Holistic approaches to organic breeding: how to address complex plant – environment interactions

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ECO-PB Summer School Tuscany

« Young Breeder – Mentor workshops »

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Several steps
from organic agriculture to organic seed

- From the pioneers to IFOAM principles

- From IFOAM principles to organic plant breeding

Naturalness
Respect of life

Four principles of IFOAM

***Principle** of*

HEALTH

Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.

***Principle** of*

ECOLOGY

Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

***Principle** of*

FAIRNESS

Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

***Principle** of*

CARE

Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

The context of organic seeds in few words,

- REGULATION: Year 2000: organic agriculture is looking for seed
- ETHICS: Coming back to the conceptual foundation of organic farming
- SCIENCE: Organic farming, health and microorganisms, the holobiont hypothesis is emerging
- ECOLOGY: Research paradigm and plant breeding, diversity is a key component of sustainability
- SOCIO-CULTURAL: The revival of peasant seed, participatory research and collective organisation

What is holistic approach?

- Holism is a philosophic theory first formulated by Jan C. Smuts (1926): “the determining factors in nature are wholes . . . which are irreducible to the sum of their parts. …”
- Holism has played a central role in Eastern cultures for millennia
- Holism is difficult to understand in the context of Western reductionist science

Nisbett et al. 2001, https://csanr.wsu.edu/blog15what-is-holistic-agriculture/

Analytic vs holistic knowledge

- Individuals have access to both analytic and holistic cognitive approaches,
- but a dominant and socially reinforced preference emerges.

DYNAVERSITY

Andrei Alexander Lux, Steven Lee Grover and Stephen Tai Theng Teo, Development and Validation of the Holistic Cognition Scale, Front. Psychol., 30 September 2021, https://doi.org/10.3389/fpsyg.2021.551623

Why develop a holistic approach for organic agriculture?

1 - Organic farming is at the origin the application to agriculture of a conception of life and of the organisation of the society:

- it has been **a cultural movement** before being agricultural techniques;

2 - Organic vision invites to consider all living beings according to their place in the living systems, their evolution and their ability to adapt and to interact:

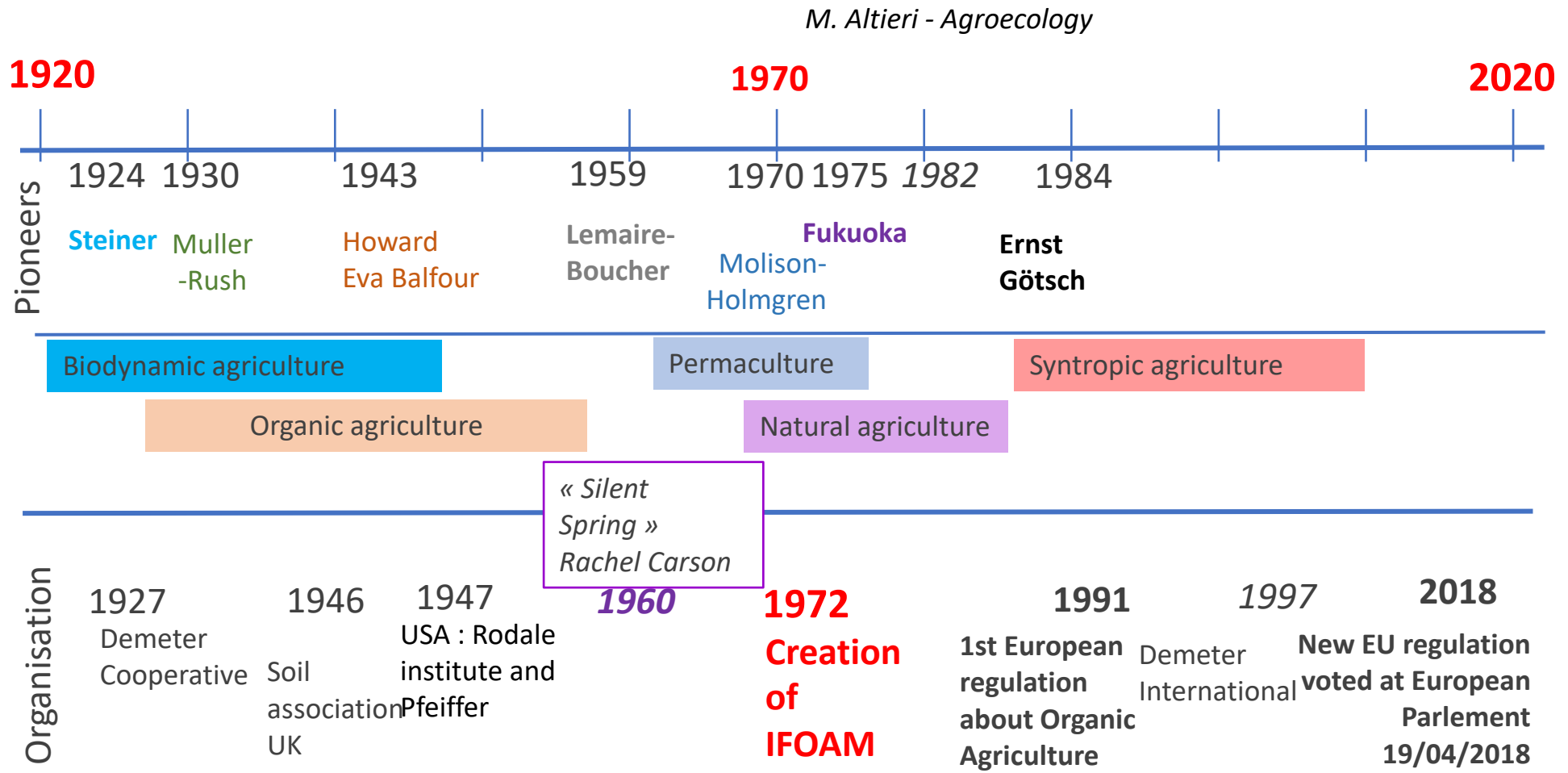
- thus we should pay attention to **health** and not to disease;
- we should pay attention to **resilience** and not to performance!

