



UMR Agroecology's research

Christophe Salon, Céline Bernard, Mickaël Lamboeuf, Christian Jeudy

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Dijon

Unité de Recherche



Institut
national
supérieur
des sciences agronomiques
de l'alimentation et de l'environnement



UBFC



UMR 'AGROÉCOLOGIE' RESEARCH

INRA, Dijon, France

Christophe Salon, UMR Agroécologie, INRA, Dijon, France

Context and Challenges

■ Context

- Increase of the world population: 2010=6.8 Md → 2050~9 Md

↳ Increased demand of food provision

- Decrease of the arable lands: Arable land/person 0.38 ha (1970) → 0.23 ha (2000) → 0.15 ha (2050)

- Increase of the inputs

✓ fertilizers with limited resources (P) or with high energy cost (NO_3^- , NH_4^+)

✓ pesticides with possible threats for agricultural products, soils and water

✓ water contributing to geopolitical tensions

- Acceleration of climate change, to which agriculture is subjected but also contributes.

Lack of sustainability of the current situation

- On the top of food provision, expectation of agro-ecosystems to deliver :

- supporting services (primary production)

- regulation services (climate regulation, pest regulation, water purification)



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AGRO SUP



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- Necessity for a paradigm change
 - Agronomic and environmental challenges
 - ✓ Provide agricultural products in high enough quantity and quality
 - ✓ Decrease the use of inputs
 - ✓ Preserve the environment (sol/water/air) / Deliver ecosystem services
 - Bring together Agronomy and Ecology
 - ✓ Design cropping systems : respect and valorize the biodiversity, the regulations and interactions among communities (biotic interactions)
 - ✓ Adapt the crop to the environment rather the environment to the crop
- ➡ Emergence and promotion of **Agroecology**

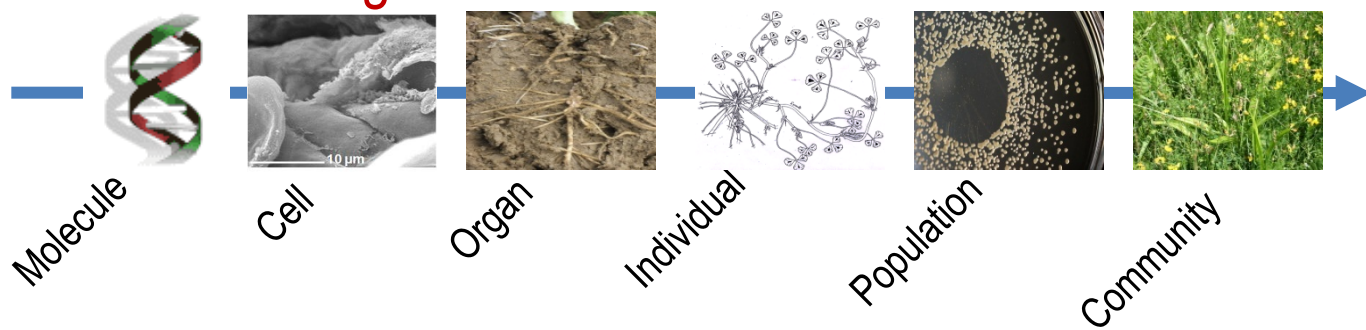
Scientific project

Understand, preserve and valorize biodiversity and biotic interactions for development of agroecological systems

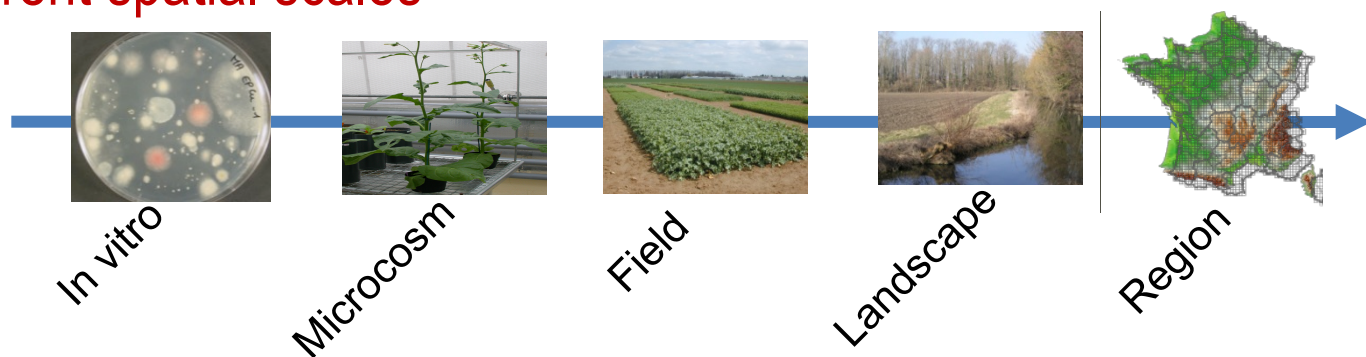
- Analyze, understand and act on the interactions and regulations among communities (microbes & plants) at different spatial and temporal scales
- Design and assess innovative cropping systems delivering agricultural products with a quantity and quality high enough, while preserving the environment quality

■ Integrating different levels of organisation & spatio-temporal scales

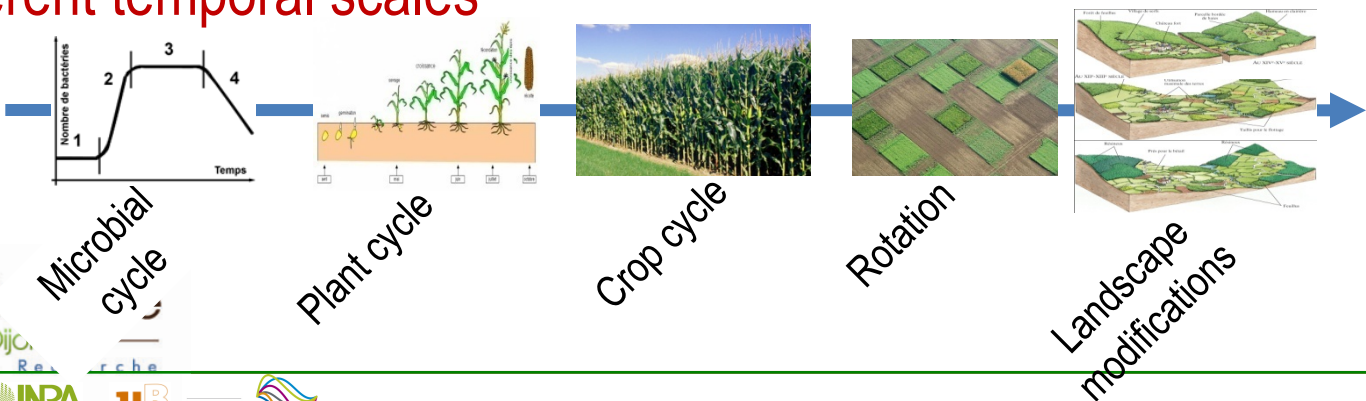
- Different levels of organization



- Different spatial scales

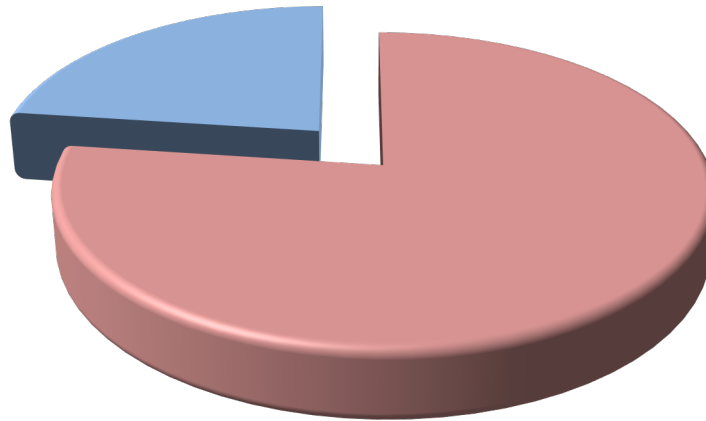


- Different temporal scales



Human Resources

31/12/2017



Total: 330

 Non-permanent staff  Permanent staff



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Teams

- **BIOmE**: Microbial ecology and biotic interactions supporting soil ecosystemic functions in agro-ecosystems
- **GESTAD**: Agronomy, ecology and genetics of arable weeds, design of agroecological cropping systems & landscapes
- **GEAPSI**: Genetics and ecophysiology of cultivated (legumes) plants
- **IPM**: Plant-microbe interactions at the molecular and cellular levels, plant immunity, fungal ecology & biocontrol

Large Research Unit « Agroecology »

⇒ Largest INRA research unit gathered around knowledge for conception & evaluation of the performance of innovative cropping systems



P Lemanceau

BIOME



**Cereals,
Brassica**

GEAPSI



**Mostly legumes,
Maize
Tomato
Cereals**

IPM



**Legumes,
Arabidopsis,
Tobacco,**

GESTAD



Weeds



F Martin



C Salon



S Jeandroz



S Petit

General organization

Research assistance

F. El Ghissassi

Administrative
& Resource
Management Cell

Support Cells

Teams

Biology and ecosystemic
functions of soils
(BIOmE)

F. Martin-Laurent

Sustainable
Management of
Arable Weeds
(GESTAD)

S. Petit-Michaut

Genetic and environmental
determinisms of the
adaptation of plants to
innovative cropping
systems
(GEAPSI)

C. Salon

Mechanisms and
management of plants-
microorganisms
interactions
(IPM)

