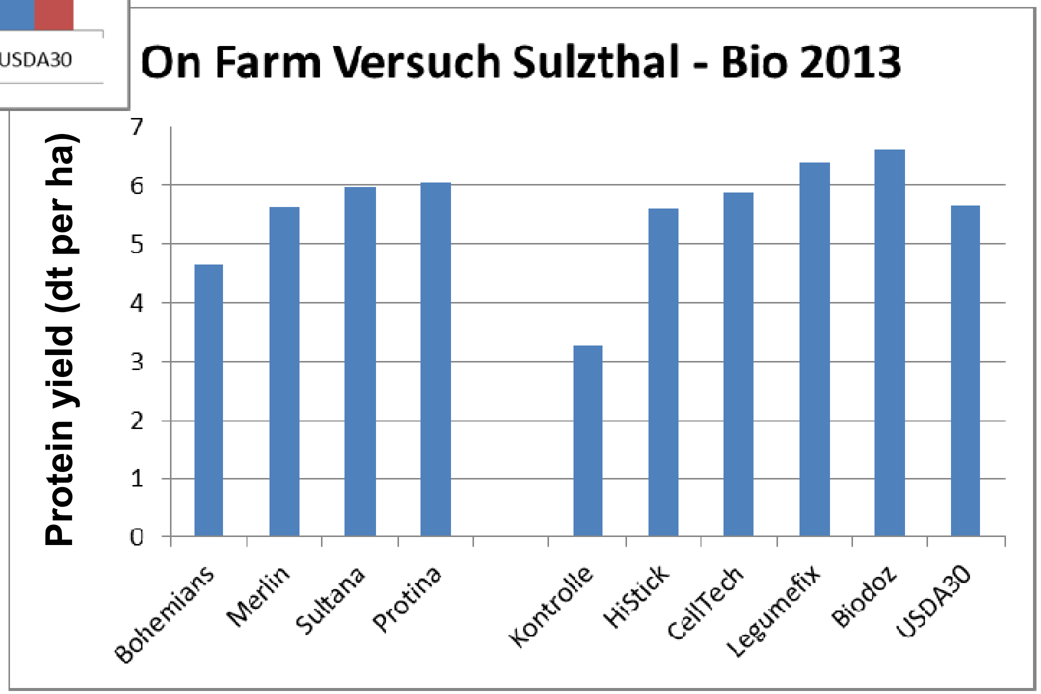
	Inoc.	Cult.	Year	I* C	I*Y	C*Y	I*C*Y
Nodulation 1 (nodules per plant)	***	n.s.	n.s.	n.s.	***	**	n.s.
Nodulation 2 (nodules per plant)	***	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Grain yield (dt/ha at 86% TS)	***	***	*	**	n.s.	n.s.	n.s.
Protein content (%)	***	***	***	***	n.s.	***	n.s.
Protein yield (dt/ha)	***	***	***	***	*	**	n.s.

I: inoculant; C: cultivar of soybean, Y: year;
***: P< 0,001; **: 0,001≤P<0,01; *: 0,01≤0,05; n.s.: not significant

Effect of Soybean variety and Bradyrhizobia strain on Nodulation and Protein yield in Sulzthal under organic conditions in 2013



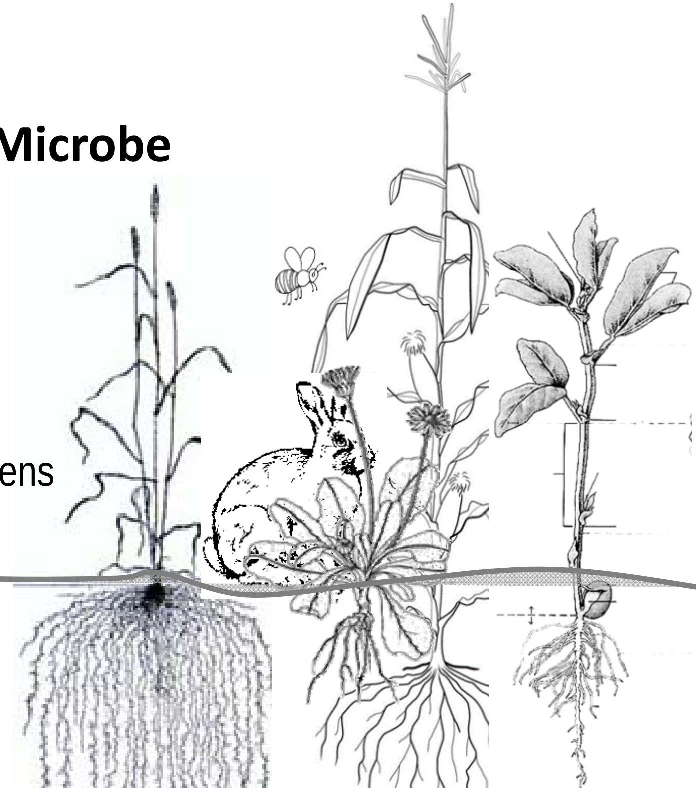
We found significant Soybean x Bradyrhizobia interaction for protein content in 2 of 3 sites



Summary

- Bradyrhizobia strains can be selected for cold tolerance
- Certain strains are especially beneficial with certain soybean genotypes resulting in higher protein content but interactions are of less importance for yield
- High number of nodulation is an important but not sufficient trait increase BNF.
- Radicin which performed well under controlled conditions in mesocosm trials failed totally in field trials (wrong formulation?)
- Losses in protein yield can be up to 50% due to insufficient symbiosis (inefficient products, wrong handling)
- The interaction of Bradyrhizobia strains with mycorrhiza strain in mesocosms trail was highly complex and also temperature dependent. Much more research is needed to understand these complex interactions to utilize synergistic effects of other PGPRs and AMF under cool growing conditions.

Breeding for mixed cropping systems



Plant – Plant Interaction

- Competition for light, water, nutrients
- Protection for light, wind, transpiration
- Soil protection and erostion prevention
- Support of beneficial insects
- Storage of water and nutrients
- Access to water and nutrients in deeper horizon
- Host of pathogens
- Allelopathic effects
- Push, Pulleffekt (Desmodia, Napiergras)
- Biofumigation, Biosanitation

Plant – Fauna – Microbe Interaction

- Herbivors
- Pests, Pathogens
- Predators
- Pollinators
- Transmiters of pathogens

Plant – soil microbe Interaction

- N fixation by symbiotic and free living bacteria
- Improved accesss to water and nutrients by mycorrhiza
- Mineralisiation of organic fertilizer
- Root exudation (carbohydrates, signalling effects, attraction, repellents)
- Plant growth promoting rhizobacteria (PGPR)
- Pathogenes & counterparts

Screening of lupin varieties intercropped with oat in 2014

Identification of optimal croping partners complementing each other for

- Nutrient demand
- Weed competition / suppression
- Nutrient acquisition
- Pest and disease suppression
- Stress resistance (risk reduction)
- Protein and carbohydrates

but similar for

- Maturity time

Arncken, C.A., FiBL, 2014

Different strategies for variety development

- **Conventional breeding:** **Status quo**
  - Selection with application of seed treatments, herbicides, optimal nutrient supply
  - Breeding goals and variety development for conventional / IP farming
  - Test registered varieties under organic farming (organic variety trials)
- **Breeding for organic farming** **Product oriented**
  - Considering of the breeding goals of the organic agriculture
  - No GMO (no cell fusion)
  - Selection partly under organic farming conditions
  - Last multiplication step under organic farming conditions
- **Organic plant breeding:** **Process oriented**
  - Breeding specifically /exclusively for organic agriculture
  - Every selection step under organic conditions
  - Breeding technics in harmony with the organic farming
  - Multiplication steps under organic conditions

Aims of Organic Plant Breeding

- **Sustainable use of genetic resources**
- **Dynamic equilibrium** of the whole agro-ecosystem
- Food security & nutritional quality
- Food sovereignty
- Secure supply of plant products
- Serve welfare of society
- **Improve Agro-biodiversity**
- Adaptation to climate change
- Breeding goals match demand of complete market chain incl. customers' needs

Criteria for Organic Plant Breeding

Ethical issues

- **Genom** is respected as indivisible entity, no technical/physical intervention (e.g. isolated DNA)
- **Cell** is respected as indivisible **functional entity**, no technical/physical intervention (e.g. cell fusion)
- Maintain **reproducibility** in species specific manner
- No legal or technical barriers to restrict **breeders' right**
- Natural **crossing barriers**
- Promotion of open pollinated varieties as alternative to F1 hybrids

Criteria for Organic Plant Breeding

Breeding criteria

- **Selection takes place under organic farming** to benefit from plant – environment interaction
- Phenotypic selection can be supplemented by other methods (e.g. Marker assisted selection)
- Exclusion of GMO progenies

Socio-economic criteria

- **Exchange** of genetic material is encouraged & patenting of living organisms is prohibited
- **Disclosure** of breeding material and techniques used
- Promotion of **participatory** breeding involving all stakeholders
- Plurality of breeding programs

IFOAM Norms on organic plant breeding

- Selection under organic conditions
- Refraining from genetic engineering
- Disclosure of breeding techniques
- genome as well as cell is respected as an impartible entity
- natural reproductive ability
- No patents on seeds

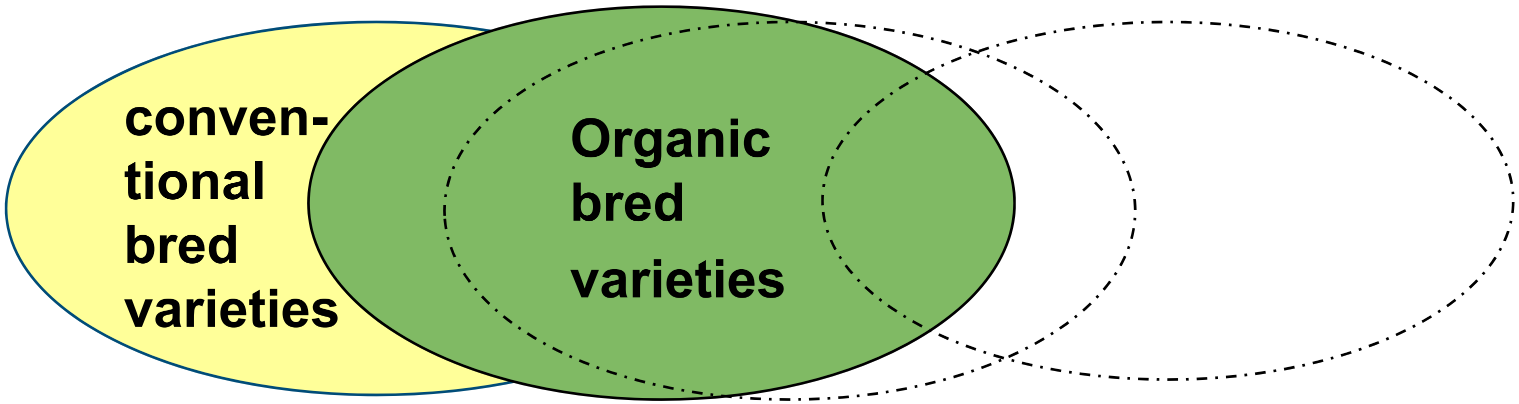
Bioverita

Label for products derived from organic plant breeding across organic label organization **www.bioverita.ch**

Conventional versus organic varieties

The degree of overlap between conventional and organic suited varieties depends on:

- Breeding goals, Selection environment
- applied breeding techniques



Consequent organic from Seed to Fork

Plant Breeding	Variety testing	Seed propagation
Conventional breeding	Conventional	Conventional untreated
conventional breeding	conventional	**organic**
conventional breeding	**organic**	**organic**
organic plant breeding bioverita	**organic**	**organic**

Guidelines for organic plant production

Bio Suisse 17.4.2013

- **Organic plant breeding defined according to IFOAM**
  - All steps performed under certified organic conditions
  - No technical intervention below cell level
  - Respects natural crossing barriers
  - Promotes fertility and natural reproduction of plants
  - Transparency of breeding methods
  - Refrains from patents on living organisms
- **From 1.1.2014 on cultivars used for the production of Knospe products are preferably from organic plant breeding programs**
- If it can be shown that no cultivar in sufficient quality and quantity is available, other cultivars may be used. Bio Suisse is responsible for the monitoring and derogation
  - This includes cultivars according to national seed legislation and UPOV regulation as well as population varieties, niche varieties, land races and farmer's selections

Organic Cereal breeding Peter Kunz

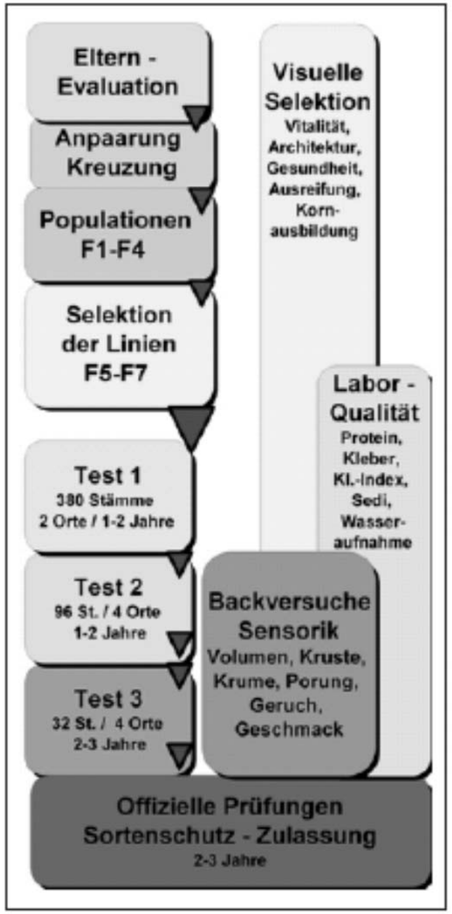


Abbildung 1: Die Sortenentwicklung von der Elternwahl bis zur zugelassenen Sorte dauert 12 - 15 Jahre. In den ersten Jahren ist die visuelle Selektion entscheidend

Breeding goals:

- Baking quality
- Yield Stability
- Weed suppression
- Resistance towards thin weeder
- Length of tiller
- stability
- Harmonic ripening
- Leaf rust, septoria tolerance
- Tilletia resistance
- Sensoric quality

30 years

Getreidezüchtung
für biologische Landwirtschaft

All breeding steps under organic dynamic cultivation conditions

www.gz.peter-kunz.ch

Organic Plant Breeding cont.