Agroecology / organic agriculture
I found a description in Miguel Altieri's publication …

- "**Those who adhere to organic agriculture have the highest degree of consciousness consistency of their thinking**.
- Their approach to the problems distinguishes them from industrial agriculture,
  - ➢not by the refusal of "progress",
  - ➢but by the rejection of a project and a particular **vision of life**,
  - ➢and the management designed and developed in the Western part of the World.

[12] Altieri, M.A.- Agroecology: The Science of Sustainable Agriculture, Westview Press (1995)

ONE CENTURY OF HISTORY



Holistic approach is a dynamic movement

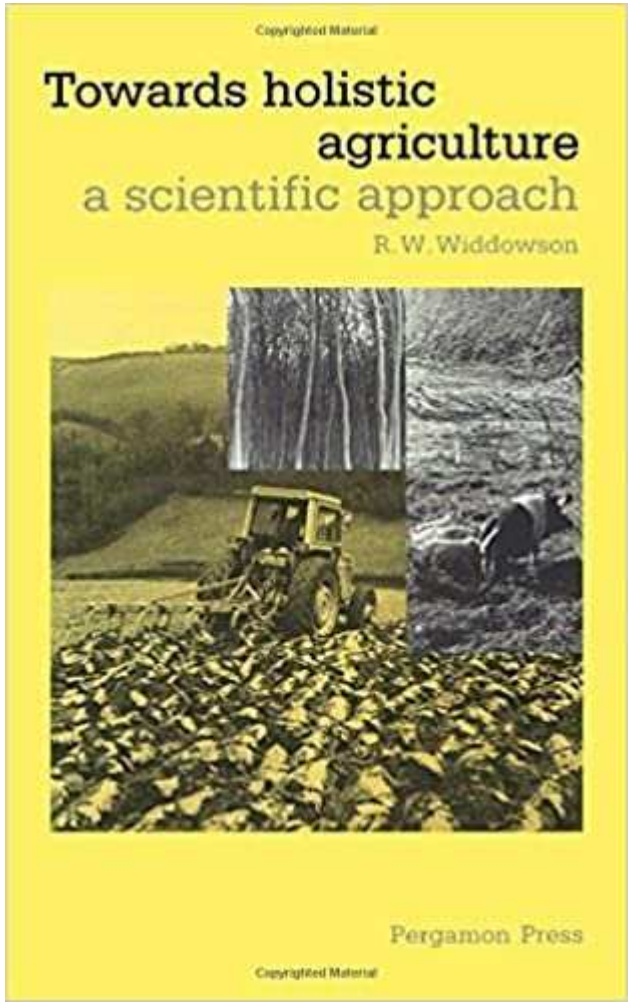
Several dimensions run through multiple meanings:

- With the inclusion of spiritual and a non-material dimension
- and more variables and interactions than conventional agriculture considers, in its material dimension.