S Jeandroz

Platforms & Biological Resource Center

GenoSol
S. Mondy

Microscopy
J. Lherminier

4PMI
C. Salon & C. Bernard

Biological Resource Center
C. Steinberg

Theme-based scientific workshops

Ecology of
communities in
agroecosystems

Design of
agroecological
systems

Ni. Munier-Jolain

Plants-
microorganisms
interactions

C. Salon & D. Wipf

Ecological
engineering

A. Hartmann

Interactions
between modeling
and experiments
/observations

N. Colbach



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Platforms & Biological Resource Center

GenoSol

Biological resource Centre

11 300 sample ; 1 500 new par year

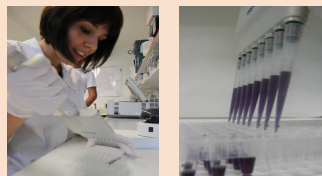


IBISA
INFRASTRUCTURES
BIOSCIENCES
SANTÉ
ET AGRICULTURE



Sampling, storage and availability to scientific collaborators

Technical platform

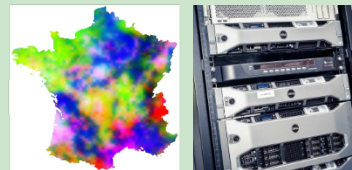


Monitoring of microbial diversity

DNA extraction, Bank preparation prior to sequencing

Bioinformatic/Biostatistic

800 000 stored data; 3 computer servers
> 70 millions DNA reads



Database (MicroSol)
Bioinformatic pipeline dedicated to analysis of microbial diversity
Statistical tools

- 4 ETP (3 permanent IR, AI, TR et 1 CDD) from april 2016



A new space to develop the platform activity (2015)

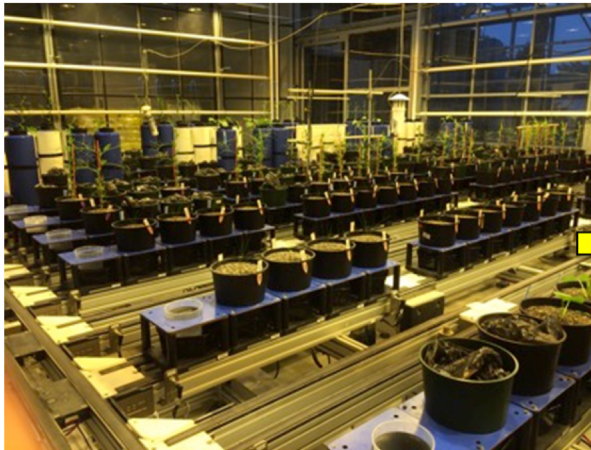


❖ An integrated platform



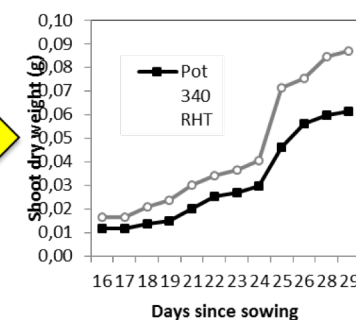
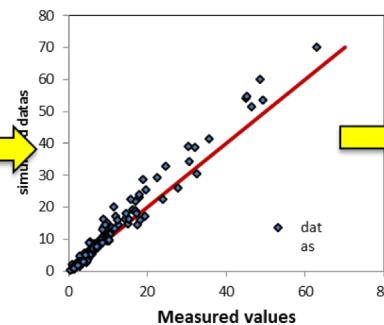
4PMI

- **Aims:** Develop innovative automated techniques for **high throughput morphometry of plants** produced in controlled conditions with a **focus on plant root-microbe interactions**
- **Staff:** 1 Research Manager, 1,5 Engineer, 1 Assistant Engineer, 6 technicians
- **Equipments:**
 - 4 automated greenhouse and 1 climatic chamber high CO₂
 - High throughput shoot and root phenotyping and their imaging cabins



Plant leaf area (cm²)

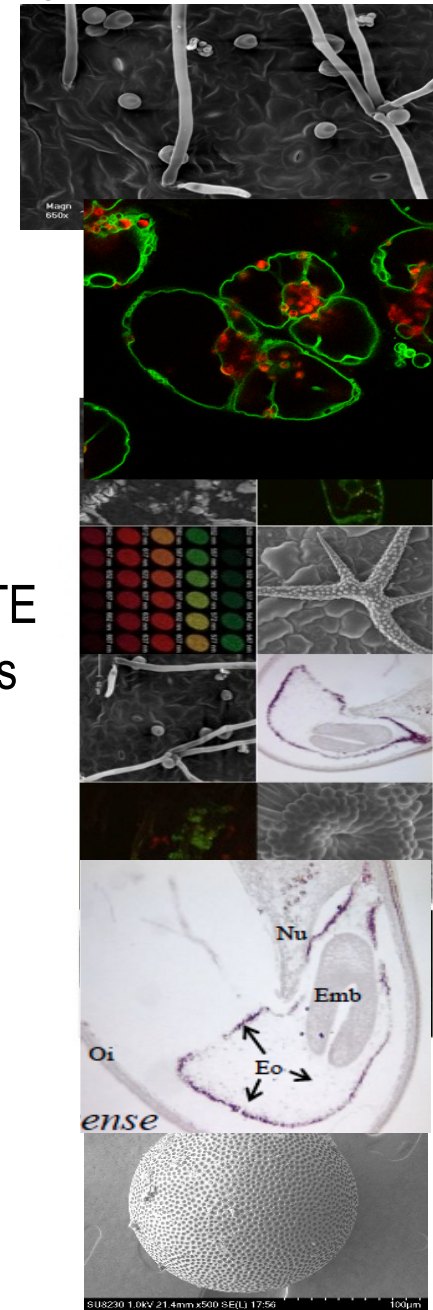
Estimated Shoot Dry Weight



Microscopy platform, part of the Campus Imaging Center



- **Aims:** Multi-user microscopy facility, *in situ* localization of molecules, cellular dynamics and molecular interactions
- **Staff:** 3 Engineers INRA, 2 technicians (INRA & uB)
- **Equipments:** confocal microscopy, laser capture microdissection, TE & SEM, equipments for sample preparation including cryo-technologies



■ Missions

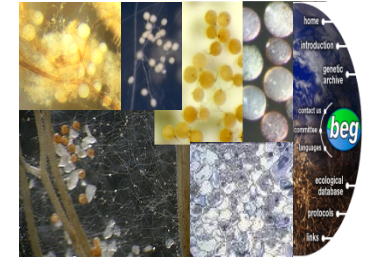
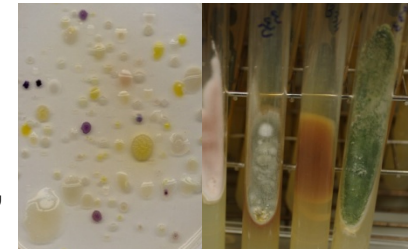
- Preservation of biodiversity and collected related information
- Opening collection to the scientific community for the purpose of research, development and identification.

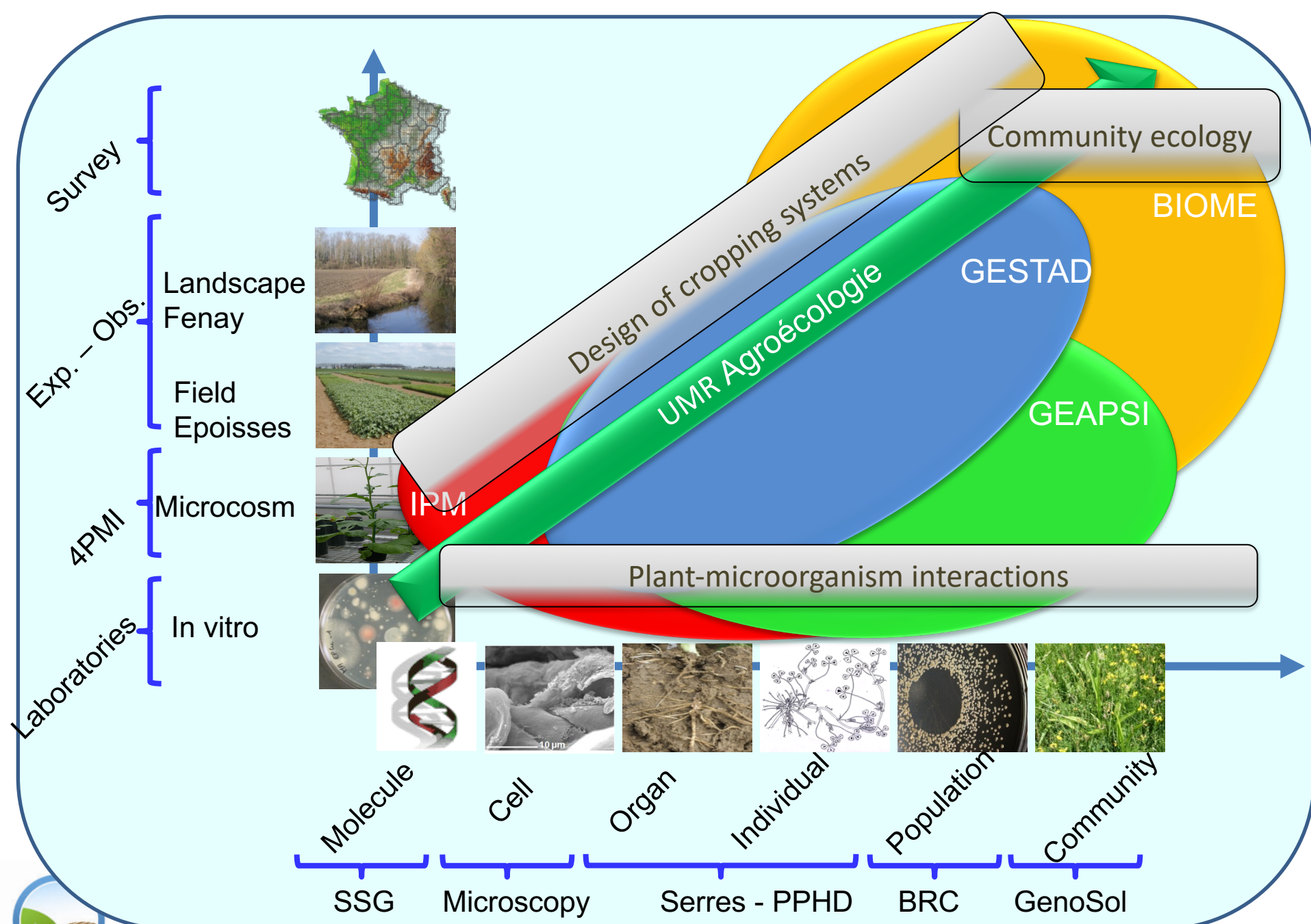
- **Staff:** 0.7 Engineer, 1.5 technicians, goodwill of researchers, but lack of a real curator