- **Cereals:**
  - **Dottenfolder Hof** www.dottenfelderhof.de
  - **Getreidezüchtungsforschung Darzau** www.darzau.de
  - **Keyserlingk-Institut** www.saatgut-forschung.de
- **Legumes:**
  - **Getreidezüchtung Peter Kunz** www.gz.peter-kunz.ch
  - **Bäuerliche Züchtung e.G.**
- **Vegetables:**
  - **Sativa Rheinau AG,** www.sativa-rheinau.ch
  - **Kultursaat e.V.** www.kultursaat.org
  - **Saat:gut e.V.** www.saat-gut.org
- **Apples:**
  - **PomaCulta e.V.** www.pomaculta.org
  - **Saat:gut e.V**. www.saat-gut.org

More infos to organic plant breeding in German

- **Studie zur Beurteilung von Züchtungstechniken**
  - Vortrag und Protokoll des Expertenworkshops
  - Grundlagenpapier zur ökologischen Pflanzenzüchtung
  - Dossier zur Beschreibung und Beurteilung von Züchtungsmethoden

  Auf FiBL homepage www.fibl.org unter News (Oktober 2011):

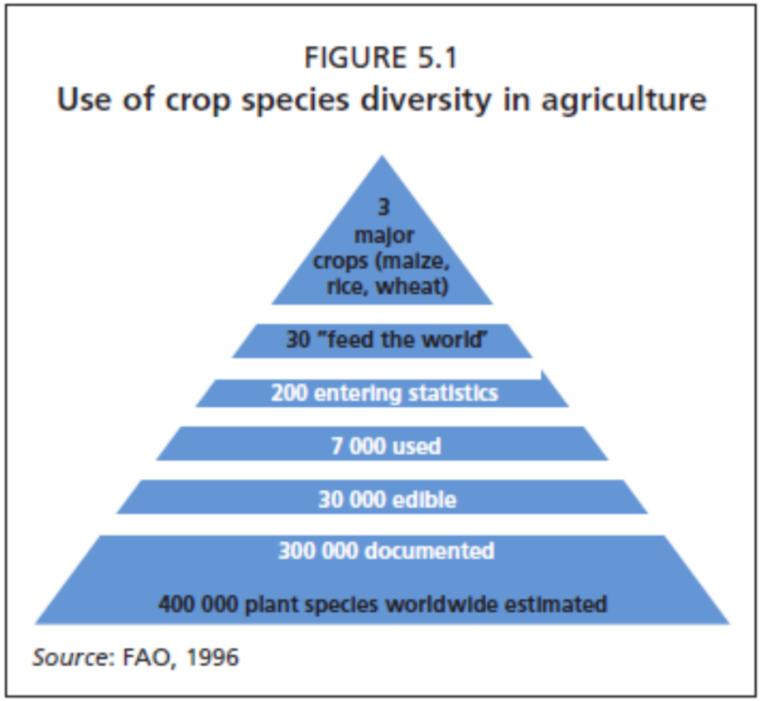
  http://www.fibl.org/de/service/nachrichtenarchiv/meldung/article/chancen-und-potenziale-verschiedener-zuechtungsmethoden-fuer-den-oekolandbau.html

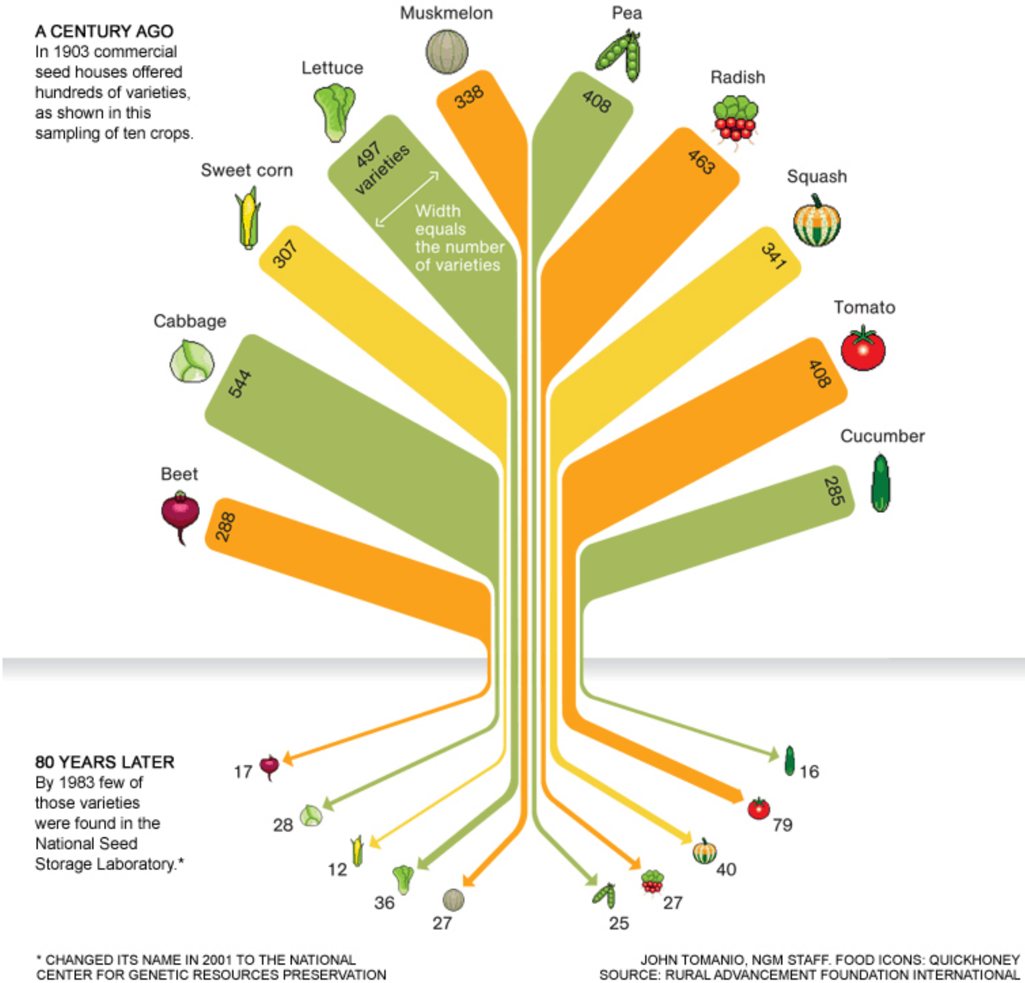
- **Broschüre über Ökologisch-partizipative Pflanzenzüchtung** (K.-P. Wilbois, FiBL shop)

- **Neuauflage des FiBL Dossiers «Züchtungstechniken der Pflanzenzüchtung»** mit Co-Finanzierung der Stiftung Mercator Schweiz und der Mahle Stiftung Deutschland (FiBL shop)
  - Will be translated in English

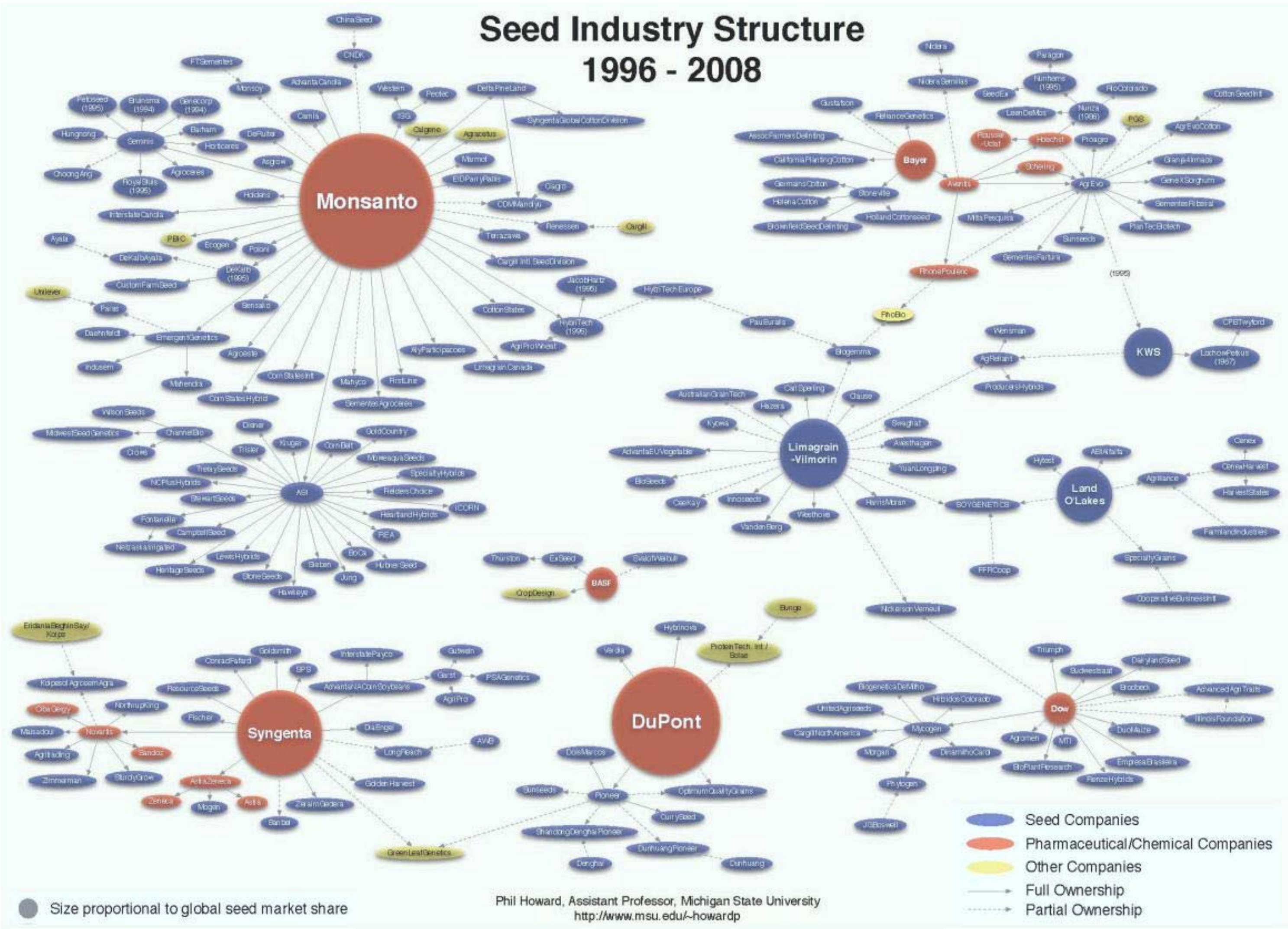
Why we need new concepts of Plant Breeding?

Reduced number of crops & varieties per crop



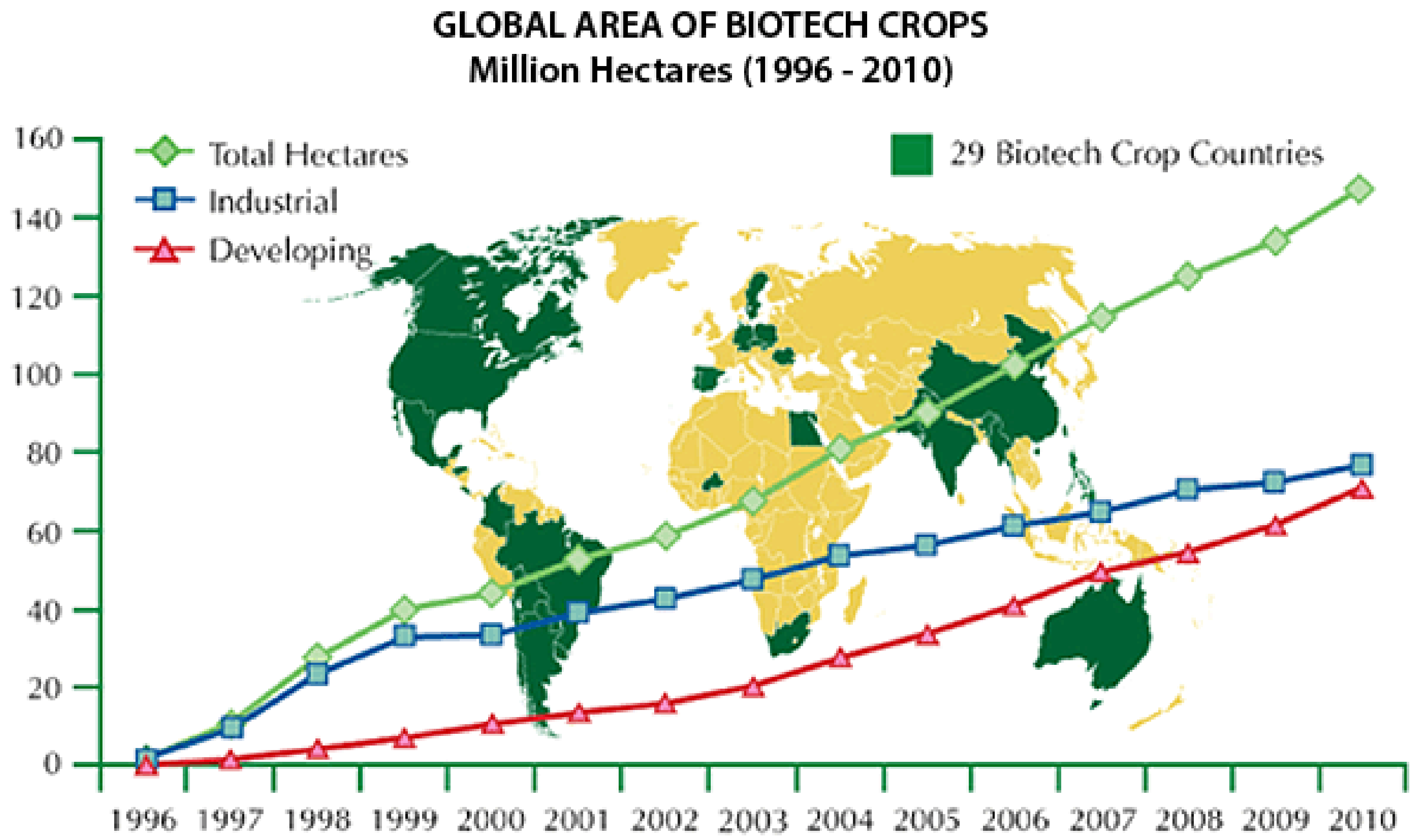


Concentration on global seed market



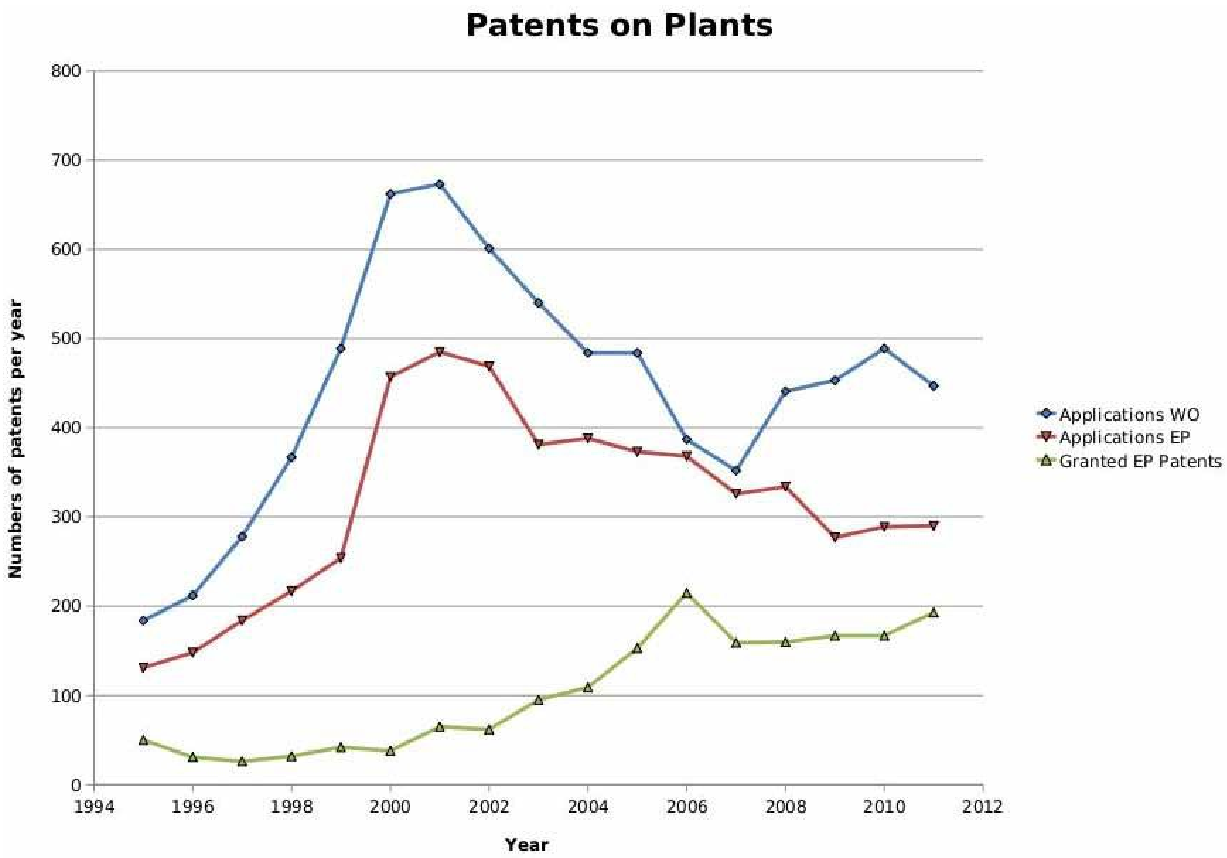
Howard, 2009, Visualizing Consolidation in the Global Seed Industry: 1996–2008 Sustainability