Today it really matter what we mean by holistic agriculture: it is not only a systemic approach, but a cultural issue.

Holistic agriculture to an “ecological alternative” to intensive chemical farming

“Opposed to holism”, he points out in his introduction, “is reductionism, a belief that complex phenomena can be explained in terms of something simple; this is the view generally held by chemical farmers.” It is also the view, I might add, of many agricultural research scientists, an attitude which too often leads to the wrong questions being asked, which in turn leads to the wrong answers being received.



(Widdowson 1987, with Lady Eve Balfour’s foreword)

An Agricultural Testament
by Sir Albert Howard, 1943

Oxford University Press
New York and London

- "… It was observed in the course of these studies that the **maintenance of soil fertility is the real basis of health and of resistance to disease**.
- **The various parasites were found to be only secondary matters**: their activities resulted from the breakdown of a complex biological system -- the soil in its relation to the plant and to the animal -- ***due to improper methods of agriculture, an impoverished soil, or to a combination of both, and unsuitable seed.***"

Conclusions from LIVESEED

D3.7

Report on the holobiont as promising selection target to improve resilience and product quality

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Holobiont concept

From the Greek holos, “whole” and bios, “life”, the term holobiont corresponds to a natural living entity constituted

- **of a higher, i.e. multicellular, organism** called a host, such as a human being, an animal or a plant,
- **and its microbiota, i.e. the cohort of microorganisms** closely associated with it (bacteria, viruses, archaea, protists and microscopic fungi).

- In short, it is a host and all its microbes (for example in the human gut, about 1 to 2 kg per adult).

https://www.lemonde.fr/blog/internetactu/2018/11/30/tous-holobiontes-et-si-letre-humain-etait-un-meta-organisme-plutot-quune-entite-unique/

The relevance of the holobiont concept for organic seed production and organic plant breeding

To think about:

- the change in the holobiont during the plant domestication process for comestible produces,
- the complexity of microbial transmission by seeds,
- and then, the important role of the holobiont in plant adaptation and co-evolution for improved resilience in the agroecosystems.