- **35 000 accessions** to characterize, preserve, multiply, manage and distribute:

- **Microorganisms of Agro-Environmental Interest**
- **Large-seed legumes** (42%) iover 5,000 accessions, pea mutants (tilling). This collection is part of a national certified CRB for legumes
- **Weeds** (12%): "libraries" of seeds, nuts, and photo allowing taxonomic identification of most of weeds

- **Databases** including continuous ecological characteristics and the added value provided by resource users.





- Strong international cooperation (54 countries)



Geographical distribution of UMR publications co-authored with international scientists (47%).

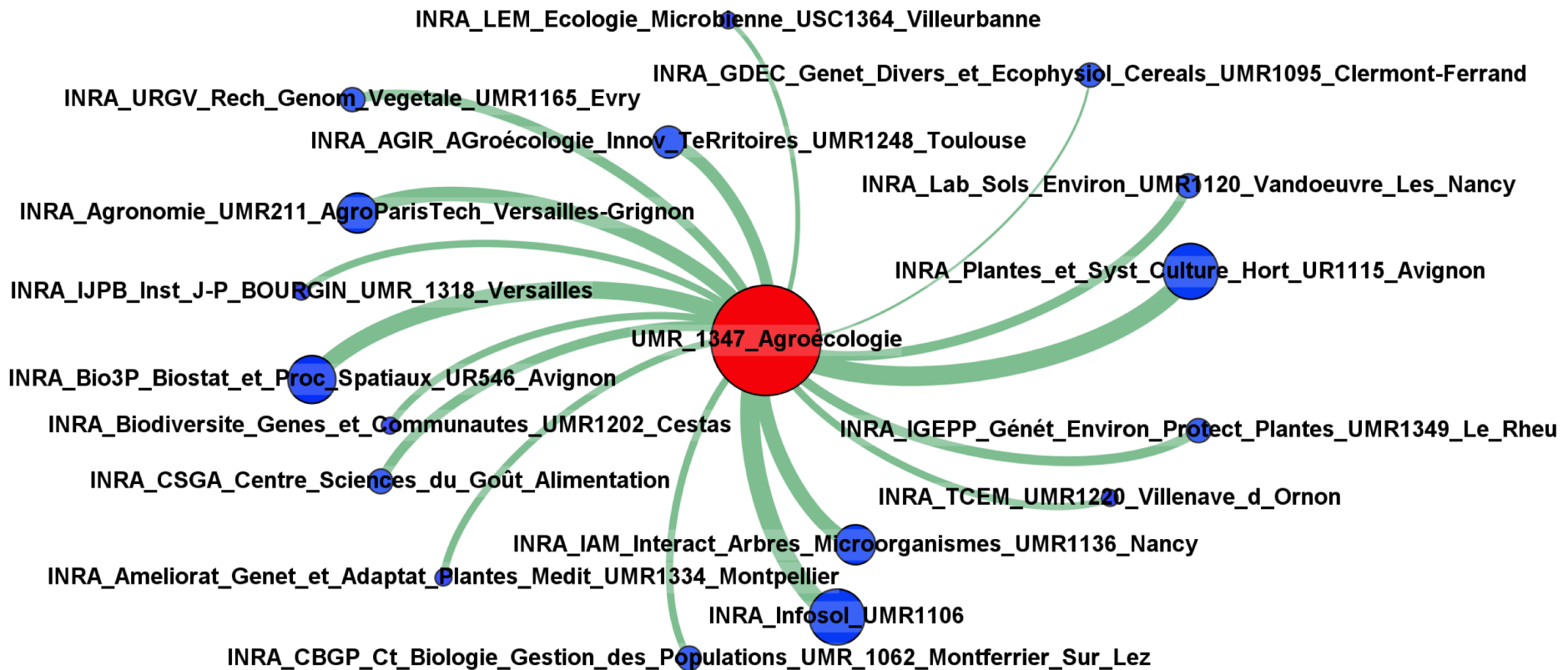


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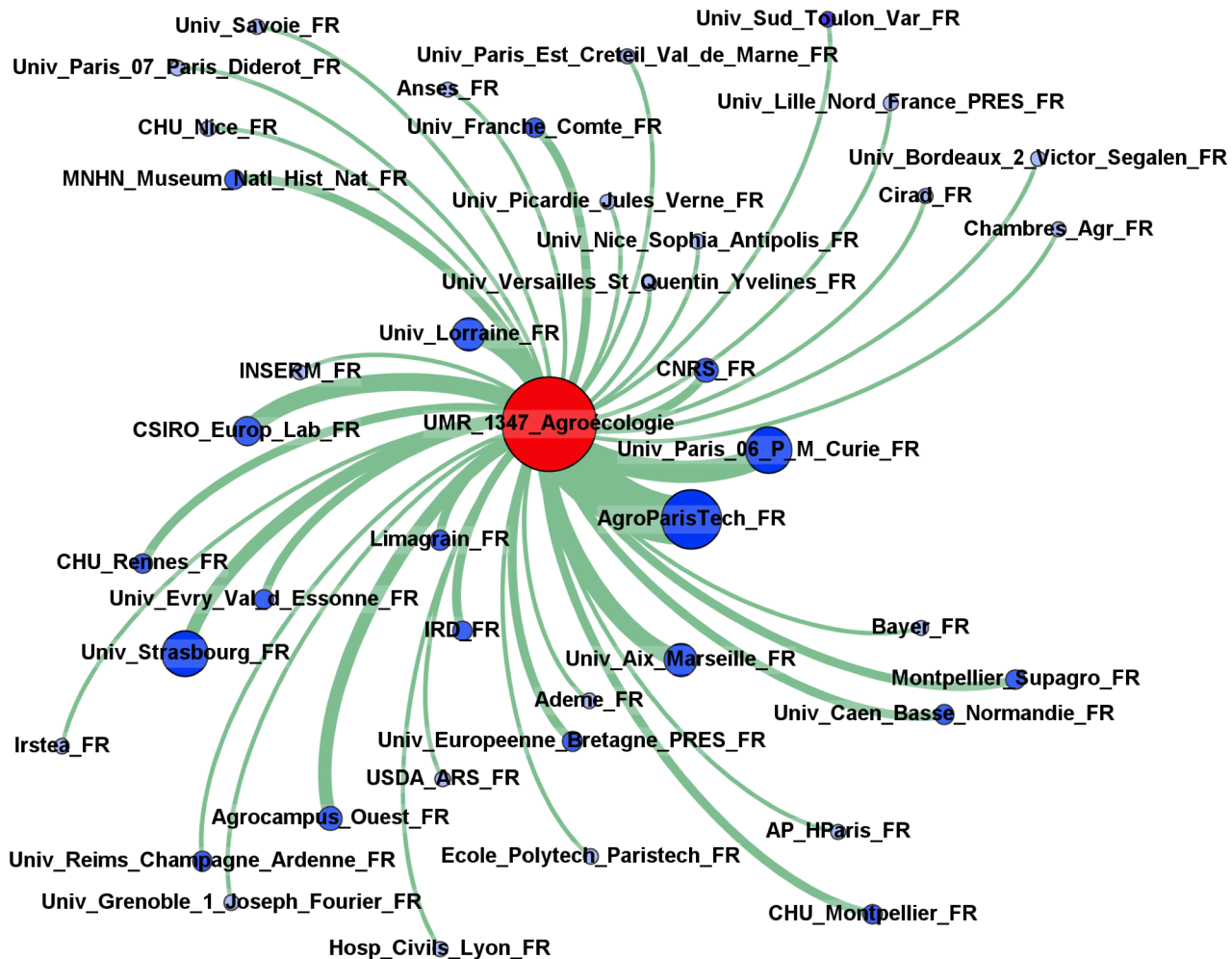