Increase of GM varieties



Source: James Clive 2011, ISAAA

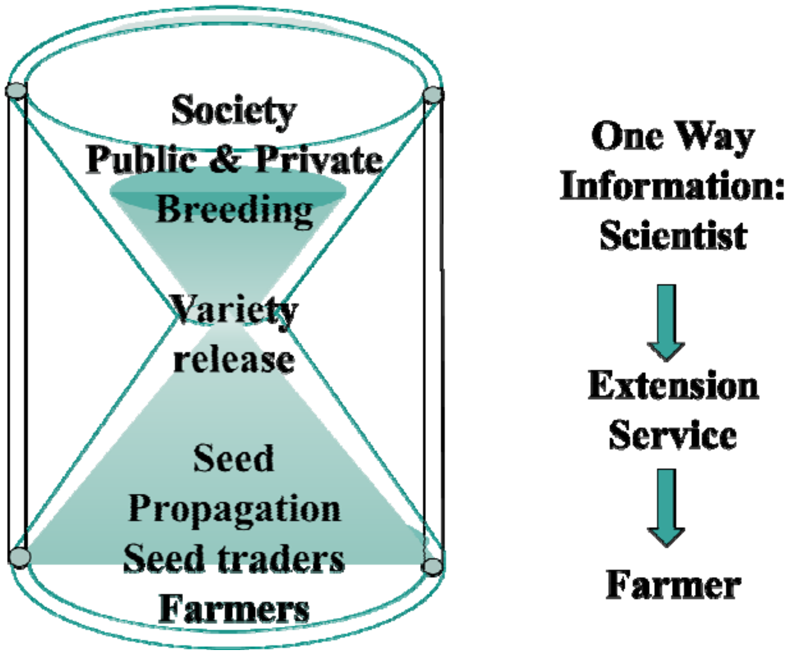
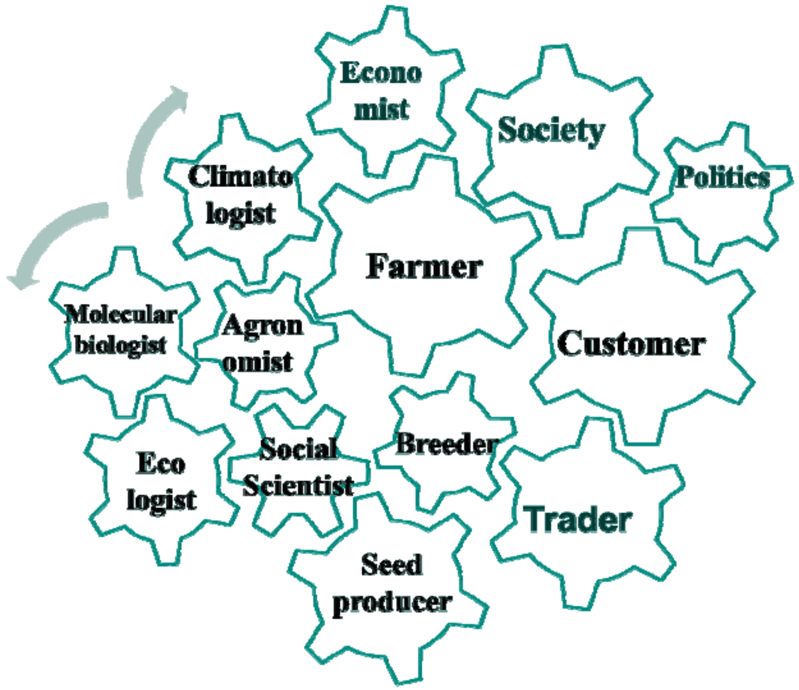
Restriction of breeders excemption by IP Rights



Overview of patent applications on plants under PCT/WIPO (WO) and at the EPO as well as of patents granted by the EPO. Research according to official classifications (IPC A01H or C12N001582). Christoph Then & Ruth Tippe March 2012
www.no-patents-on-seeds.org

Who will control the *Green Economy?* www.etcgroup.org

Participatory Cultivar Evaluation and Participatory Breeding as a viable Alternative to Seed Monopoly

Formal plant breeding and seed supply	Participatory plant breeding and seed multiplication
	

Different concepts of plant breeding

- Evolutionary plant breeding
- Participatory plant breeding
- Participative-evolutionary plant breeding

Evolutionary plant breeding
Genetically heterogenic varieties

Composite cross (Wolfe, Elm Farm, UK)

- **Instead of breeding homogeneous varieties, as many elite varieties as possible are crossed and planted at different sites and multiplied under natural selection pressure**

→ ideal adaptation of varieties to local site demands

→ varieties can handle stress more easily because of high heterogeneity

→ reduced risk of breakdown of monogenic inherited resistances

Example: Composite crosses of winter wheat

Phillips and Wolfe 2006 Evolutionary plant breeding for low input systems

Participative-evolutionary breeding of wheat USA

Breeding for organic and low-input farming systems

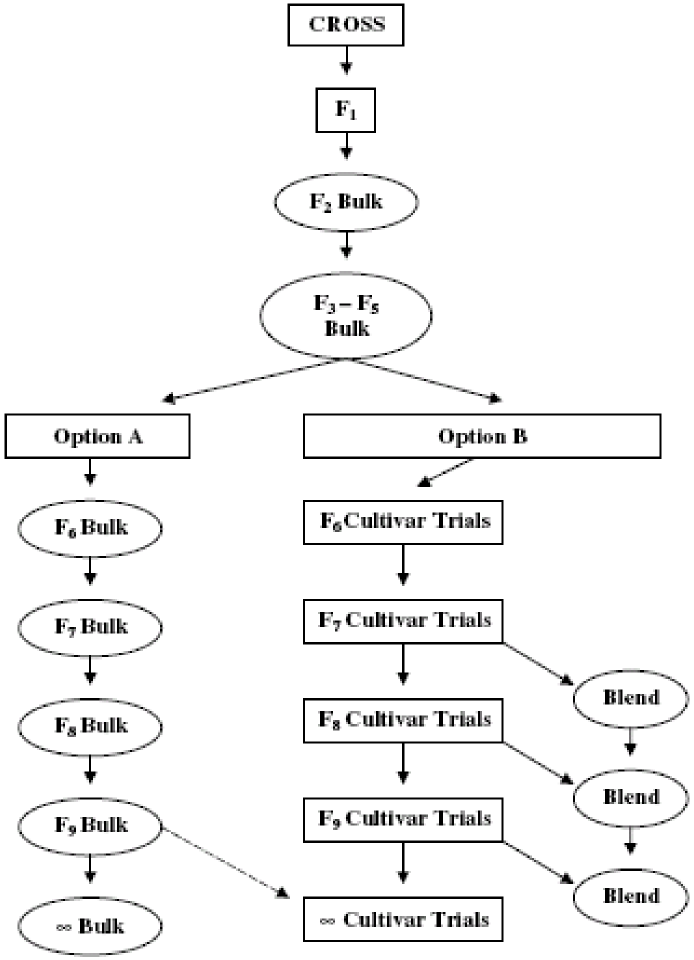


Figure 1. An evolutionary participatory breeding method.

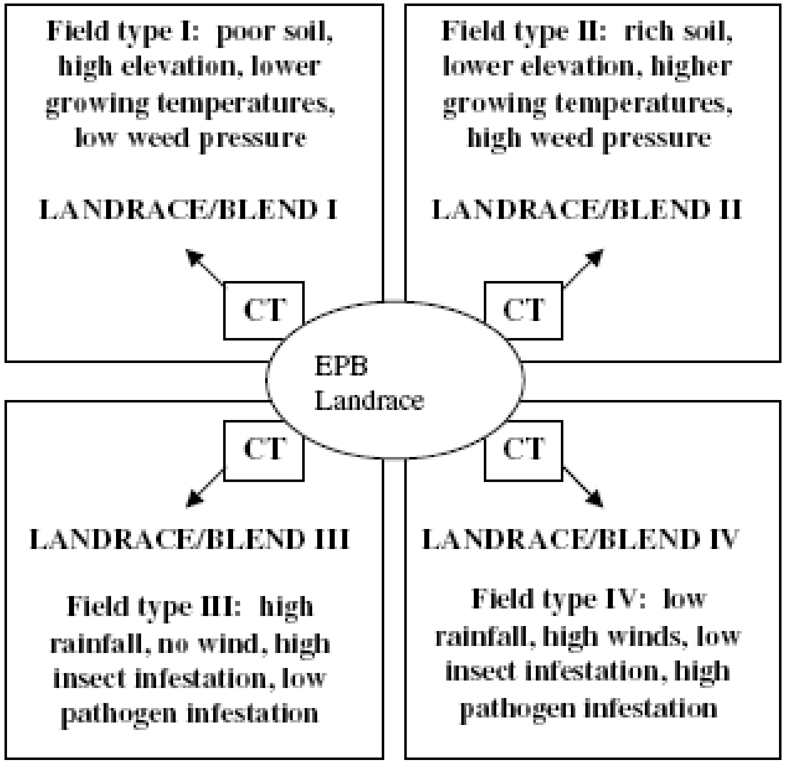


Figure 2. Farmer field overview. Stratified bulk selection. EPB landrace and cultivar trials (CT) are a part of the farming system, receiving the same agricultural and environmental selection pressures as the cultivated crop.

Quelle: Murphy et al. 2005: Breeding for organic and low input farming systems: An evolutionary- participatory breeding method for inbred cereal grains

System breeding as alternative model proposed by Edith Lammerts van Bueren

- On-farm Research
- Participatory Research
- Multi stakeholder networking
- Open Source
- Action Research

→ **Restoring/renewing lost relationships among partners in the community!**

System breeding as alternative model proposed by Edith Lammerts van Bueren

- **Farmer-based breeding**

- **Chain-based breeding**
  - Shared economic interest
  - Design approach, aimed at particular product
  - Example: club varieties tomato (Tasty Tom)

- **Community-based breeding**
  - Shared culture
  - Idea driven, multiple options, process important
  - Example: Kultursaat

Level of participatory research

- **Conventional**

  Research managed on station or on farm trials

- **Consultative**

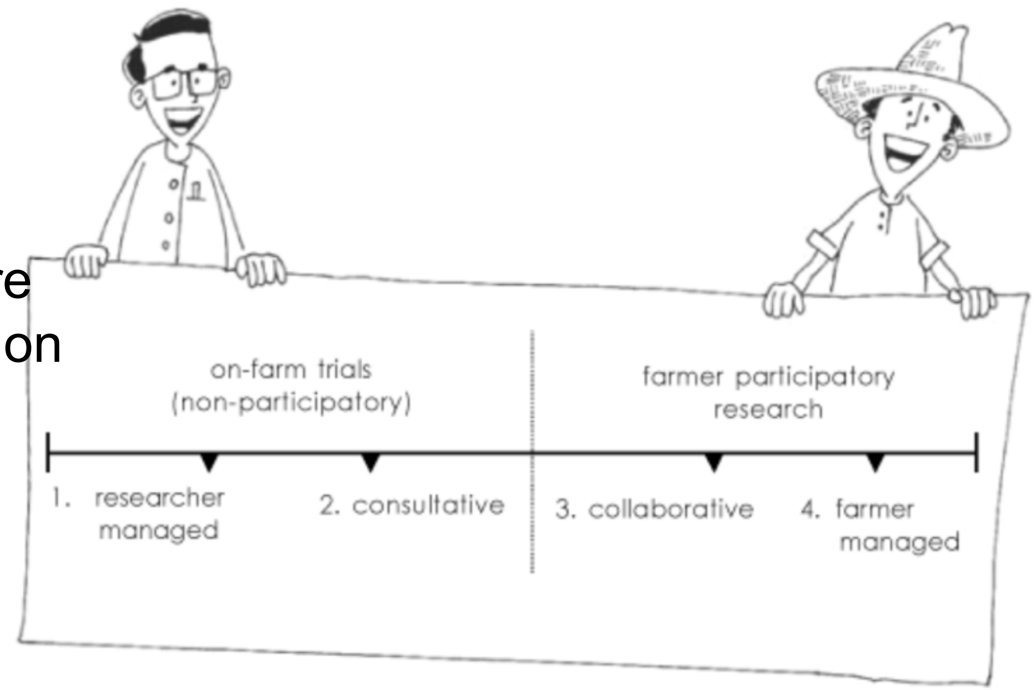
  Information sharing, farmers are consulted scientists take decision

- **Collaborative**

  Task sharing between farmers and scientists

- **Farmer managed**

  no scientists involved



Gonsolves et al. 2005

→Collegial: collective decision in group process, sharing responsibility and accountability

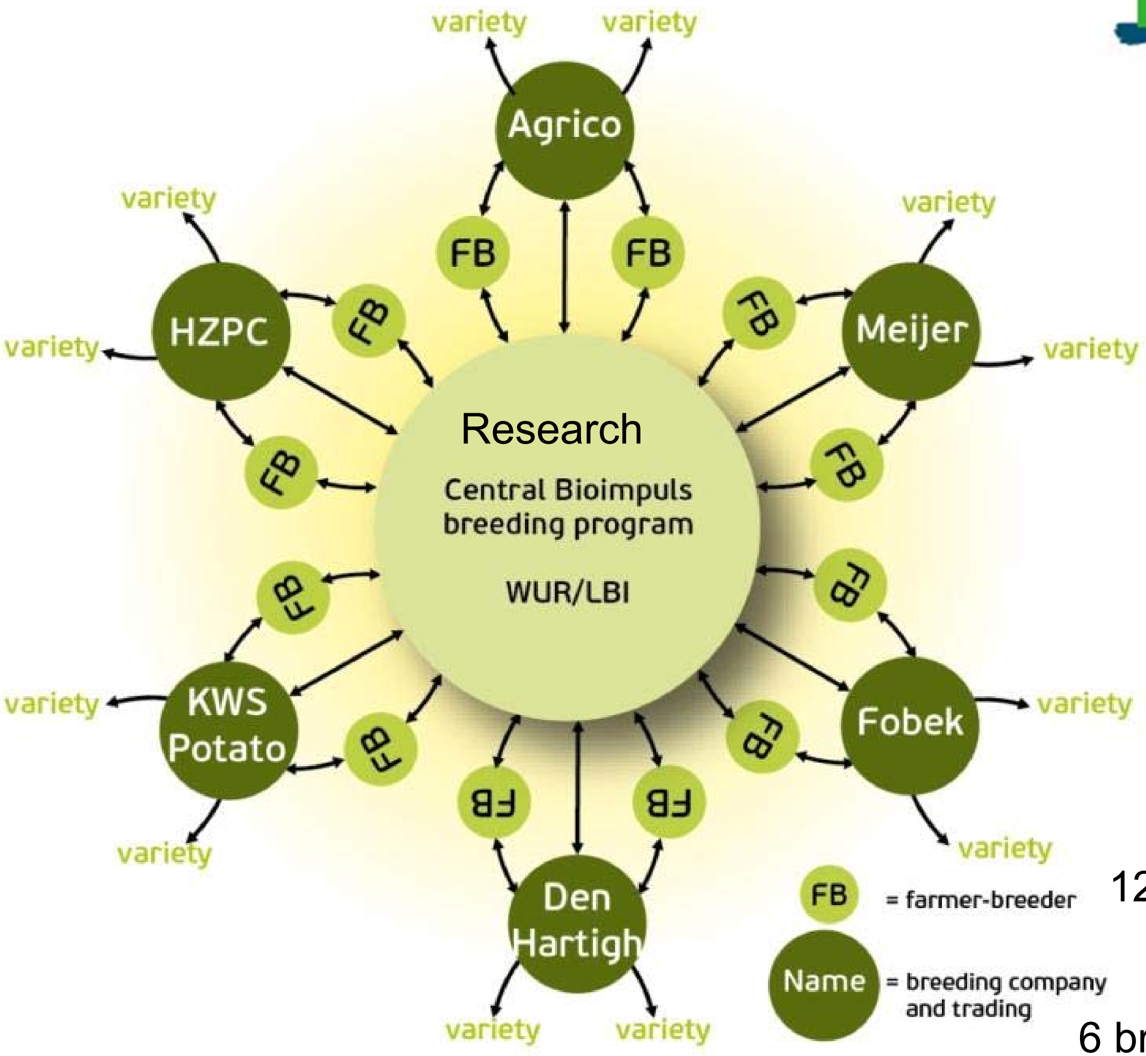
Farmer based breeding of open-pollinated broccoli varieties (USA)

- Started from an initial broad base population;
- 500 - 1000 seeds sent to each grower to plant, select, allow random mating and harvest seed;
- Portion of harvested seed returned to breeder;
- Seed mixed and redistributed for 3 cycles;
- Cultivar development.