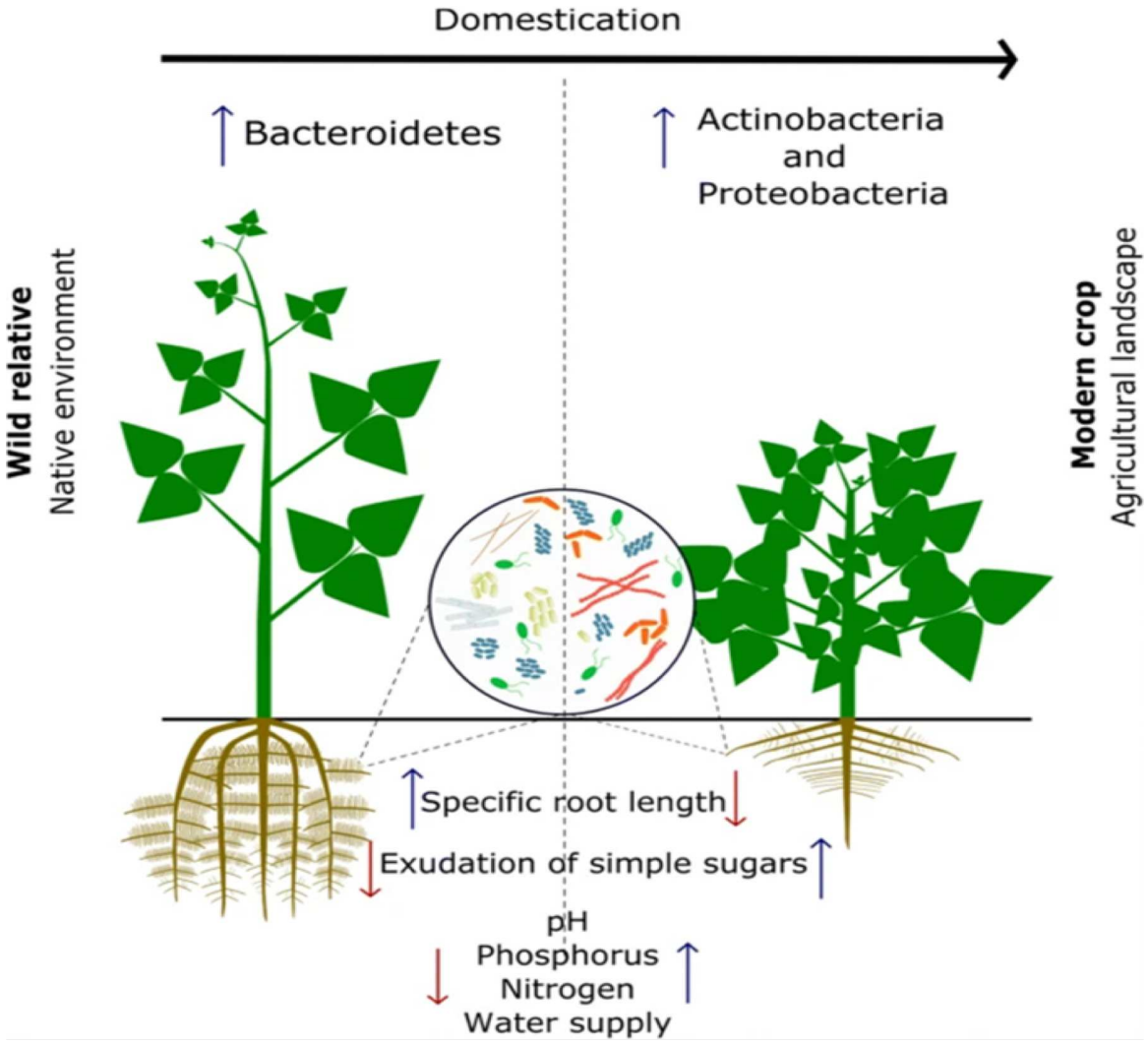
Impact of domestication on soil management, plant phenotype, plant physiology, and rhizobacterial diversity

In this hypothetical schematic representation:

- **the root morphology** of the wild relative of bean substantially differs from that of the modern counterpart.

Readily available macronutrients and water associated with agricultural management led to shallower roots in the modern crop cultivars as compared to the roots of the wild relatives which are rooting deeper with conspicuous lateral roots.

- Domesticated crop plants presumably also exude **more "simple" sugars** than their wild relatives.
- The impact of the domestication process on **rhizobacterial community composition** is reflected in a decrease in Bacteroidetes abundance (*for slow growth*) on modern crop plants, while the abundances of the Actinobacteria and Proteobacteria are increased (*for rapid growth*).