Academic reputation and appeal

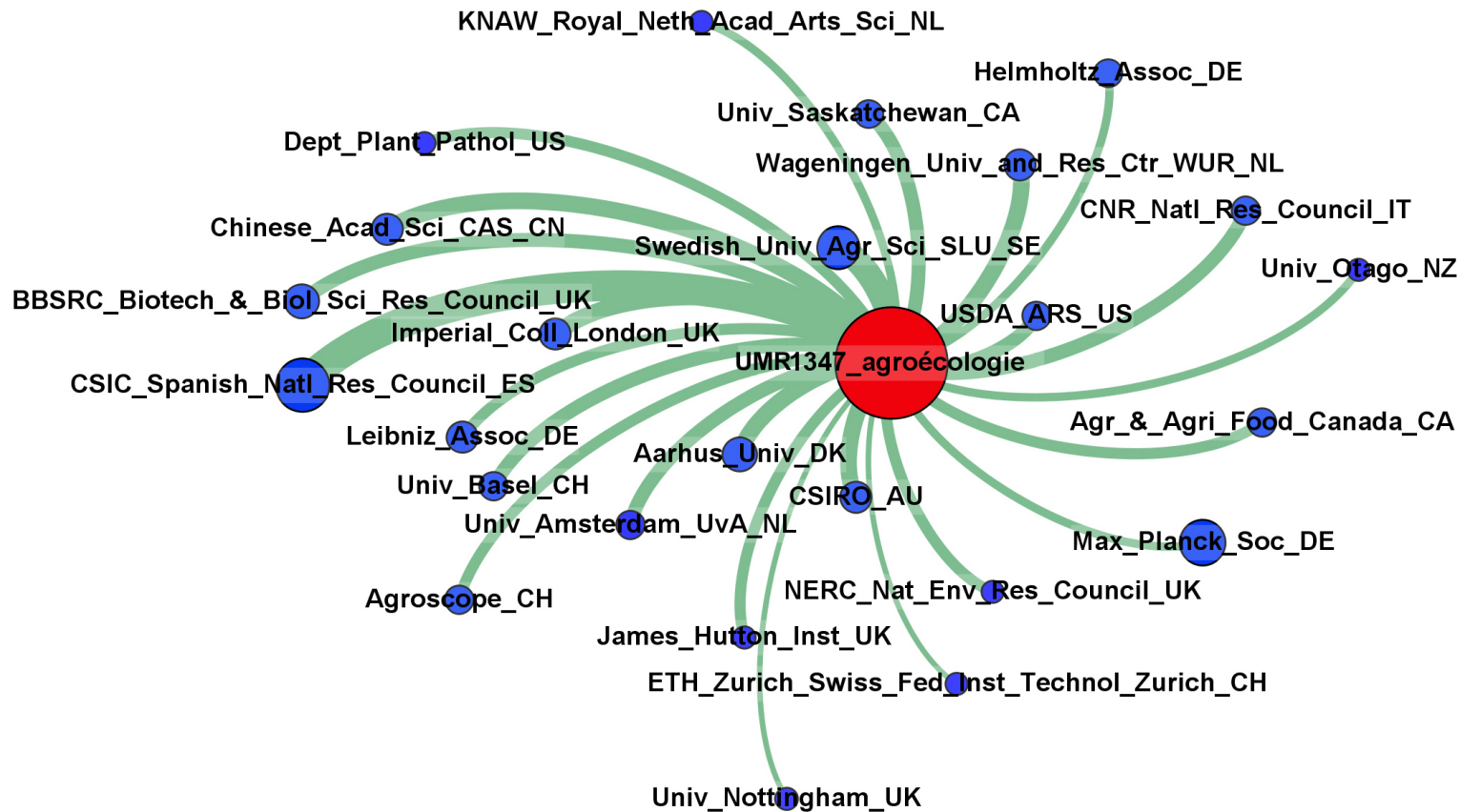
- Collaborations with French Institutes: INRA labs (17 out of 55)



■ Collaborations with French Institutes (40) excluded INRA labs



■ Collaborations with international Institutes (25 out of 242)



GEAPSI TEAM

Genetic and Environmental determinisms of Plant Adaptation to Innovative cropping Systems

Leader :
C. Salon



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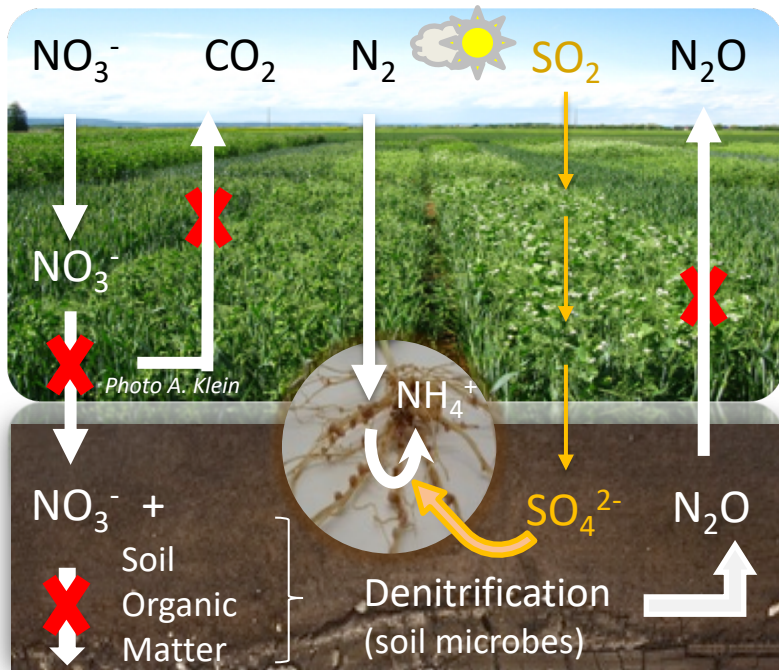


➤ Scientific objectives

Mechanisms underlying the adaptation of plants to agroecosystems

- **multidisciplinary approaches** : genetics, genomics, ecophysiology, molecular physiology
- **different species** : target species and model species, depending on available genetic and genomic resources

Project centered on legumes



A sulfur deficient budget

Merits for agroecology

- Reduction of nitrogen fertilizer; greenhouse gas and nitrate leaching
 - Positive effects on following crop
 - Diversification of cropping systems
- ➔ Exploit nitrogen symbiotic fixation with legumes in cropping systems
- ➔ Essential in Agroecology cropping systems

Merits for nutrition:

- Protein source
- ➔ Grain legumes of proximity rich in proteins

But under represented:

- 3 % EU arable land, < other continent

Main objectives: increased profitability through higher and more stable yield and protein content, and new uses.

➔ **Stabilize yield and seed quality in a fluctuating environment**
ex. water and nutrient availability (e.g. sulfate)

➤ Finalized objectives:

- Identify **plant ideotypes** for lower input agriculture
- Improve crop **adaptation and resilience** to environmental constraints
- Implement **breeding** programs towards these aims

Background and aims

➤ Research topics :

- optimization (time x space) of **soil resource uptake** by legumes in a **context of fluctuating resources** (soil N, S, water) in **connection** with **soil microflora**.

Low input systems
Less pollution
➔ **S deficiencies**

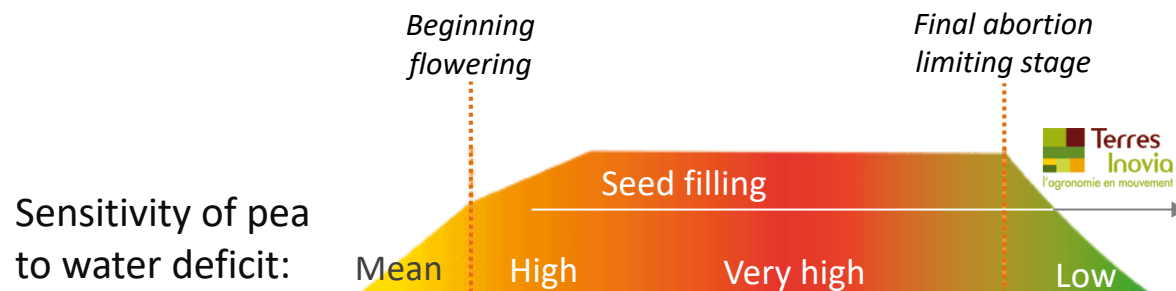
Climate change
➔ **water deficit**



➤ **Symbiotic N fixation**

➤ **yield**

➤ **Seed quality**



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➤ Research topics :

- optimization (time x space) of **soil resource uptake** by legumes in a **context of fluctuating resources** (soil N, S, water) in **connection** with **soil microflora**.
- understanding of **legume functioning** to **improve** and/or **stabilize yield components**, including **seed composition and quality**, particularly during **heat, water-stress** and **nutrient deficiencies** (N, S, Fe, others).

➤ Research topics :

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- understanding of **legume functioning** to **improve** and/or **stabilize yield components**, including **seed composition and quality**, particularly during **heat, water-stress** and **nutrients deficiencies** (N, S, Fe, others).
- study of the **genetic bases** and processes enabling plant **adaptation to agrosystem** habitats.

Background and aims

Tools & resources

- Plant phenotyping tools
- Plant modeling tools
- Genetics and genomic tools
- Legume genetic resources

LEGUMES

Research axes

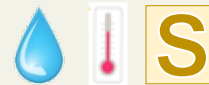
Shoot

N S partitioning and remobilization



Seeds

Seed filling, development and quality



Plant nutrient uptake



Nodulated Roots

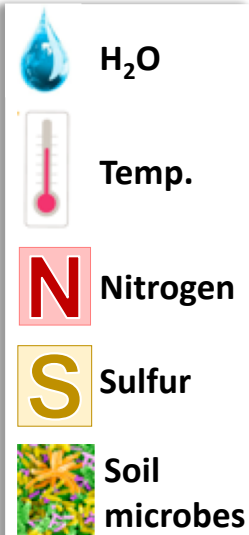
Soil nutrients
Soil microbial communities

Impact of plant species/genotype on soil microorganisms



Environmental factors

Genetic variation



The path...