J. Myers, Oregon State University

Edith Lammerts van Bueren (Wageningen University & Louis Bolk Institute)

Chain based breeding in Bioimpuls – organic late blight resistance potato breeding



12 farmer breeder

6 breeding companies

Community based breeding of locally adapted Durum wheat

coordinated by Dominique Desclaux INRA Montpellier

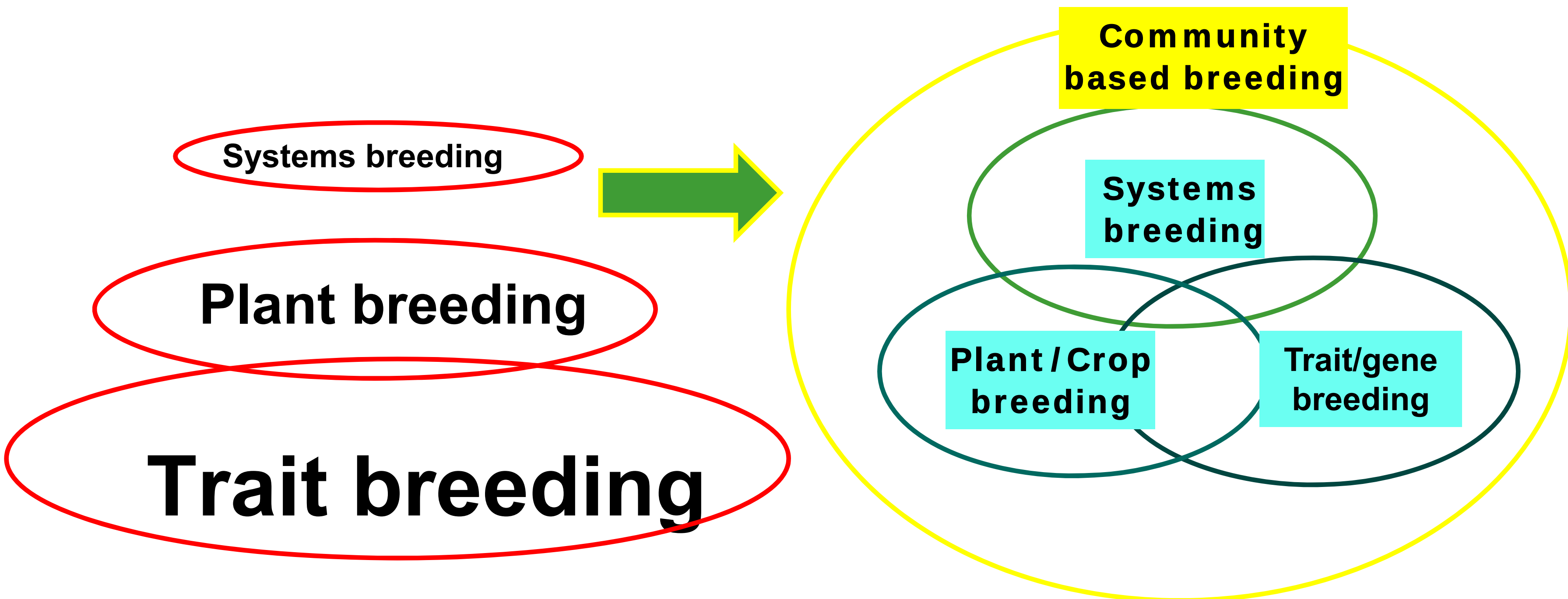
Goal: locally adapted varieties for local products, supporting diversity, strengthening of rural regions

- Comprehension of **farmers, breeders, merchant, consumer, sociologists** (supports exchange of industry & farmers, consciousness of consumers) → leading to new breeding criteria
- Respecting local conditions (soil, climate, management) → decentralized test ***on farm***
- Farmers are involved in decision processes (not only end user of varieties but included in development stage)
- Marketing aspects are included from the start

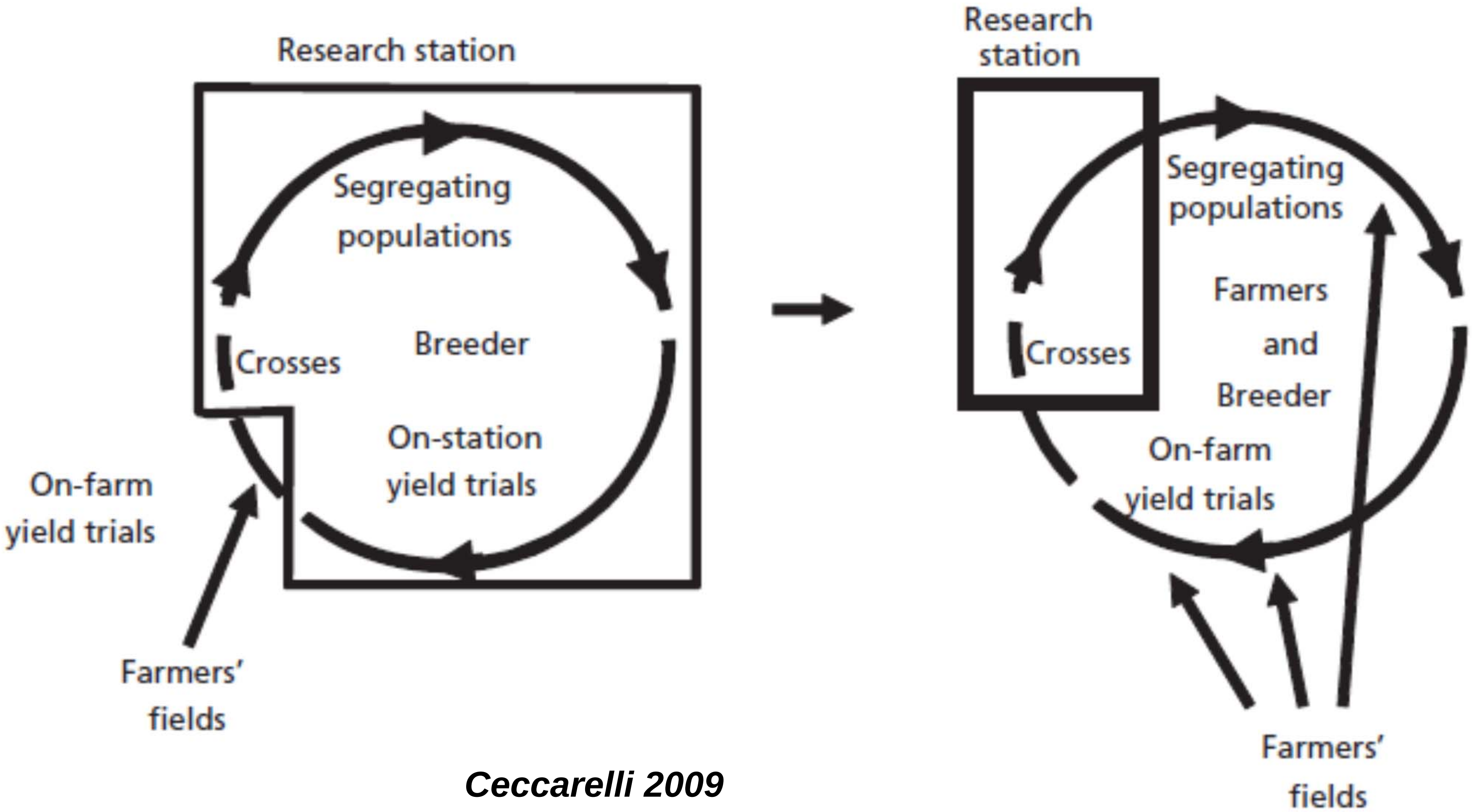
→ **collegial process**

www.selection.participative.cirad.fr

Future research?



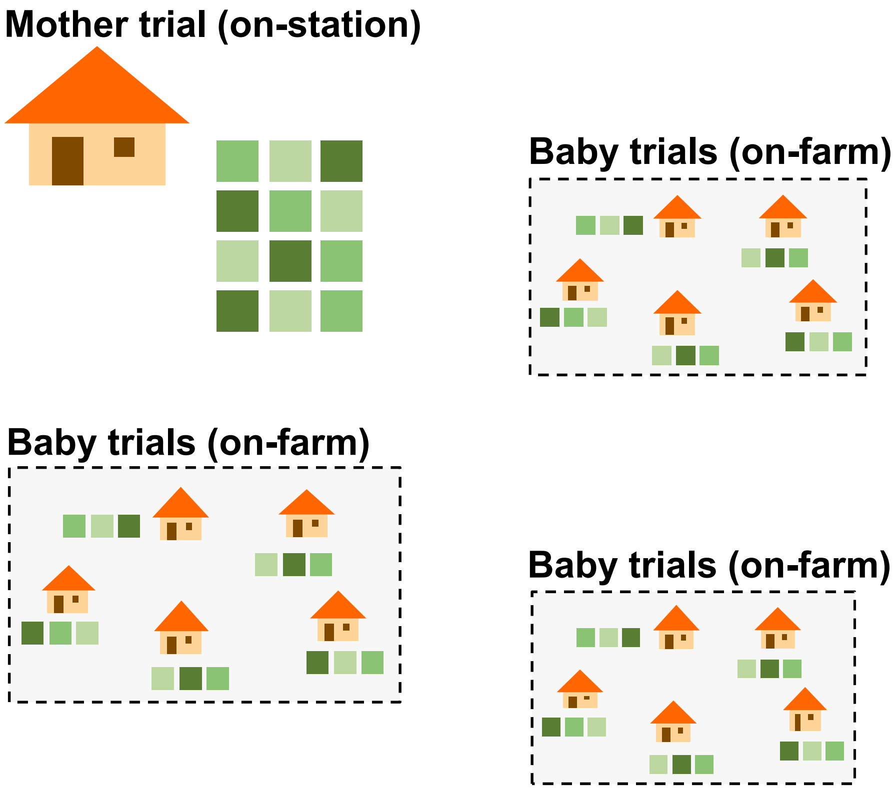
Different Timing of Participation in the Breeding Process



Ceccarelli 2009

Methodologies and Tools for Participatory Research

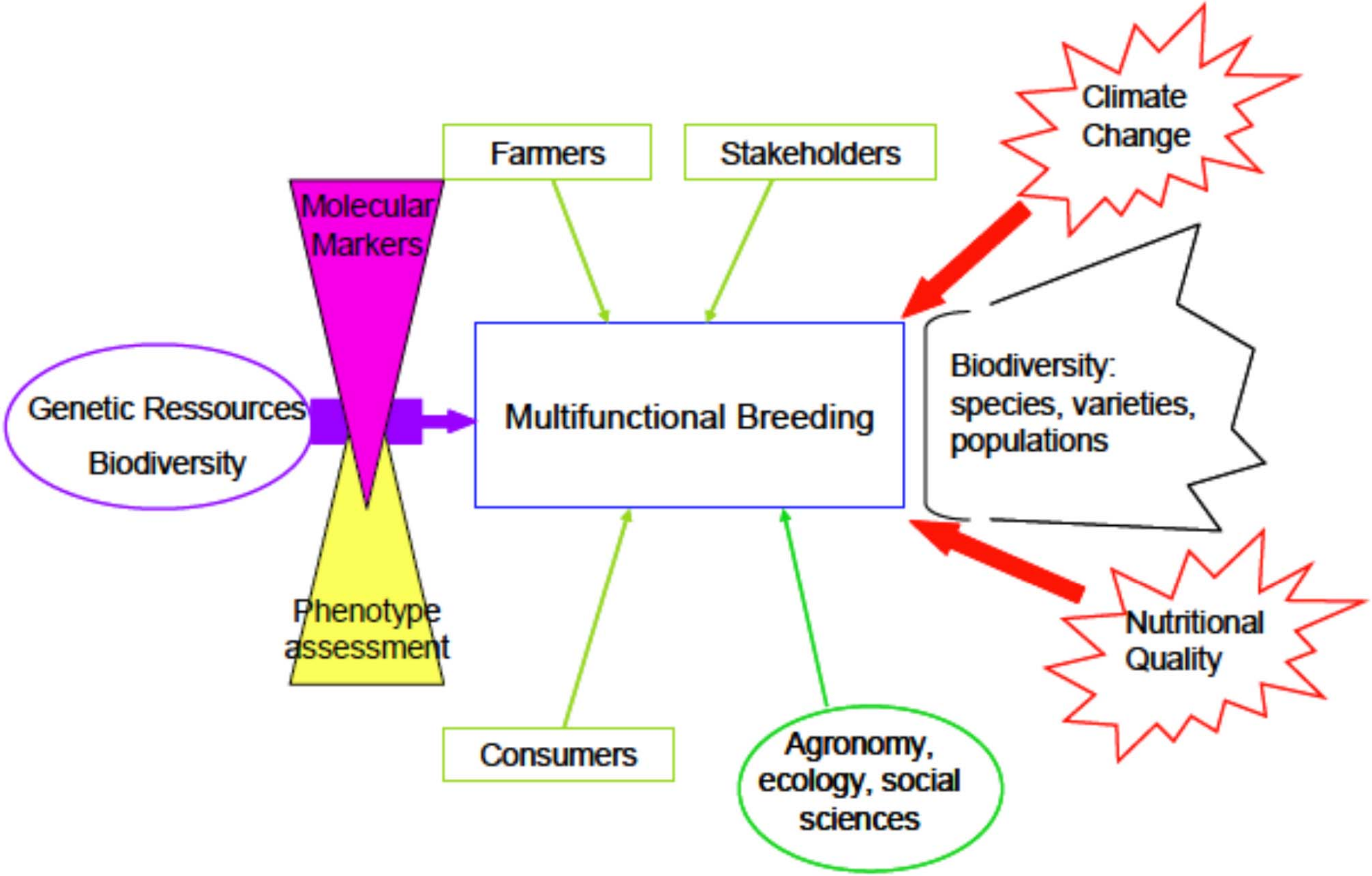
- Participatory rapid appraisal
- Mother Baby Trial
- Farmer field schools
- Farmer research committees
- Participatory technology development
- Action research



Pool relevant knowledge

- **Traditional & local knowledge of farmers**
  - On cultivation & utilization practice, seed multiplication & farmer's selection often very difficult to get access
- **Breeder's knowledge**
  - Crossing techniques, heritability of traits, relatedness of different traits, selection methods, artificial inoculation
- **Processors/Trader's Knowledge**
  - Technological quality, customers preferences, quality requirements
- **Researchers' Knowledge**
  - Genetic basis of traits, genetic diversity of accessions, access to genetic material, physiological important traits
- **Socio-economic Knowledge**
  - on market potential