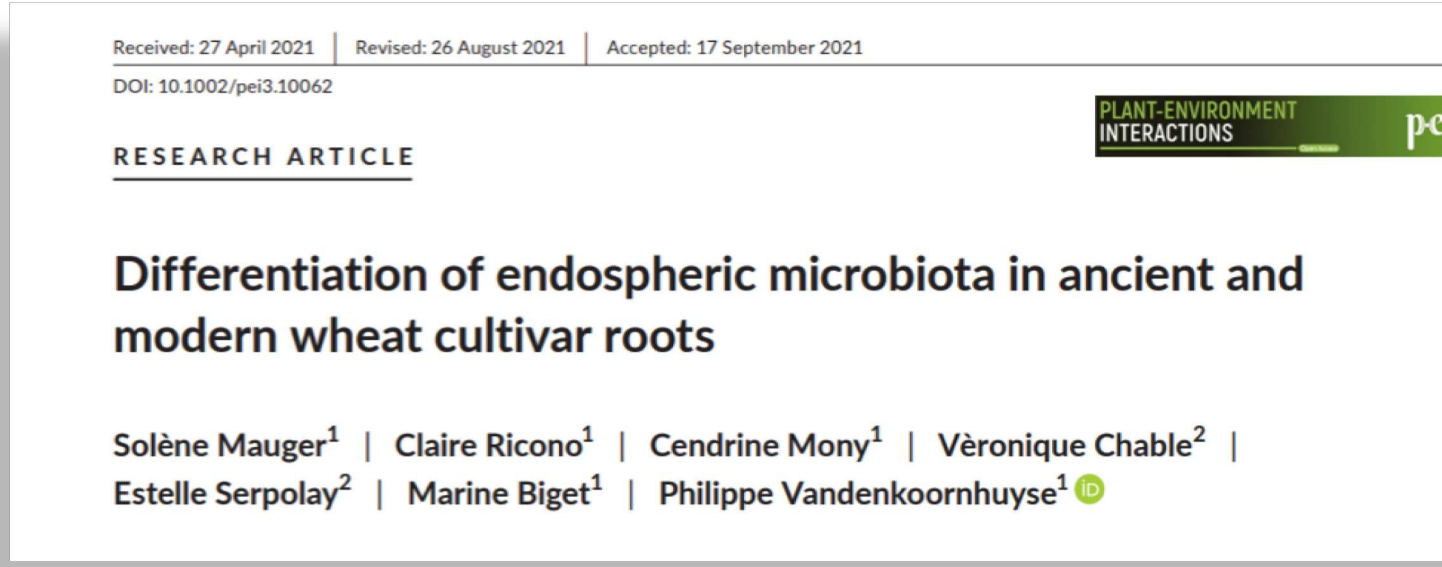


Pérez-Jaramillo et al, 2018

Could modern plant breeding and agrosystems artificialization have altered plants' ability to filter and recruit beneficial microorganisms in its microbiota?

Modern cultivars harbored higher richness of bacterial and fungal pathogens than ancient cultivars.

Both cultivar types displayed specific indicator species.



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PLANT-ENVIRONMENT INTERACTIONS

RESEARCH ARTICLE

Differentiation of endospheric microbiota in ancient and modern wheat cultivar roots

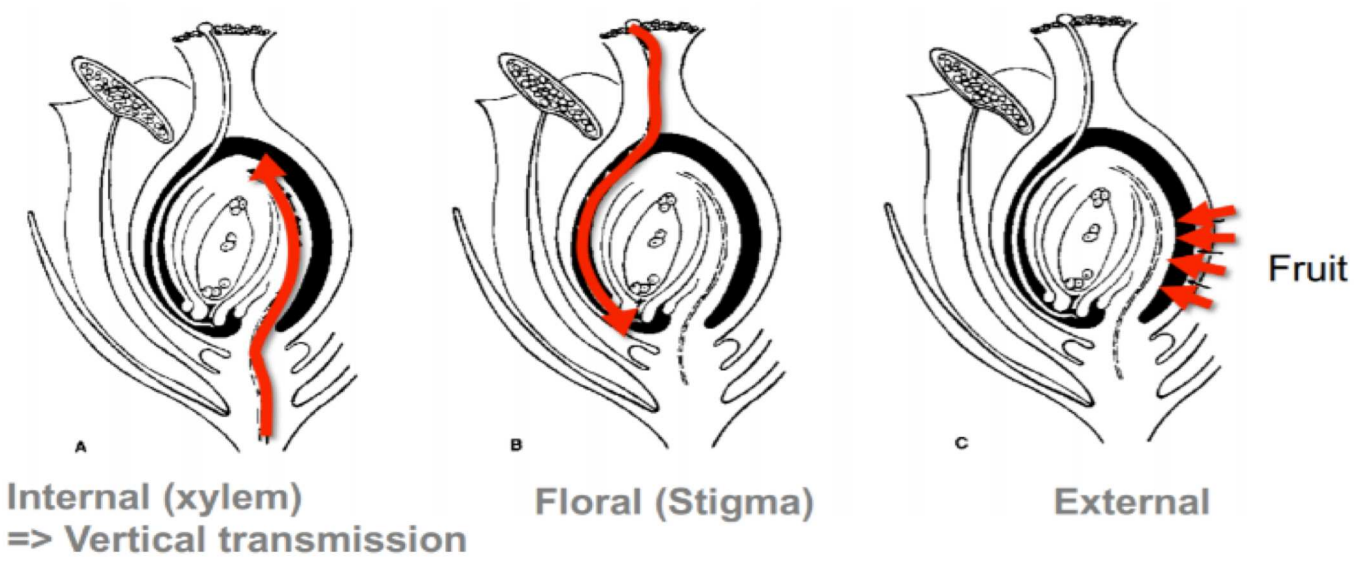
Solène Mauger[1] | Claire Ricono[1] | Cendrine Mony[1] | Vèronique Chable[2] | Estelle Serpolay[2] | Marine Biget[1] | Philippe Vandenkoornhuyse[1]

The present study shows the effect of plant breeding on the microbiota associated plant root.