Tools and methods set up

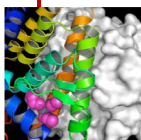


**Building genetic variability for
root and nodules development**



CONCEPTION of LEGUME IDEOTYPES

**Characterizing mechanisms and
molecular basis associated to N
nutrition**



The path...: Tools and methods



Tools for growth culture and phenotyping

Characterizing root development



Growth pouches, hydroponics



Split root

C, N, S flux measurement

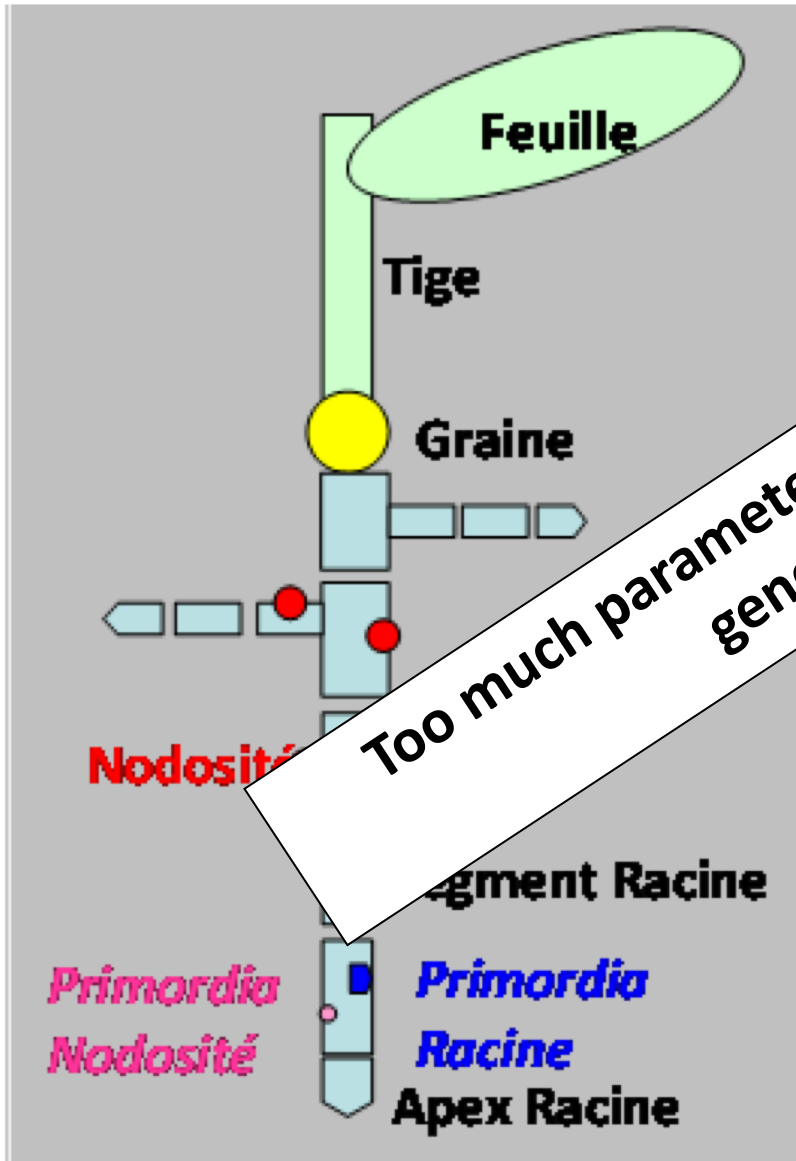


Labeling chamber $^{13}\text{C}/^{15}\text{N}/^{34}\text{S}$

The path...: Tools and methods



Mechanistic models : PEA NOD (coll. L Pagès)



Understand key interactions and their

- many N interactions, structure, evaluating environmental variations.

Too much parameters for taking into account genetic variability

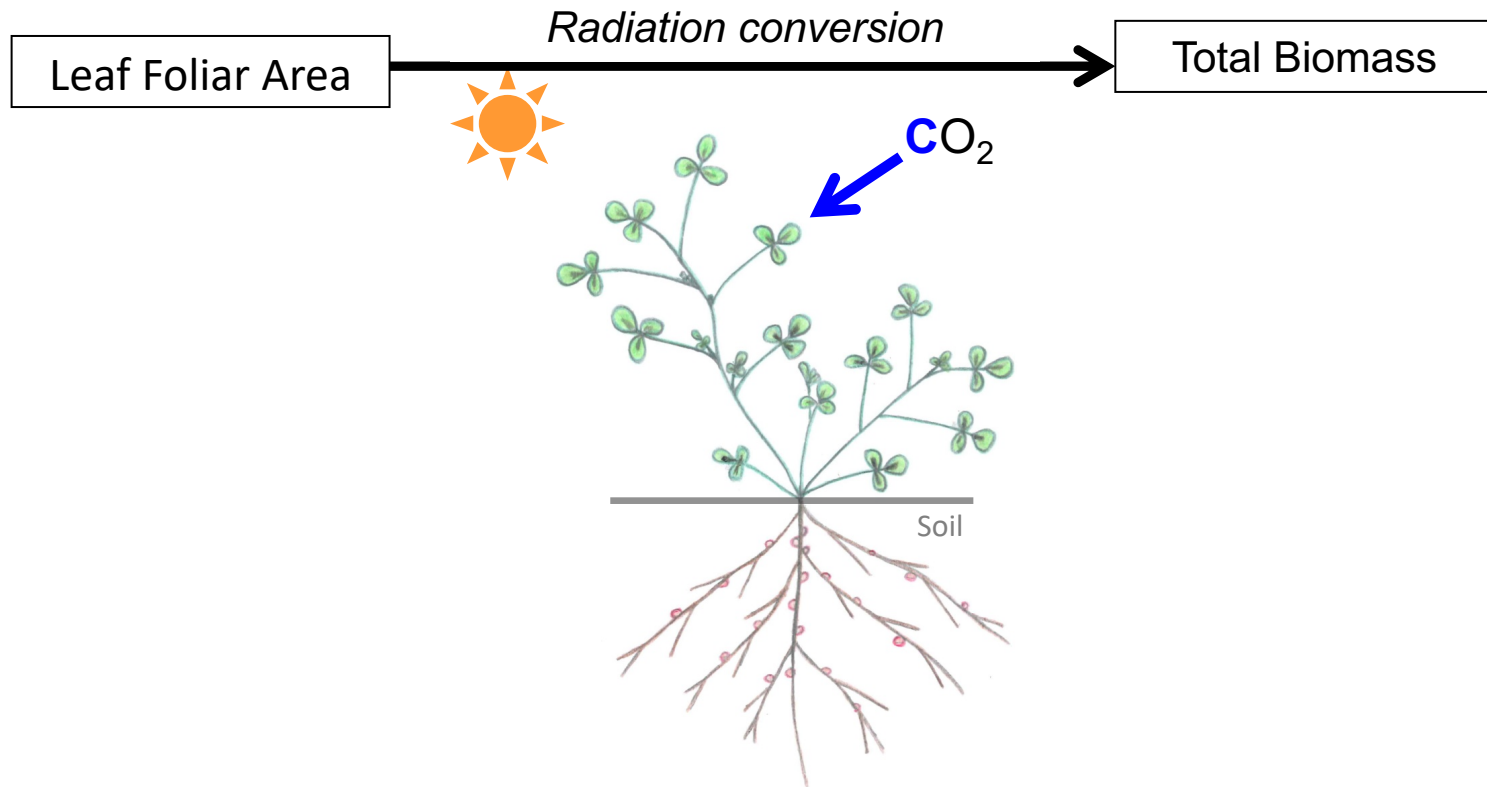
Naudin et al. Plant & Soil 2011
Agrophysiologie du pois 2010
Voisin et al. Plant & Soil 2010
Salon et al. CR Biologies 2009
Voisin et al. Annals Bot 2007