Plant Breeding



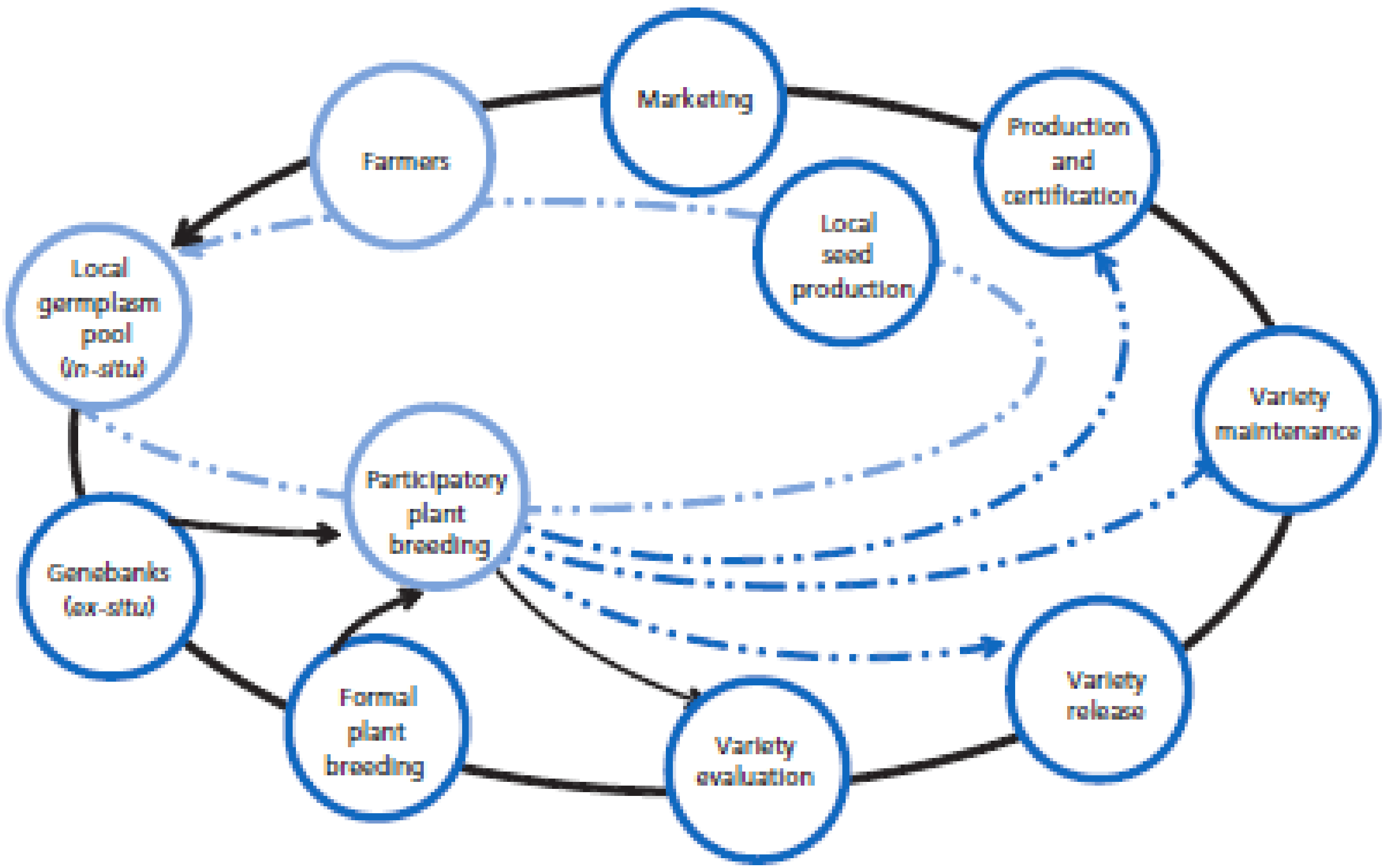
Sourcing of Seeds

- **Farm saved seeds (e.g., landraces)**
- **Commercially available seeds if not**
  - **protected by IP rights (Patent)**
  - **Restricted by breeder's exemptions** (needs registration as breeder)
- **International and national gene banks, research intistutions**
  - Small quantity of seeds
  - Genetic resources are of national ownership, MTA and ABS→ complex negotiations
- **Exchange with commercial and public breeders**
  - Often restricted due to conflict of interest (competition)
- **Local and international seed net works, NGO** → open seed source

Quaranteen regulations !!!

FIGURE 21.1

Linkages between participatory plant breeding and seed supply



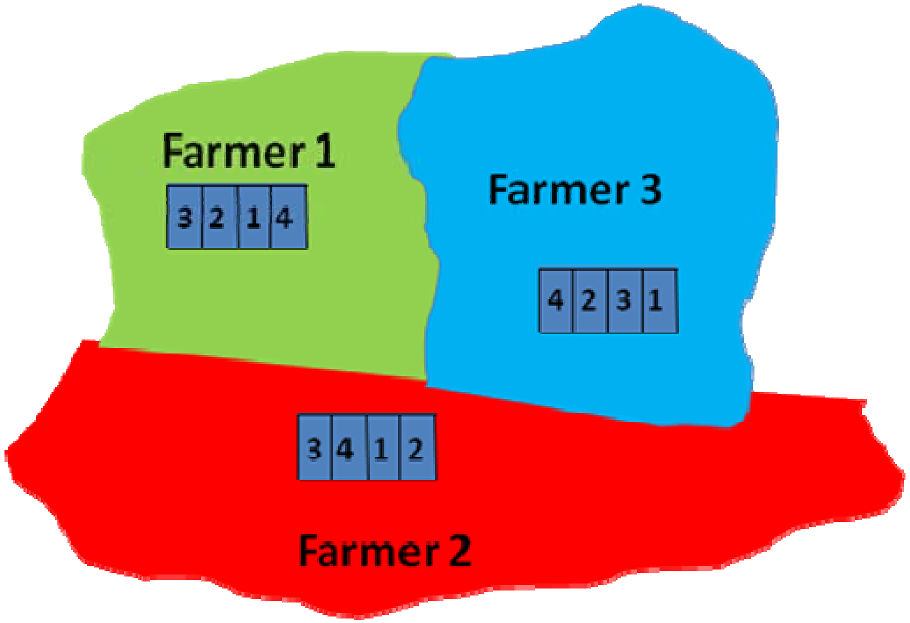
Source: adapted from Bishaw and Turner, 2008.

Implementation of PPB

- **Adjust design to local condition, field size, number of involved farmers**
  - Choose homogeneous farmers' fields
- **Keep it simple**
  - limited number of entries, reps
- **Focus on most relevant traits & contextual data**

  (Documentation of crop management & most relevant soil and weather conditions)
- **Use different techniques to collect the same data by different participants to verify assessment**
- **Assess G x E interaction based on unreplicated farmers' fields**

Start of on farm trial and training



Ceccarelli 2010

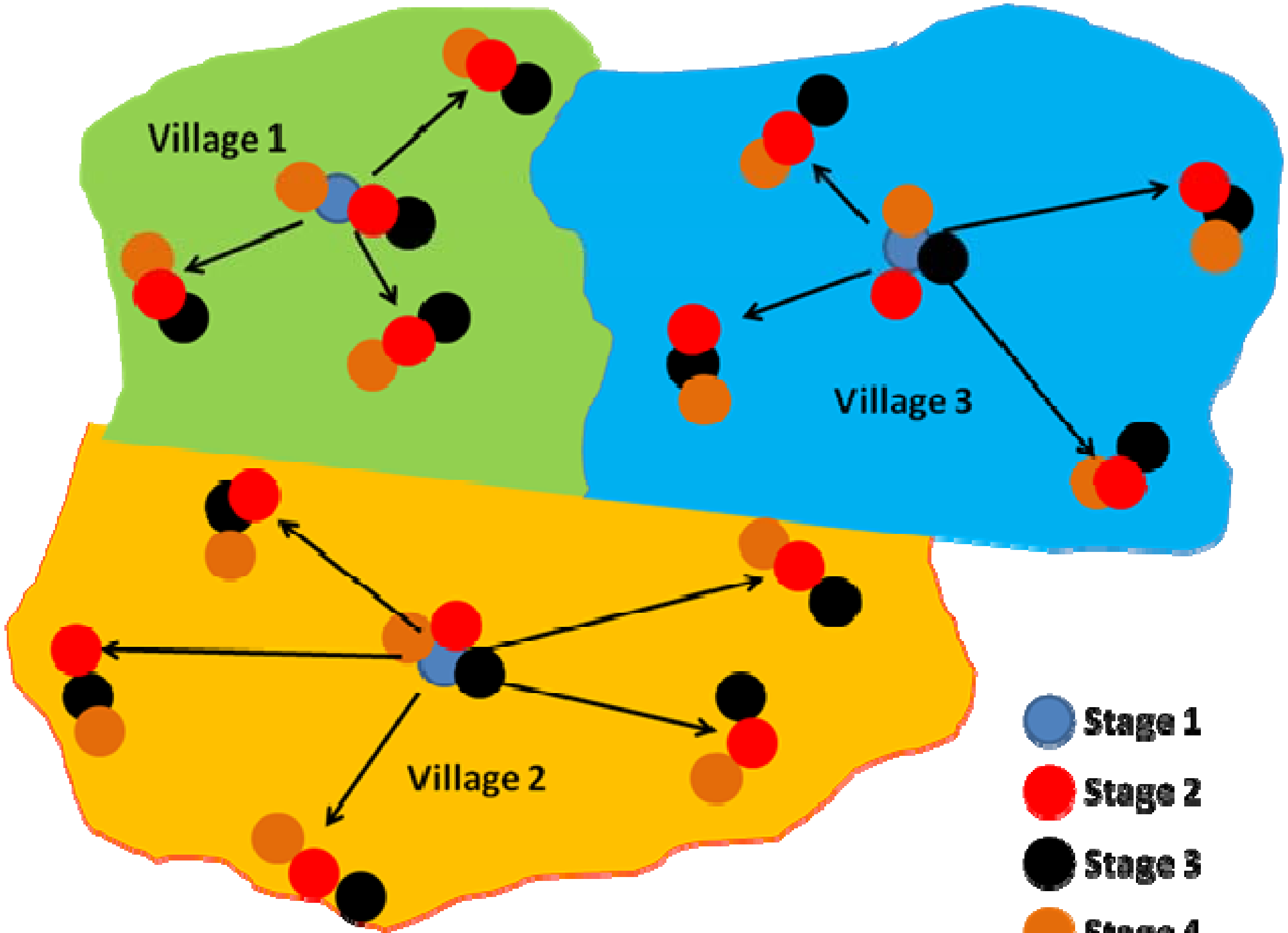
Capacity building in

- Varietal Testing
- Seed multiplication
- Seed processing & cleaning
- Germination Testing
- Seed Health
- Storage
- Crossing techniques
- Selection techniques

Regular Workshops with all Stakeholders

Farmers Field days and Demo Trials

Spreading of on farm trials



Ceccarelli 2010

PPB as evolving process

- **Challenges of on farm trials**
  - Demanding to organize decentralized field trials
  - Communication with many actors with different background
  - Unexpierienced in field trial set up, recording field data
  - Less controlled conditions
  - Less homogeneous
  - Limited availablibility (not all have e-mail, mobile phones)
  - Risk of neglecting field trial during peak times

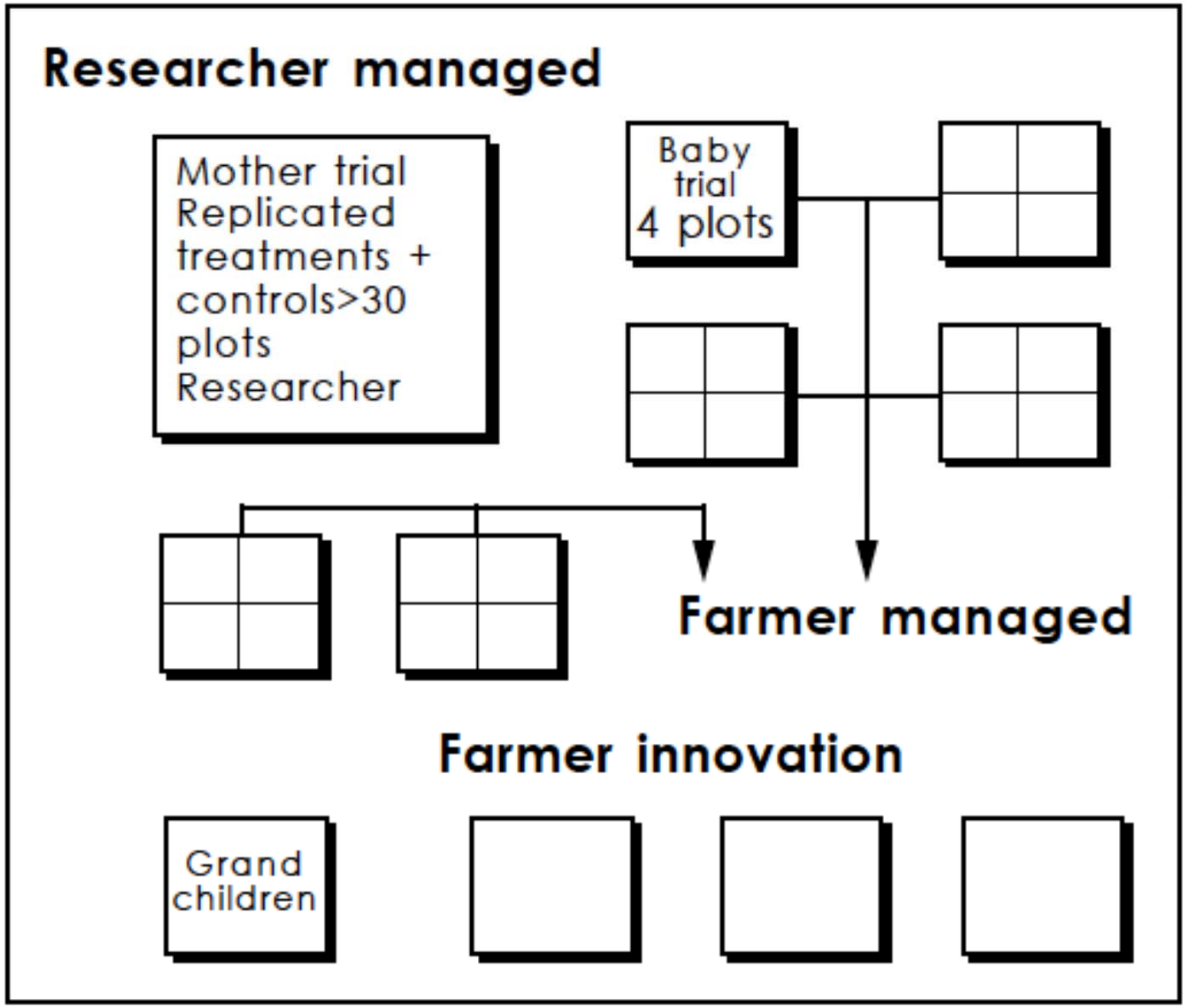
→ **develop clear field plan and field book together with farmer after definition of best field site**

→ **develop permanent and easy labelling system**

→ **agree on recording and sampling procedure**

→ **continuous learning and adjustments**

Shift from research managed trials to farmers innovations



Snapp 2012 http://www.extension.org/organic_production

Accompanying process of PPB

- Review knowledge obtained
- Agree and update on a shared agenda
- Adopt research questions and options to test (some may participate at different levels)
- Invest in partnership building, education and capacity building
- Facilitated discussions and brainstorm sessions
- Build in time for reflection
- Keep all participants motivated and engaged
- Communication and exchange is essential !!!
- Acknowledgement of achievements

Long term engagement of participants

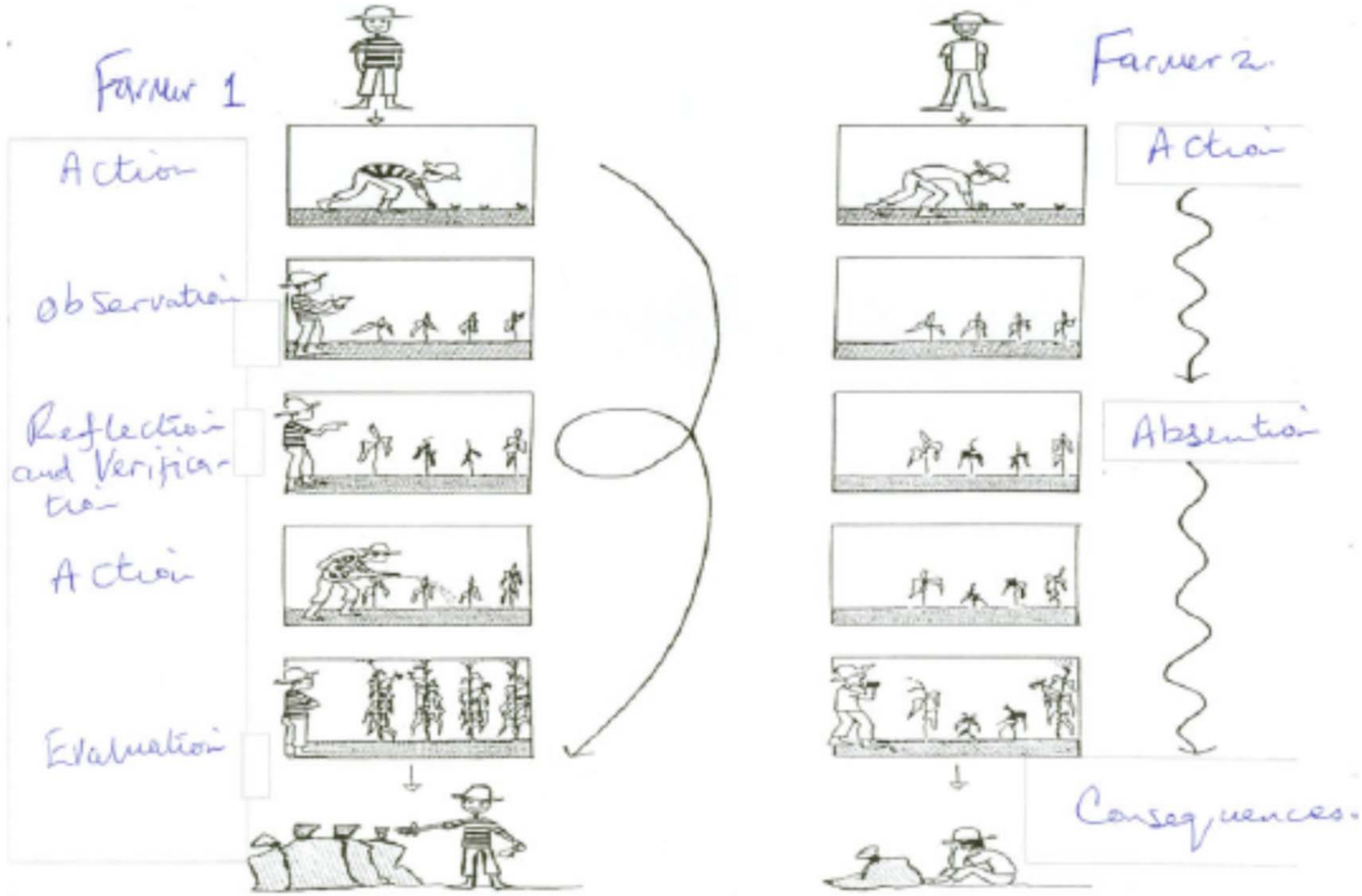


Fig. 1 Two farmers cultivating maize (German and Gohl, 1996)

Gender aspect in PPB

- Women have often less access to land, new technologies but are heavily involved in field work, food processing, responsible for traditional knowledge and house keeping
- Special emphasis are needed to include women in the participative process for their empowerment

Women

- have different focus on crops than men $\rightarrow$ different more comprehensive criteria are considered
- are often better distributors of information, better team players
- are often more persistent to long term activities while men are more enthusiastic about short term progress

Requirements for participatory plant breeding

- Trusting relationships among members must be developed in order for a consensus about project goals, data collection methods, an analysis of findings, and recommendations can be reached.
- Training about research methods, data collection, and analysis must be provided for the participants.
- Establishing a good organizational structure to support the work team
- The provision of strong administrative support and adequate resources for the project
- A skilled facilitator to coordinate the process.