Seed production to better manage for organic sector

Three main routes of transmission of microorganisms on the seed, as currently described:

- **internal** (from whole plant to seed),
- **floral** (from stigmate to seeds),
- **external** (through fruit) (Maude, 1996)



Among others, the seed microbiome supports:

- **seed germination, seedling growth and establishment** as well as the recruitment of other taxa by interacting with other microorganisms in the spermosphere (Nelson et al., 2018) for the plant fitness (also strongly impacted by plant species and soil type together (Berg & Smalla, 2009)).
- **disease resistance** with the example of the role of endophytic microbiota of rice seed (Matsumoto et al., 2021)
- **preservation of the continuity of transmission from one generation to another for plant adaptation** (Berg & Raaijmakers, 2018).

From industrial agriculture to organic farming

Looking back at the domestication process and development of industrial agriculture,

- the genetic diversity of the associated microbiome reduced and shifted,
- the selection of traits (based on genetic knowledge) which mainly focused yield increases to cover humans' calory demand, but not the quality.

The consequences: the disorders of ecosystems and human health (malnutrition, obesity).

Genetic science has gained importance with the creation of professional breeders and a seed market (and seed regulations) for an industrial agriculture.

- How to better balance between all scientific approaches in matter of resilience of our food systems?

Less genetic, more holistic

Poor understanding about genetic factors in shaping beneficial plant microbiomes.

The interaction with the environment seems often more relevant.

- Can this lack of knowledge become an invitation to relativise the supremacy of genetical approaches of the selection and to broader the question of plant adaptation and co-evolution with its environment and with farming practices?

The complexity of the question also invites to conceive the answer collectively with other actors, mainly organic farmers to organize organic plant breeding and seed production.

Several new perspectives for organic seed production and organic plant breeding

starting with the relationships between soil and seed, thinking practices and plant breeding together

- Plants nourish soil microbial life (plants makes soil)
- Soil life makes evolve plants and this information can be transmitted

Three forms of heredity connecting genetic, epigenetic and holobiont knowledge that can contribute to the further development of organic plant breeding and seed production,

in various contexts: on-farm, small scale breeding, large companies.

Conclusion
How to integrate:

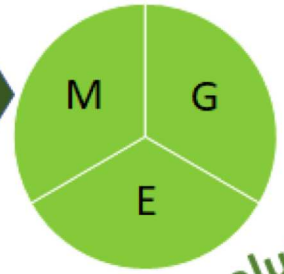
- the recent discoveries and new understandings of the co-evolution between plants and their microbiome
- and the resulting dynamic interactions in plant breeding and seed production

underline the importance of a holistic concept of organic plant breeding and seed production, a key for the further development of a “true” organic farming.

SEED

Balance between Genetic, Epigenetic and Microbiome information in the **relationship**

between the plant growing from the seed and the place where it grows



Type of selection

Type of production

Coevolution

Natural selection

Wild life

Coevolution

On-farm plant breeding and seed production

Organic and peasant farming

Organic farming

Organic plant breeding and local/regional seed production

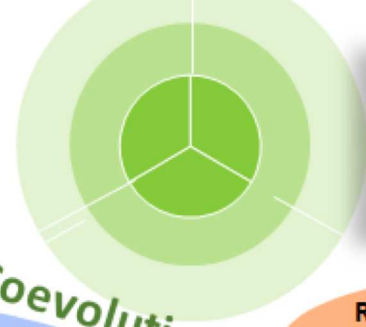
Industrial farming

Modern plant breeding and large seed market

Industrial organic farming

Modern plant breeding and organic seed on large market

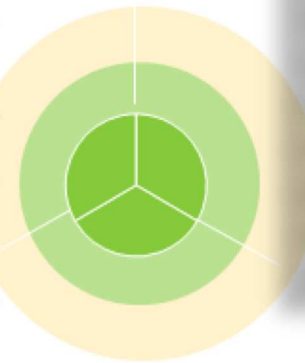
Ruptures due to plant domestication, loss of diversity and production outside the origin



Comment: Environment, practices and selection make crops evolve and adapt generation after generation

Ruptures due to stability of varieties, and seed are produced in the region but outside the farm