The path...: Tools and methods



Integrative Model: *Medicago*

Decomposing integrative variables in physiological processes



Moreau et al. Plant Cell Environn 2006

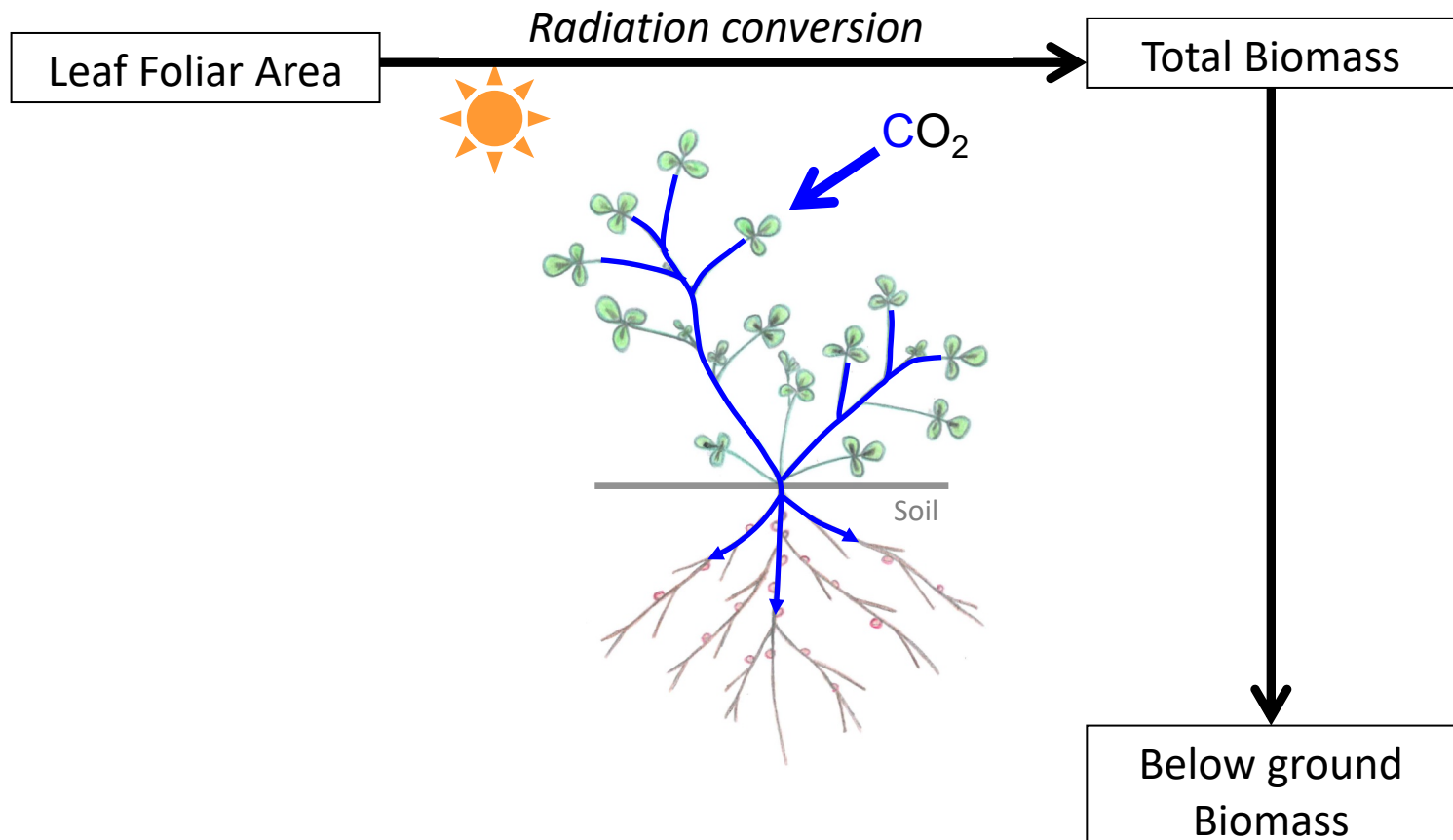
Moreau et al. JExp Bot 2008

The path...: Tools and methods



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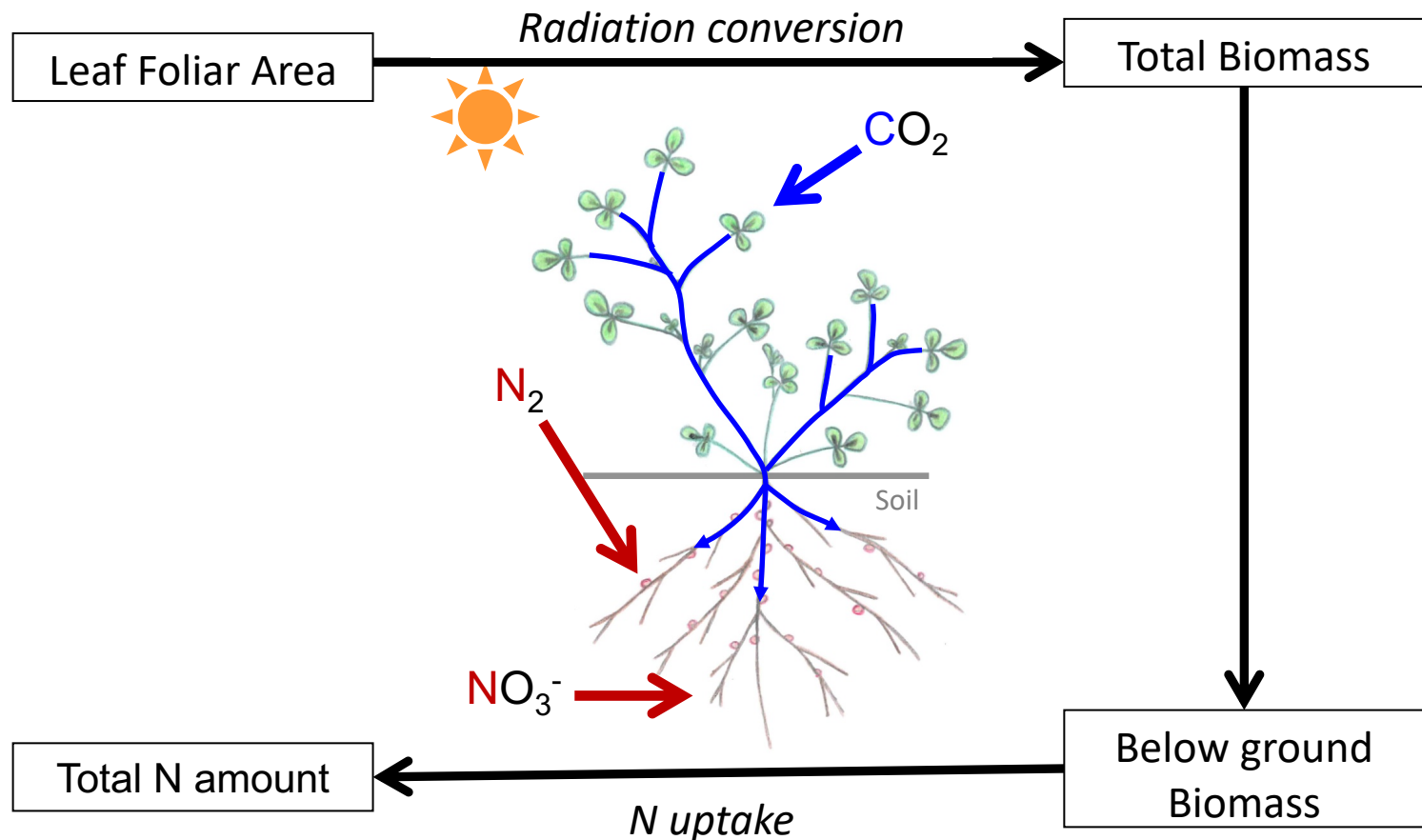
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The path...: Tools and methods



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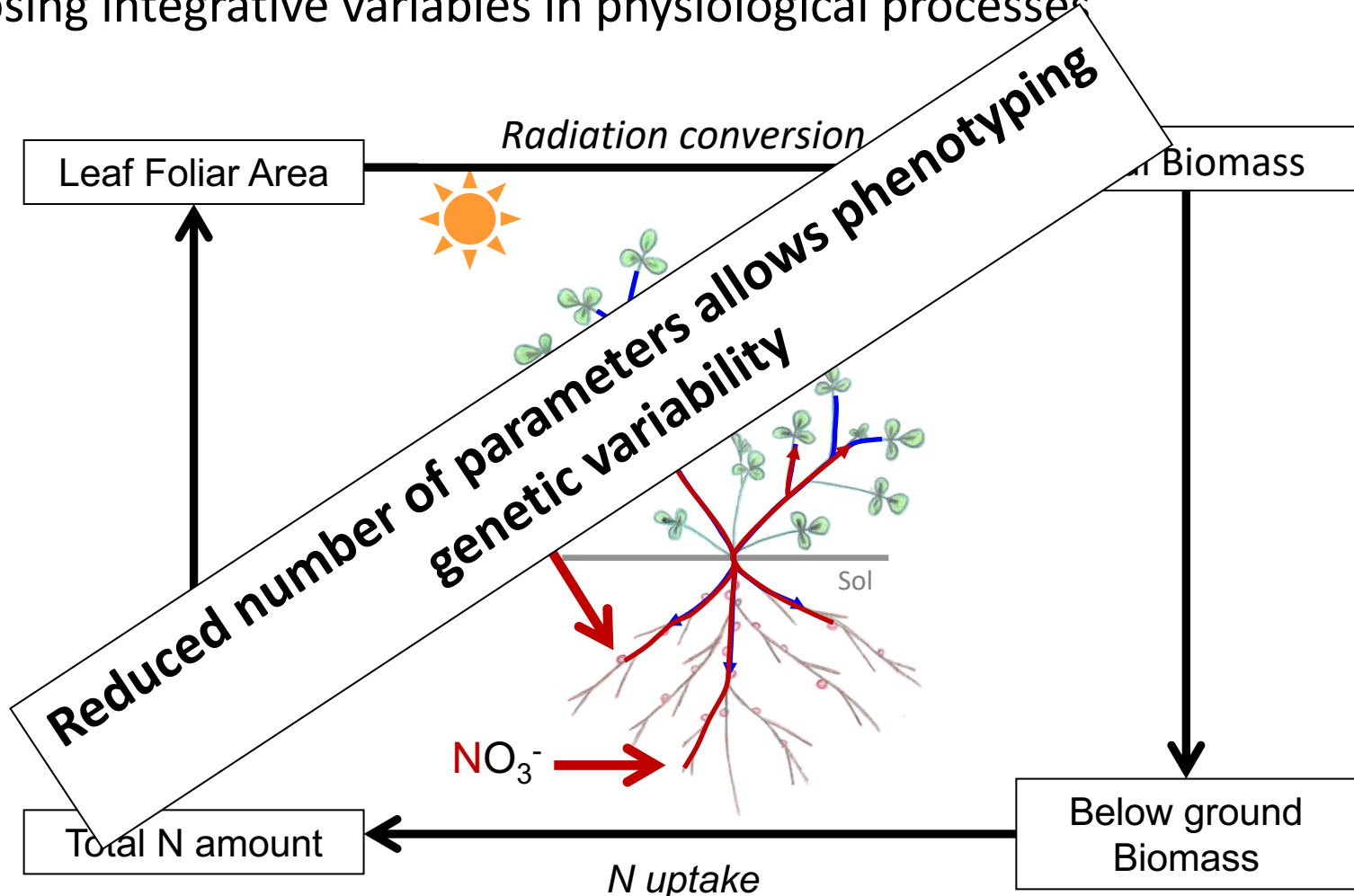
Moreau et al. JExp Bot 2008

The path...: Tools and methods



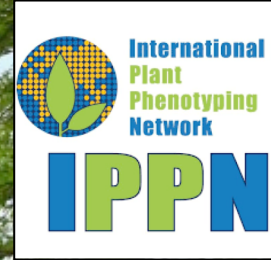
Integrative Model: *Medicago*

Decomposing integrative variables in physiological processes



Moreau et al. Plant Cell Environ 2006

Moreau et al. JExp Bot 2008



4PMI: Plant Phenotyping Platform for Plant and Microorganisms Interactions










InoviaFlow



INRA
SCIENCE & IMPACT



SHAKTI

World wide
distribution



Phenoware



Qubit
SYSTEMS

PhenoTrait

Trademark







The path...