Experience after 3 years of participatory barley breeding in Syria

- Farmers were able to handle large number of entries, develop oown scoring method
- Farmers select for specific adaptive traits
- Diversity was higher among farmers' selection in own fields than on station evaluation and also higher than breeders' selection on station or on farm
- Farmers and breeders used almost the same selection criteria
- Farmers were slightly more efficient to identify highest yielding cultivar in own fields than breeders
- Breeders were more efficient selection on station irrigated, while farmers were more efficient in on station selection under low rainfall conditions

Ceccarelli et al. 2010

Greatest impact of PPB given when

- **Demand of farmers, traders, consumers poorly understood or not recognized by formal seed sector**
- **High degree of risk and uncertainty**
  - Volatile or emerging markets
  - Climate change
  - Very diverse cultivation management or stress environment
- **Wish of producers and stakeholders or even larger part of society to have control over food system**
  - Proprietarity of seed
  - Introduction of plants into food chain (GMO)

→ **Changes the organisation and costs of breeding process and technology management**

→ **Improves trust in research, research efficiency; enhances productivity and welfare of farmers, traders & consumers**

Legal situation

- International Treaty of Plant Genetic Resources
  - www.planttreaty .org
- Standard Material Transfer Agreement
- UPOV Convention
- Agreement of Application of Sanitary and Phytosanitary Measures
- Biosafety Protocol
- National variety testing
  - New, distinct, uniform, stable (DUS test)
  - Value for cultivation and Use (VCU) tested under high input farming conditions
- National seed law

Legal Situation

- **New regulations needed that allow formal and informal seed sector to coexist**
- **Establishment of new criteria for variety evaluation**
- **Easier access to plant genetic resources**
  - Farmers acknowledged as breeders
  - Momorandum of Understanding between partners, national and international institutions needed (access & benefit sharing)
- **Ownership of varieties derived from PPB**
  - Develop concept of „open source“ genetic resources
- **Political awareness for importance of access to seed and planting material**
- **Institutionalisation and upscaling of PPB**
- **$\rightarrow$ improves agrobiodiversity & local adaptation**





Participatory Cotton Breeding and Cultivar Evaluation for Organic Smallholders in India

M. Messmer[1], S. Vonzun[1,2], D. Wele[3], Y. Shrivas[3], L. Mandloi[3], A. Yadav[3], R. Sana[4], H. Uzzaman[4], G. Rao, S. Valluri, A. Ambatipudi[4], S.S. Patil [5]

1 Research Institute of Organic Agriculture, FiBL, Switzerland

2 University of Basel, Switzerland

3 bioRe India, Kasrawad, Madhya Pradesh, India

4 Chetna organic, Odisha, India & Forum For Integrated Development (FFID) India

5 University of Agricultural Sciences (UAS) Dharwad, Karnataka, India

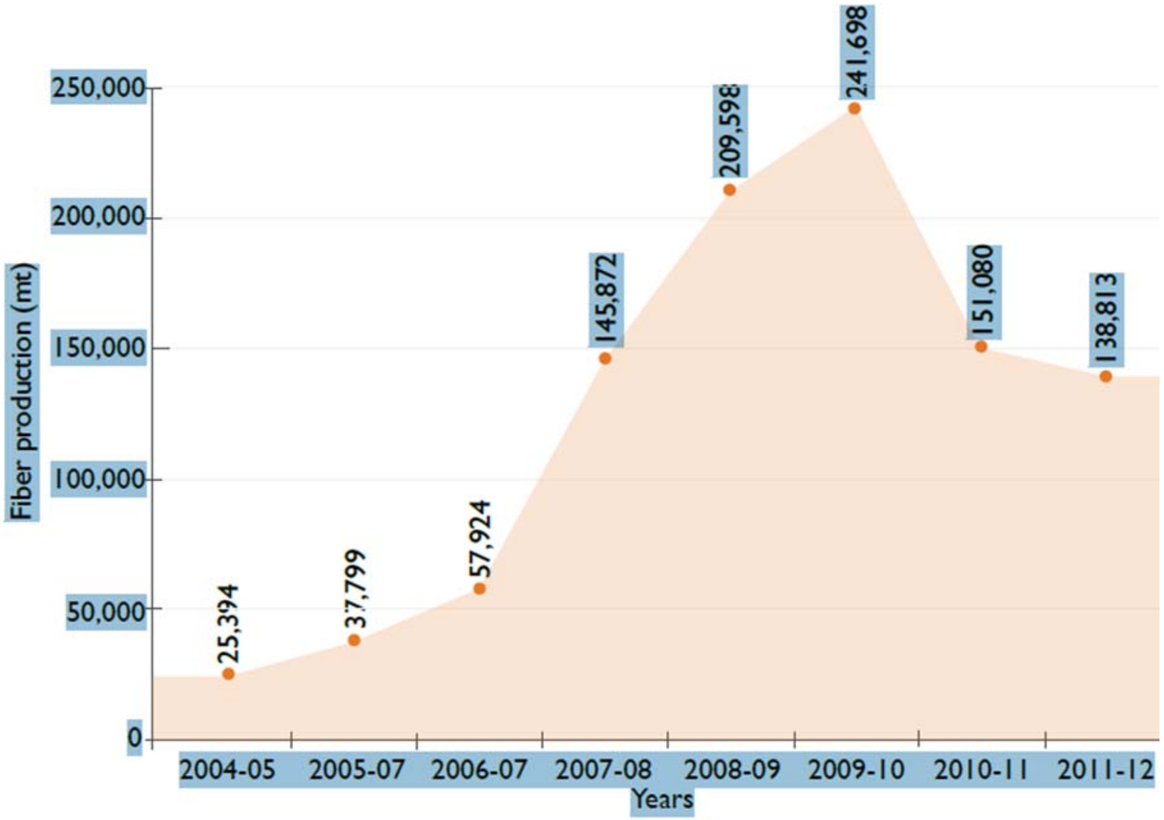
www.fibl.org; monika.messmer@fibl.org

bioRe
Organic cotton cooperation in Madhya Pradesh

Chetna Organic
Organic cotton producer cooperation in Orisha

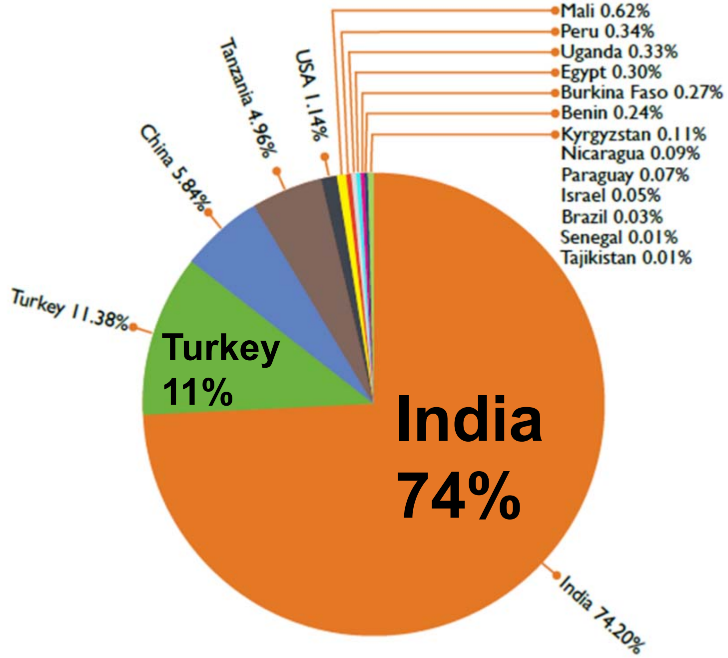
University of Agricultural Science (UAS) Dharwad
in Karnataka

Organic Cotton Production on global level



footnote:

1. Data rounded to the nearest whole number

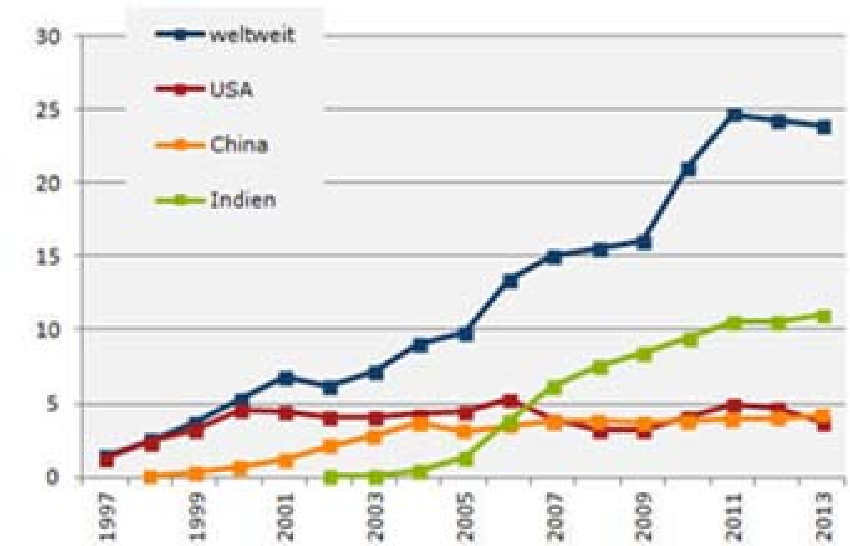


Farm & Fiber Report 2011_12,
Textile Exchange 2013

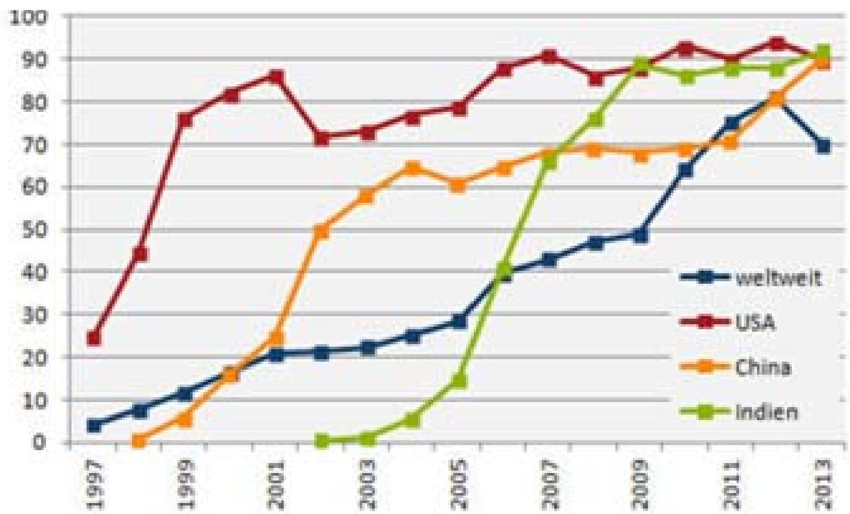
Challenges of Organic Cotton in India

- **Organic cotton in India is less than 2%, while genetically modified Bt cotton reached 95% in less than 10 years**
- **Seed market for non GM seed completely eroded**
- **High cost for certification / tracing system (Tracenet) and for testing GM contamination of seeds and harvest**
- **Reduced interest of farmers to grow organic cotton:**
  - Reduced yield & longer picking periods compared to Bt cotton
  - → Improvement of organic cotton cultivation (composting, irrigation, systemic plant protection, **resilient cultivars**)
  - → Market development for other crops in cotton rotation
  - Other labels like BCI are more attractive, easier to achieve
  - Other crops become more attractive (market price, time till sale, risk of contamination, availability of seed in time)