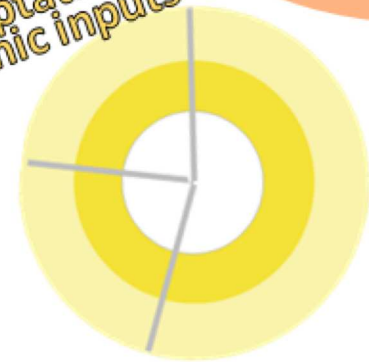
Local adaptation
No coevolution



Comment: Organic practices, organic selection for diverse cultivars and seed multiplication allow crops to adapt to environments similar to the area of production

Ruptures due to homogeneity/stability of varieties, and seed are produced far from the area of production

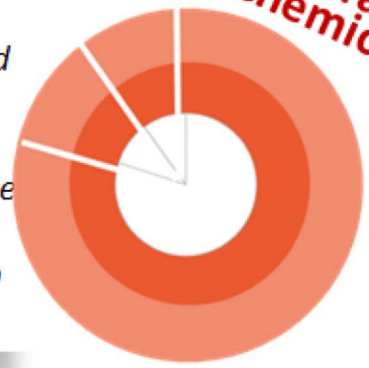
No coevolution,
Adaptation
Organic inputs



Comment: Breeding traits for better links between plant/microorganisms and in organic seed multiplication enhance crop adaptation in diverse organic farming conditions

Ruptures due to artificial inputs, biotechnologies, seed multiplied outside the area of production and seed treatments

No coevolution,
No natural adaptation
Chemical inputs



Comment:
Breeding traits for yield and disease/pest resistance, industrial seed production and see treatments don't allow any natural adaptation processes.

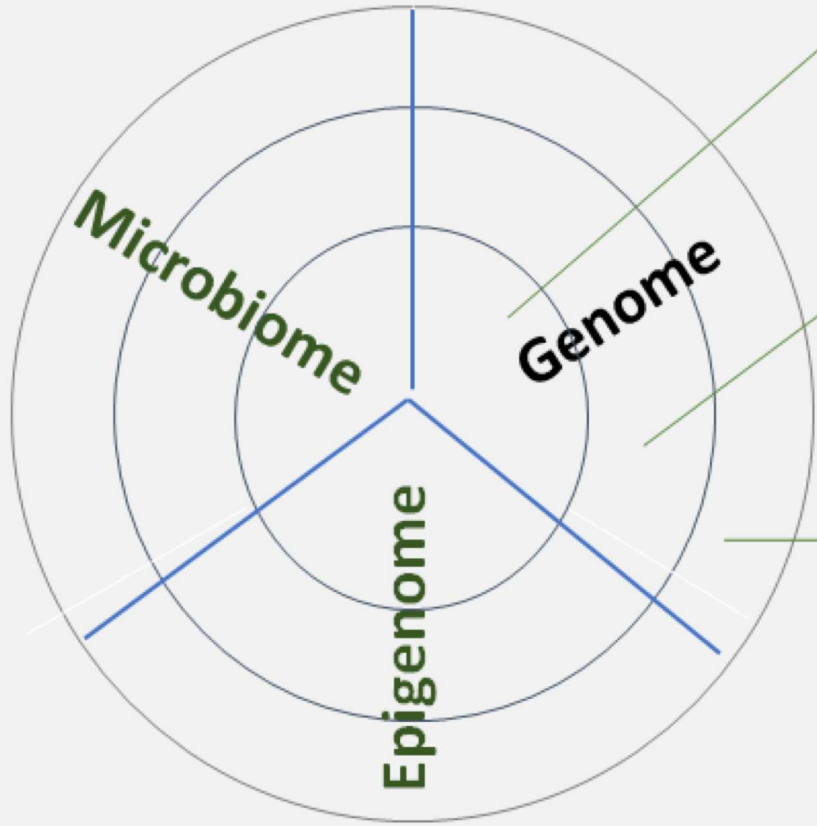
Explanation of the seed representation

Registered in:
Genome – Epigenome - Microbiome

Information which favour at the same time co-evolution, plant adaptation, and production

Information which favour preferentially plant adaptation to a farming system

Information which favour preferentially crop productivity in a food chain system



Influence on hereditary information of the:

Natural environment of the field where the mother plant grows

Type of agricultural practices in the field

Type of human selection

One seed: its supports of hereditary information and sources of modifications/influences of these supports of information

On farm plant breeding and peasant seed