Tools and methods set up

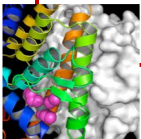


**Building genetic variability for
root and nodules development**



CONCEPTION of LEGUME IDEOTYPES

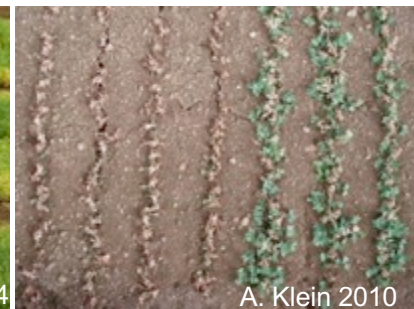
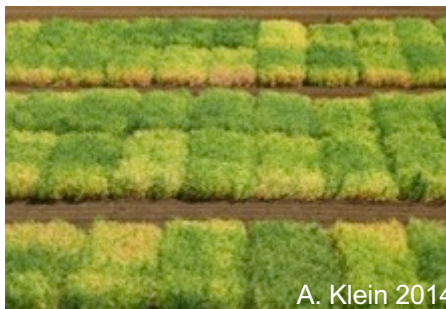
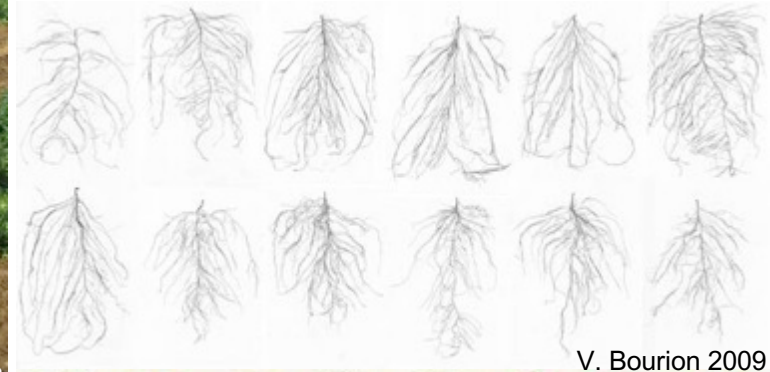
**Characterizing mechanisms and
molecular basis associated to N
nutrition**



Background and aims : Among available tools

Pea genetic and genomic tools for functional & structural approaches

An impressive phenotypic diversity available in the *Pisum* genus



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The path...



Tools and methods set up

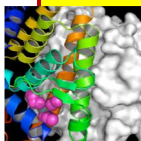


**Building genetic variability for
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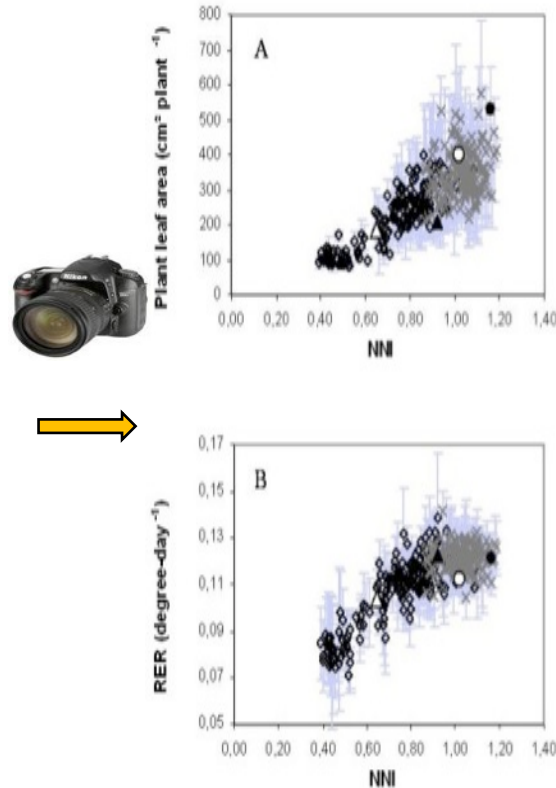
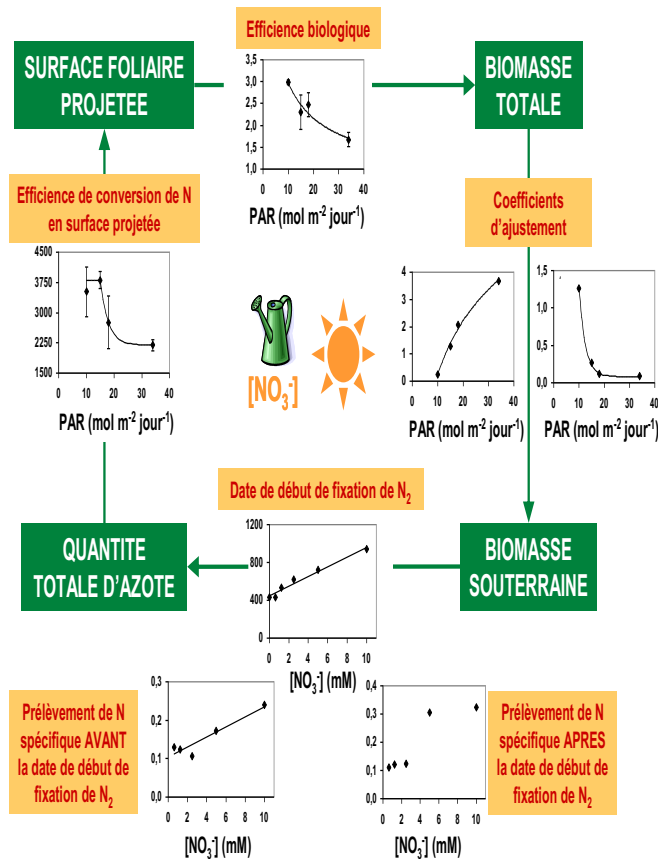


CONCEPTION of LEGUME IDEOTYPES

**Characterizing mechanisms and
molecular basis associated to N
nutrition**



Detect contrasted N nutrition: “archeo phenomics”



Genotypes of Medicago RIL ranked for ability to uptake N

Model

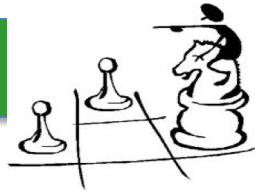
Dynamic leaf area measurement

Moreau et al. (2006), Plant, Cell and Envir., 29:1087-1098.

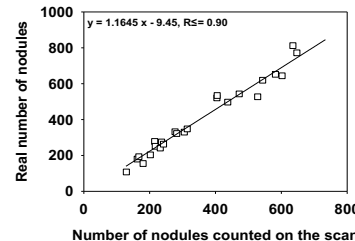
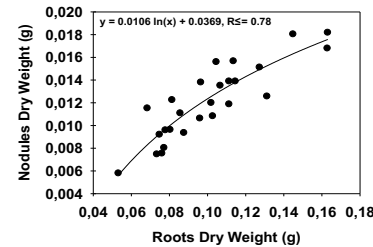
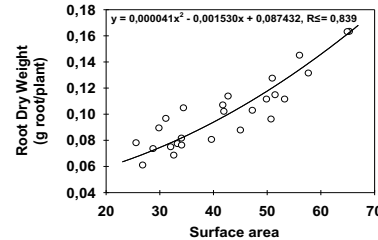
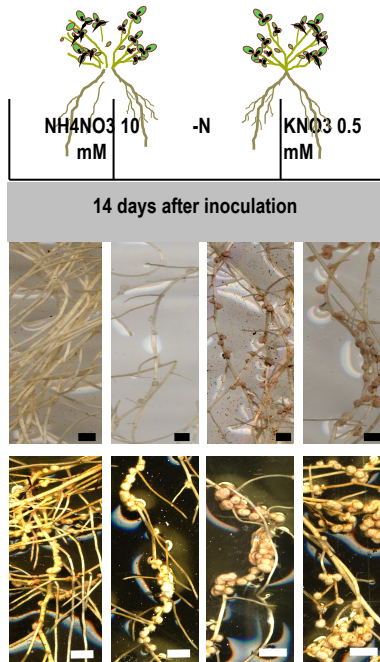
Moreau et al. (2007), Plant, Cell and Envir., 30:213-224.

Moreau et al. (2008), J. Exp. Bot., 59:3509-3522.