Area under GMO cotton of main producing countries



Anbauflächen gv-Baumwolle in Millionen Hektar



Anteil gv-Baumwolle an der Anbaufläche eines Landes in Prozent

Reference:
www.transgen.de

Cultivated cotton species in India

Gossypium hirsutum

Upland cotton
tetraploid

Gossypium barbadense

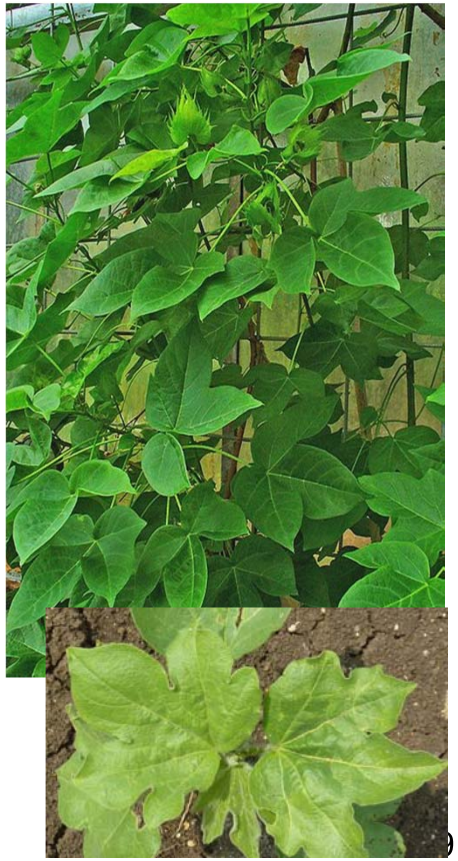
Pima /
Egyptian cotton
tetraploid

Gossypium arboreum

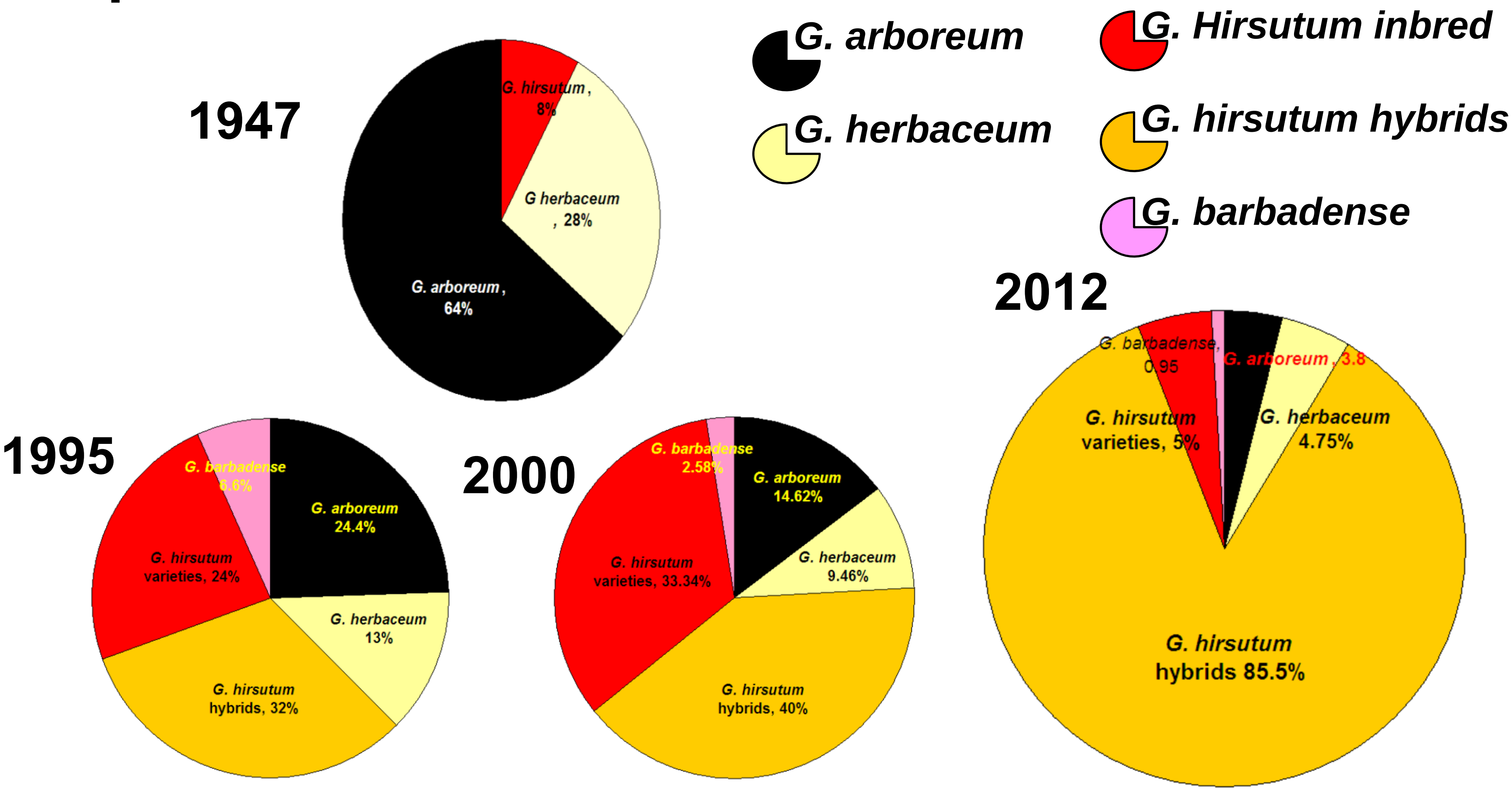
Desi cotton
diploid

Gossypium herbaceum

Desi cotton
diploid



Change of cultivation area in different cotton species in the last decades in India



Prof. Dr. R. W. Bharud, Mahatma Phuke Agricultural University Rahuri, MA
All Indian Cotton Improvement Project

How can organic cotton be safeguared in India?

- **Shortterm action: Secure seed supply**
  - Establish **Networks** with public and private cotton stakeholders that share the same interests (Dharwad declaration)
  - **Training & Capacity building** of organic cotton growers in on farm cultivar testing and seed multiplication
  - **On-Station and On-Farm Cultivar Testing** together with Farmers for suitability of cultivars under diverse local smallholders' organic growing conditions

- **Mid- and longterm action: Improve cotton cultivars adapted to organic farming**
  - Collection and utilization of the full **Diversity** of the cotton germplasm, especially the more **robust endemic Desi cotton (*G. arboreum*)** and adapted *G. hirsutum* inbred varieties & public hybrids
  - Establishing dezentralized **participatory cotton breeding programs** focusing on the growing conditions of organic cotton producers

  → Regain **Seed Sovereignty** of high quality cotton germplasm

Networking, Collaboration, Awareness rising

On National Level

- National Workshop on Safeguaring non-GM cotton in Dharwad 2011 → Dharwad Declaration (Press release)
- National Workshop on Breeding and Seed supply of non-GM cotton in Kasrawad in March 2013 (exchange among stakeholder)
- Indian Round Table of Organic Cotton co-organized by CottonConnect and C&A Foundation in Indore in March 2014

On International level

- Round Table of Organic Cotton organized by Textile Exchange in Hongkong Oct. 2012, Istanbul Nov. 2013, Portland Nov. 2014
- Pre-Conferences on organic cotton of OWC in Oct. 2014 organized by Textile Exchange and Helvetas
- www.organiccotton.org; http://farmhub.textileexchange.org
- www.greencotton.org

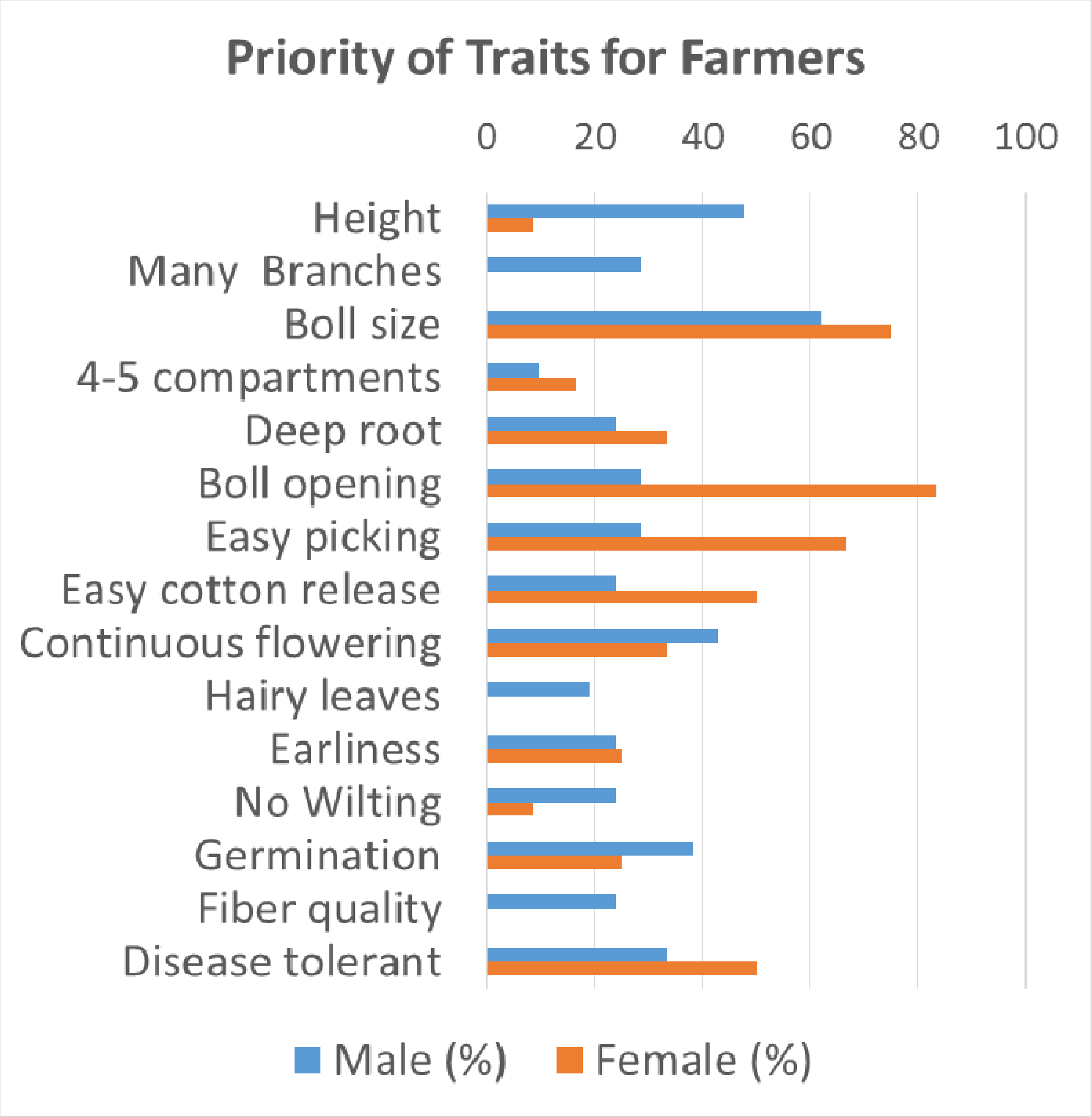
GREEN COTTON

Capacity buiding

Involve farmers in selction criteria, cultivar testing & selection, breeding activity

Cultivar selection

Single plant selection



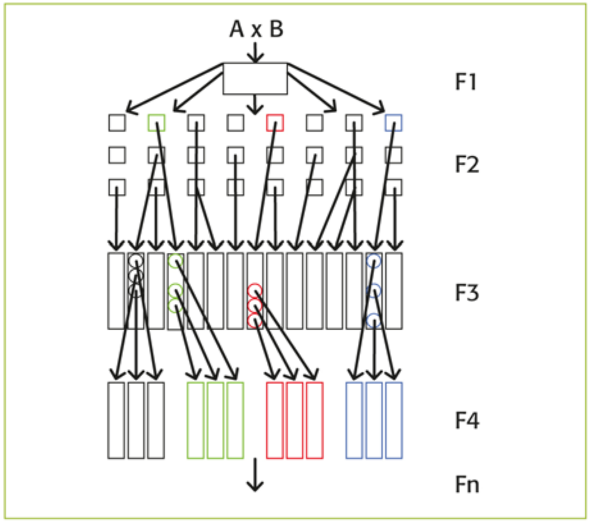
New crosses of *G. arboreum*

Fig. 1 *G. hirsutum* 4x hybrid

Fig. 2 *G.hirsutum x barbadense* 4x hybrid

Fig. 3 *G.arboreum* 2x varietal line

Phänotypische Selektion im Feld



- Collection of desi cotton *G. arboreum* 2013
- Intra (interspecific) crosses 2013/14
- Multiplication of offspring 2014/15
- Single plant selection 2015/16
- Decentralized single plant selection 2016/17

Segregating F2:3 populations

5 $F_{2:3}$ progenies to select in F3

Compare selection criteria of researchers with farmers' preferences

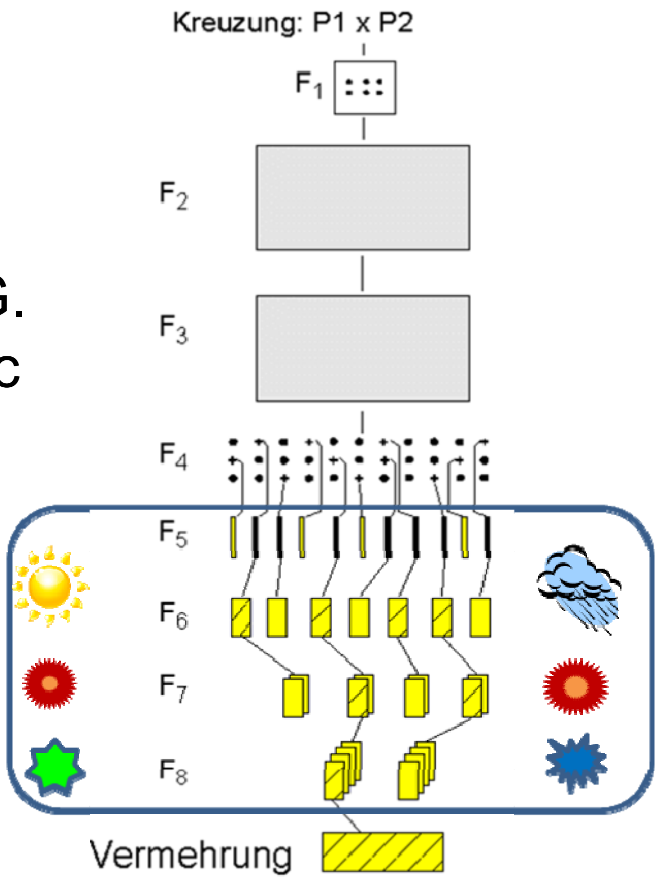
Farmers have different priorities for the selection of cotton cultivars than researchers

Pop	Total	Farmers' group	Researcher	both
1 (n =1000)	8.1	3.9	6.5	2.3
2 (n =1000)	1.7	1.5	0.6	0.4
3 (n =1000)	7.8	5.9	5.4	3.5
4 (n =1000)	2.5	1.6	1.3	0.4
5 (n =1000)	1.5	0.7	1.2	0.4
Tot (n = 5000)	**4.32**	**2.7**	**3.0**	**1.4**

FiBL

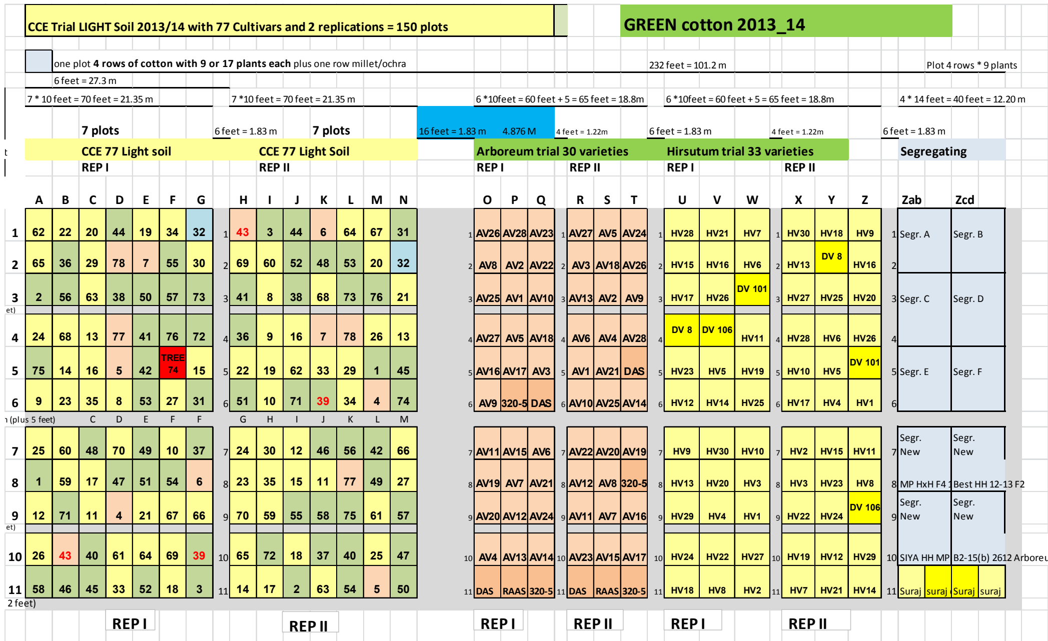
Selection of locally adatped advanced lines

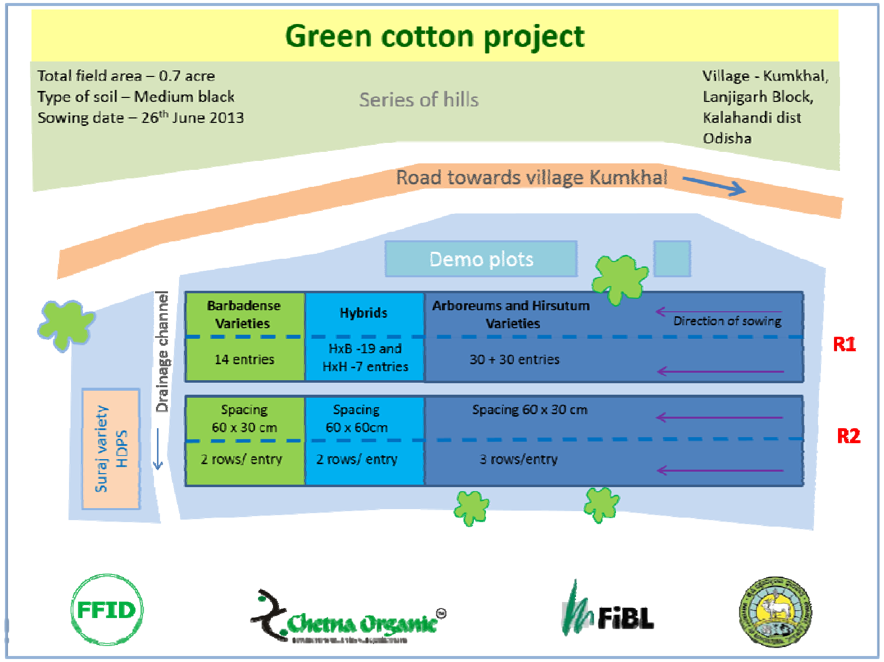
- Observation trials of advanced breeding lines of G. hirsutum, G. arboreum at Kasrawad by BioRe
- Observation trials of advanced breeding lines of G. hirsutum, G. arboreum and G. barbadense at Orissa by Chetna organic
- Selection of best lines for further evaluation in the following years
- On station trails at several locations managed by breeder at each region
- On farm trials managed by instructed farmers
- Pilot cultivation of best selections



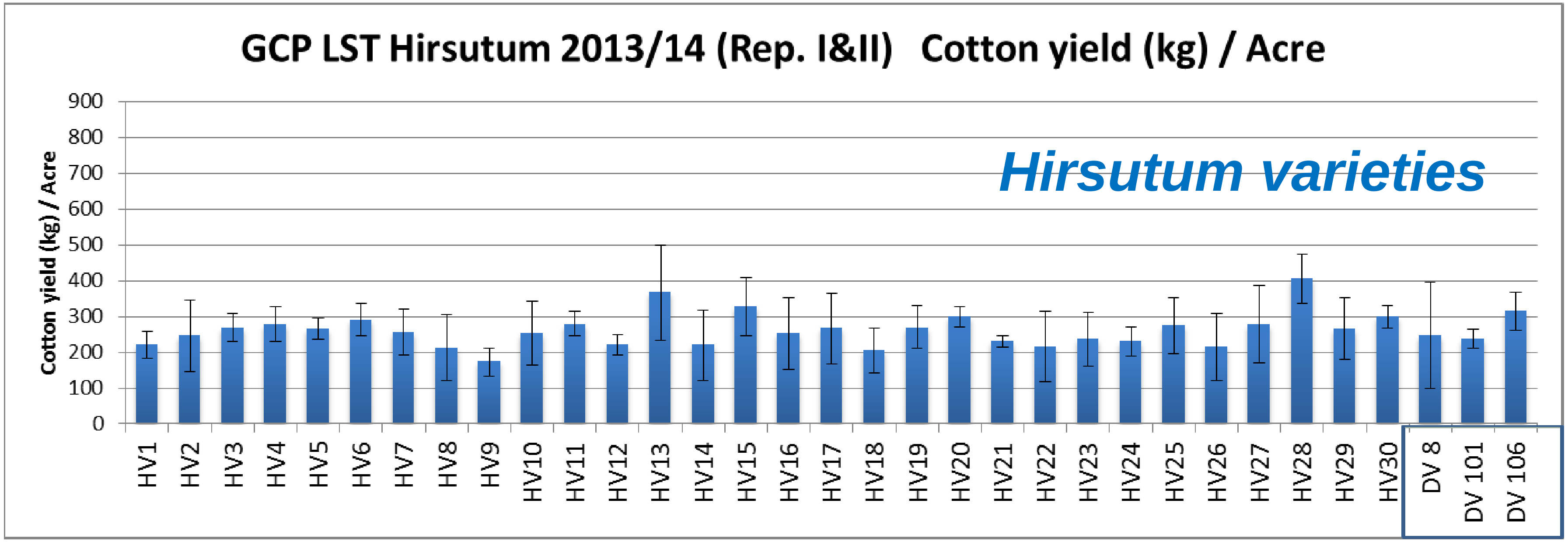
Field trials 2013/14

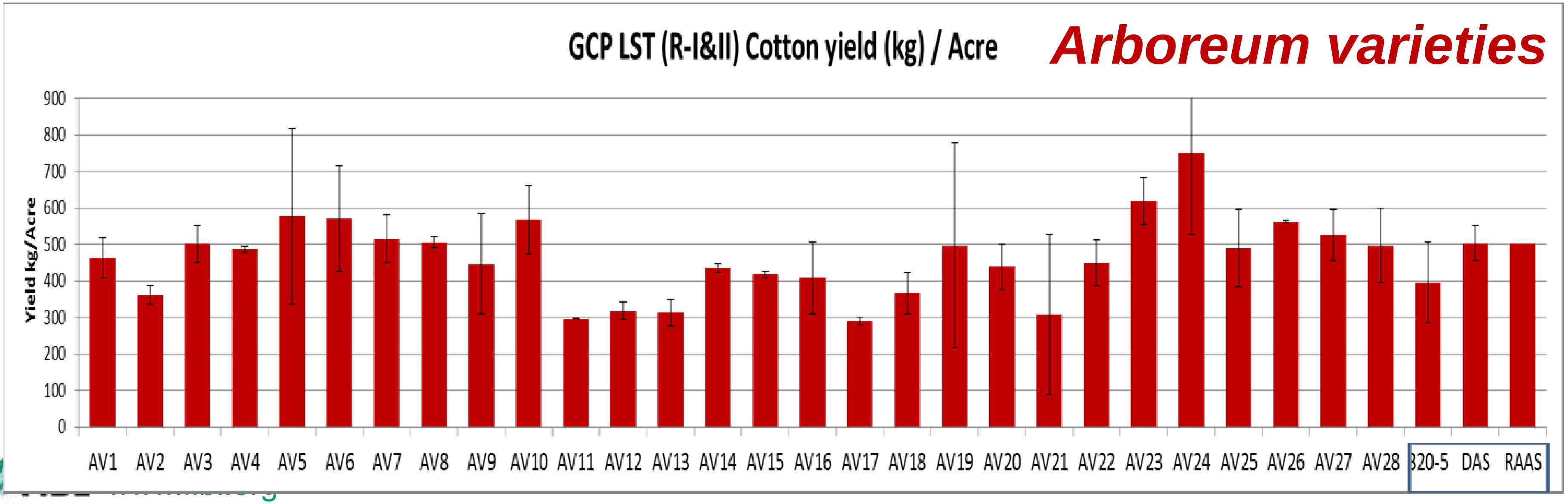
- Two sites at Madhya Pradesh
  - Heavy soil with drip irrigation
  - Light soil with limited irrigation
- Two sites at Odhisa
  - Shallow soil rainfed
  - Black soil rainfed
- 24 on farm trials in neighbouring villages





Madhya Pradesh Light Soil Trial rainfed 2013/14





Reasons for the selection of the 3 best cultivars

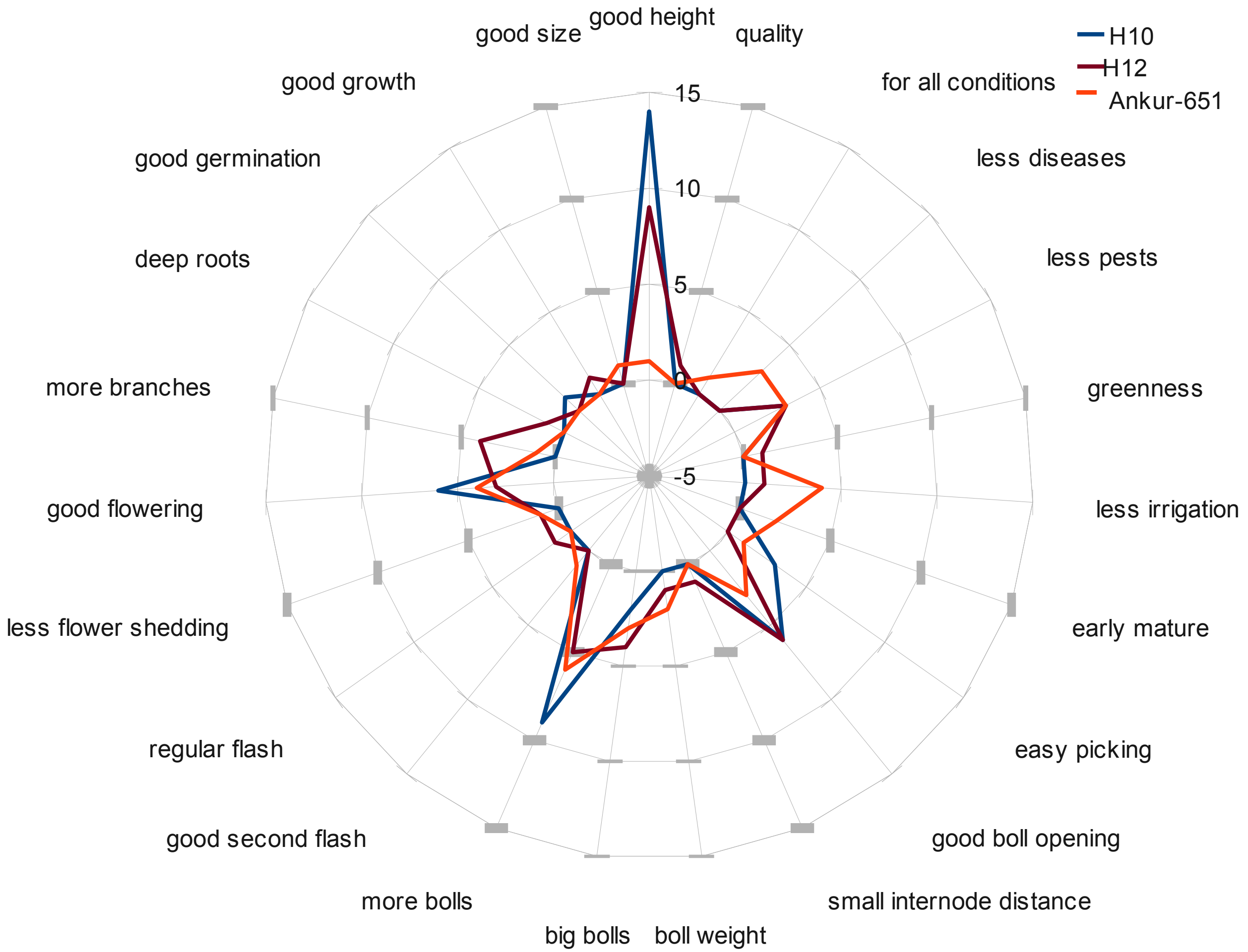
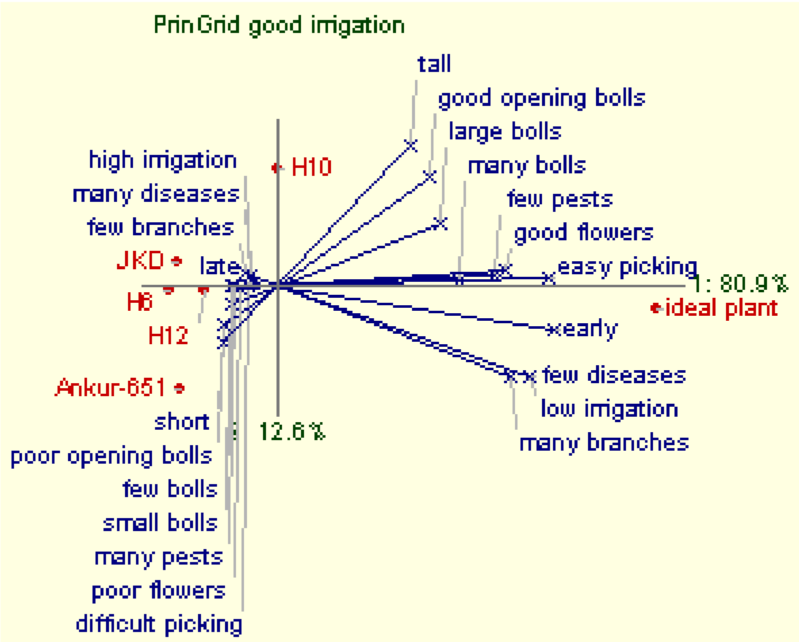


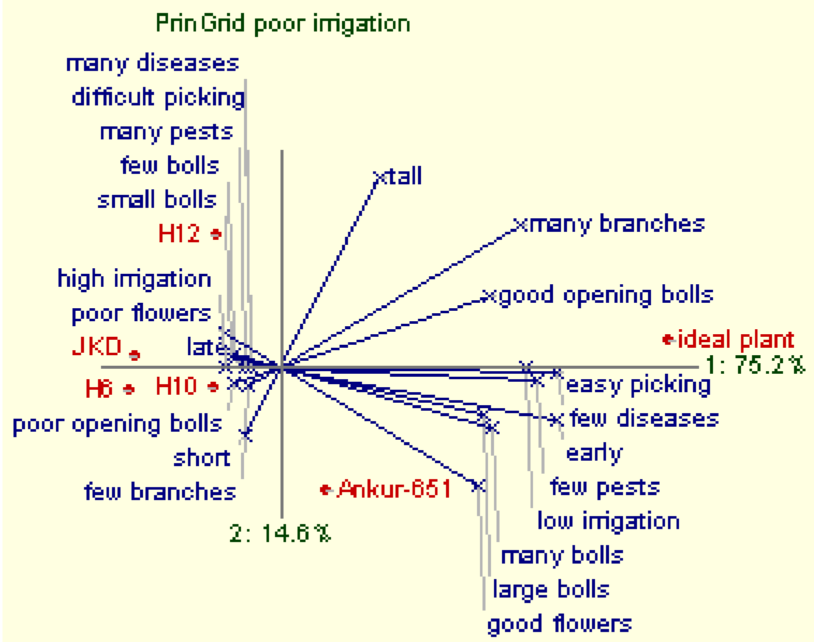
Figure 22: Farmers' reasons for preferring cultivar H-10, H-12 and Ankur-651

On farm selection by farmers

On land with good irrigation



On sandy soil without irrigation



Conclusions

- **Organic Sector has to take responsibility for its own seed supply** otherwise organic cotton is lost in India
- Priorities for optimal traits are quite different between breeders,farmers, also between female vs. male farmers, and the textile industry, to be successful **ALL aspects must be considered**
- Under low fertility and rainfed conditions traditional ***G. arboreum* have much higher yield** than *G. hirsutum.* Introgression lines of *G. arboreum* can meet good fiber quality, but picking time is increased. Inbred lines can outyield hybrids under less favorable conditions.
- A **broad range of genotypes is needed** to cover the different growing systems and pedoclimatic conditions & demands of textile industry. Breeding is indispensable to cope with climate change and new pest & diseases evolving
- Cultivation (e.g. plant density) need to be adjusted to each cultivar, therefore **breeding must go hand in hand with improvement of plant management** and anticipated future trends like mechanical harvest

Thanks a lot to your attention and to all who have supported the cotton seed projects so far

LED LIECHTENSTEIN DEVELOPMENT SERVICE

BIOVISION

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

coop Sustainability fund

fondation fondazione fundaziun
stiftungcorymbo

FOUNDATION bioRe STIFTUNG
HUMAN RIGHTS ORGANIC COTTON

coop Sustainability fund

Stiftung Mercator Schweiz

Financing of organic breeding programs

- **Private breeders finance themselves by selling seeds:**
  - In case of increased farm saved seeds income with license is not sufficient
  - Shift in breeding towards few profitable cultures and hybrids
  - Association of companies → closed club varieties
  - Patenting instead of variety protection →loss of breeders' privilege
  - Concentration on seed market→ dependence on global companies →limited access to genetic resources
- **Foundations:**
  - Often only short term sponsorship (1-3 y), only partly financed (GZPK: up to7 private foundations) → uncertain, time consuming
- **Price increase on final product:**
  - Consciousness of consumer, communication of additional value (Demeter)
- **Public support (is decreasing steadily):**
  - Preservation of agricultural diversity and freedom of choice (e.g. GMO free)

→ **Sustainable food security and food sovereignty**

Valorization of organic plant breeding along the value chain

bioverita

Saatgut aus biologischer Züchtung

www.bioverita.ch

- **Communication tool to show added value of organic plant breeding**
- **Labell for organic products derived from organically bred cultivars**

What kind of breeding should be supported by public funding?

- Which strategies are needed to face climatic change and increased word population?
- Can we rely on private industry for the seed of our food?
- Can we rely on four species for food security?
- Can we rely on monoculture or do we need new cropping systems?
- Which breeding methods are most cost efficient?
- Ethical issues of plant breeding?

Thanks a lot for your attention

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