Identify a strategy: “archeo phenomics”



Adaptative strategy of plants faced to a N constraint



**Morphometry
versus
functional
strategy
identification**

**Split
roots**

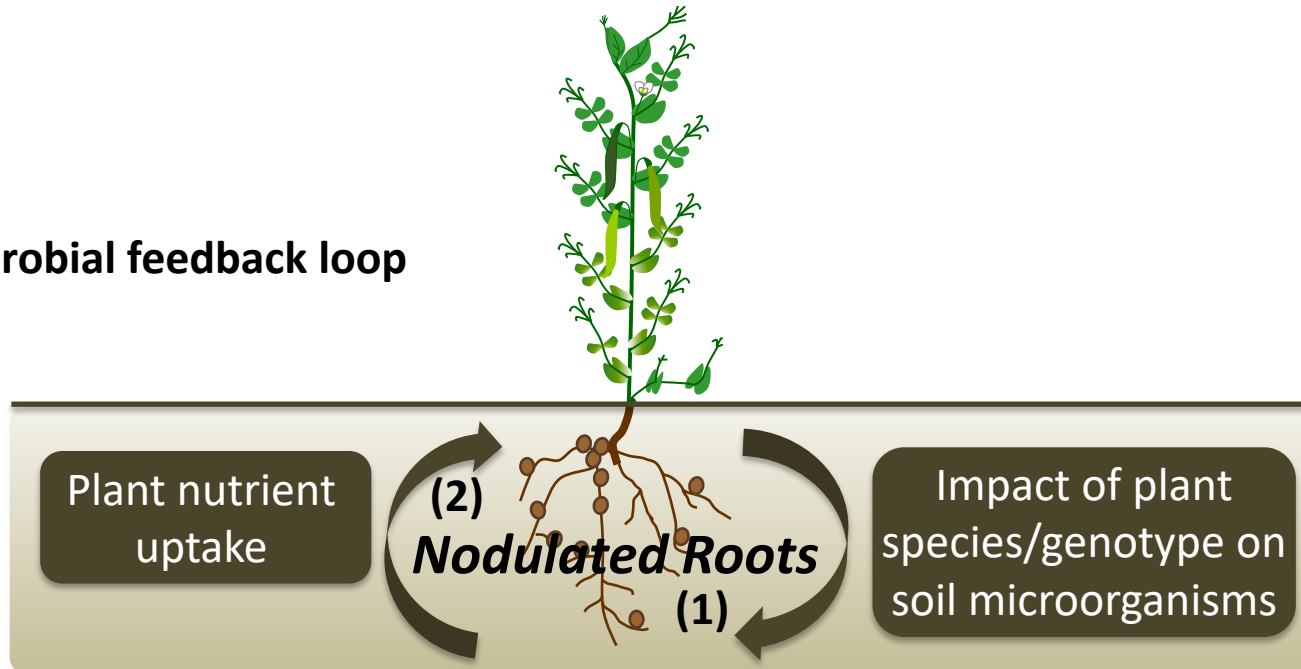
**Nodules number and
size, appearance**

Ruffel et al. (2008), Plant Physiol. 146: 2020-2035.
Salon et al. (2009), CRAS, 332 :1022-1033.
Jeudy et al. (2010), New Phytol, New Phytol., 185:817-828.

Background and aims: among research themes

Legume-microbe interactions to improve plant growth and nutrition

Plant – Microbial feedback loop



(1) Impact of plant genotype on the selection of soil microbes

not only rhizobia : whole microbiome

(2) Impact of soil microbe diversity on plant growth

N nutrition and tolerance to other stresses

**Final aim: drive plante-microbe interactions through plant genotype
= a new breeding target**



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Background and aims: among research themes

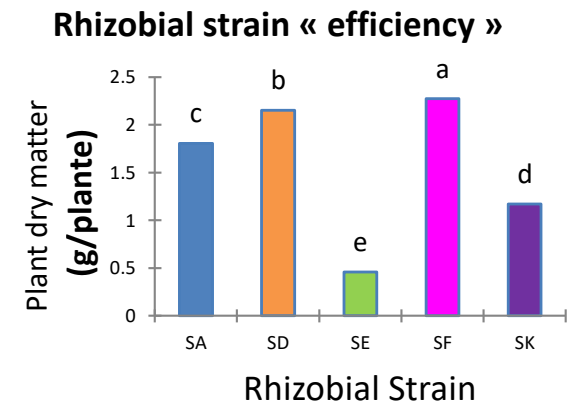
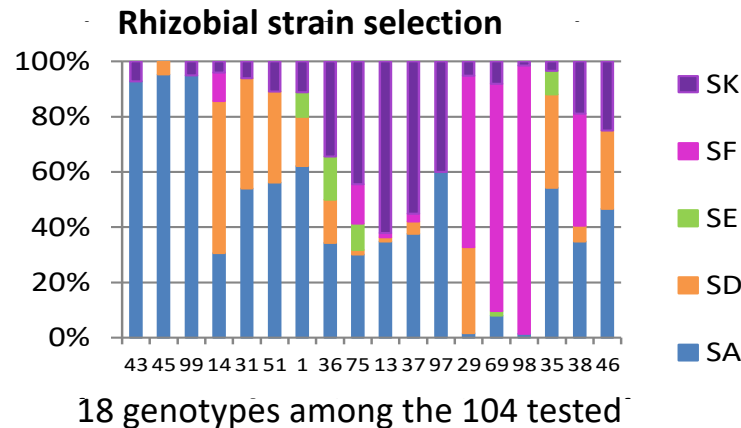
Legume-microbe interactions to optimize plant growth and nutrition

Impact of Pea genotypes on associated Rhizobial symbiotic strains :

Coll BPMP, Montpellier

104 genotypes inoculated with 5 rhizobial strains :

INRA SYMBIOPEA project



Pea genotypes selected different symbiotic strains

Symbiotic strains have different efficiencies

Perspective : identification of plant genetic determinants of rhizobial selection by pea

Genome Wide Association Study on a wider range of plant genetic variability

+ candidate gene approach

GRASP project (ANR)

➔ Towards breeding of pea varieties with improved symbiosis for N₂ fixation



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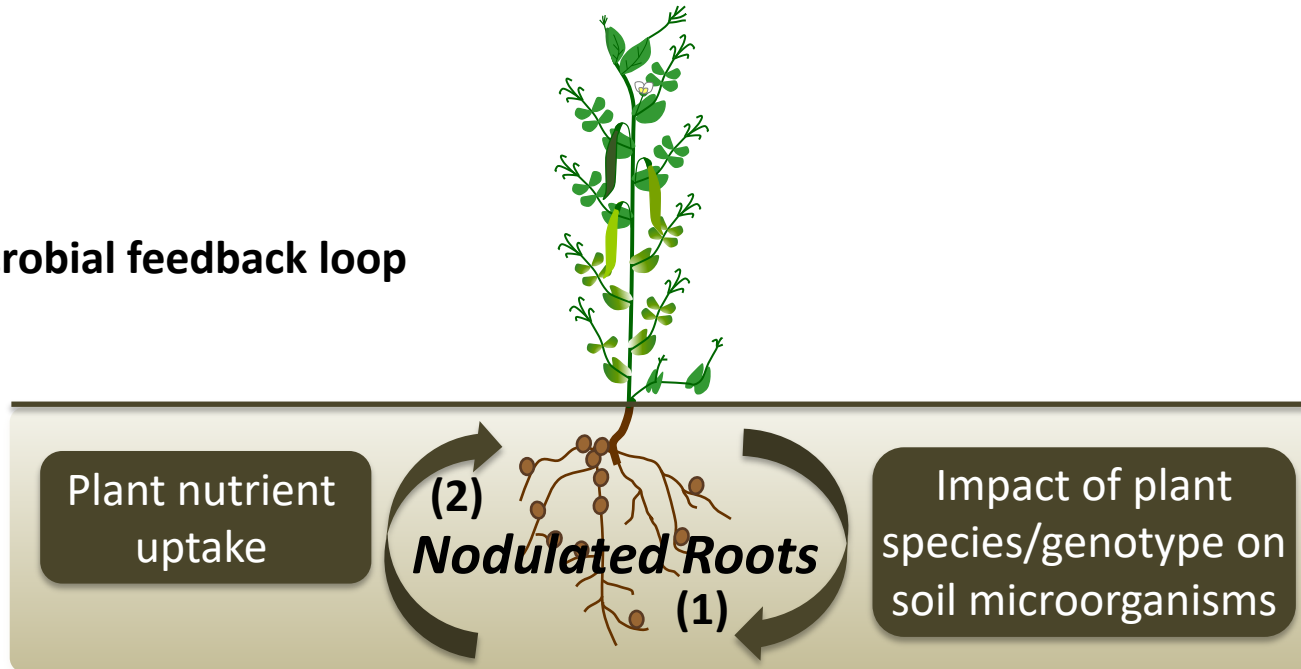


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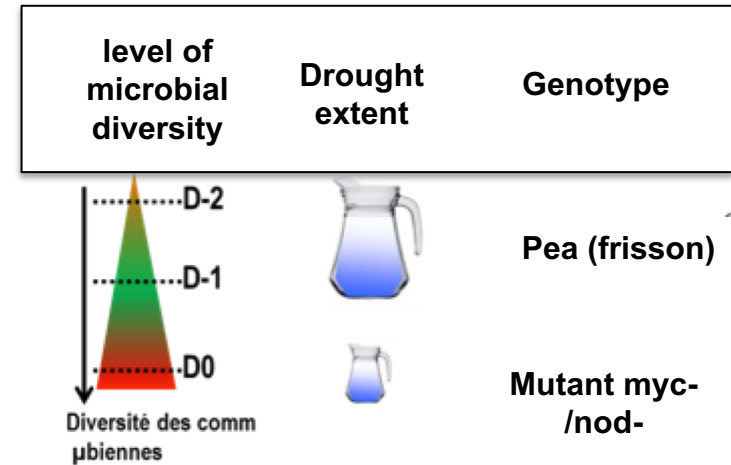
Background and aims: among research themes

Legume-microbe interactions to optimize symbiotic N₂ fixation

BQR project

- Impact of diversity level of soil microbial communities on pea plant response to water stress

Varying:



- A higher diversity level of soil microbial communities

Floral initiation

Drought

Flowering

Maturity



- has no impact on pea drought tolerance...
 - Similar response with or without symbioses: non symbiotic communities play a role in this response
- ... but provides better pea resilience after stress

The GEAPSI Group...



FILEAS (molecular biology and physiology)



Proteaginuous target crop (genetics, genomics)

