UMR Agroecology's research

Christophe Salon, Céline Bernard, Mickaël Lamboeuf, Christian Jeudy

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

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

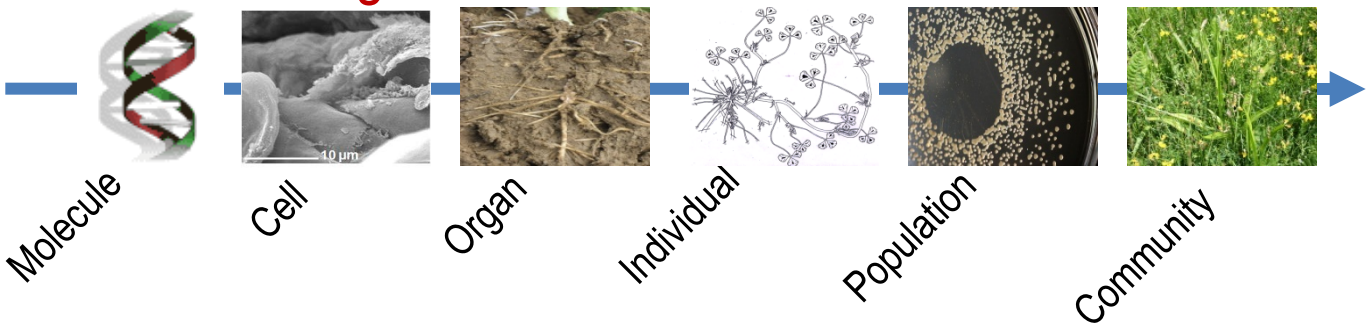
Understand, preserve and valorize biodiversity and biotic interactions for development of agroecological systems

- Analyze, understand and act on the interactions and regulations among communities (microbes & plants) at different spatial and temporal scales

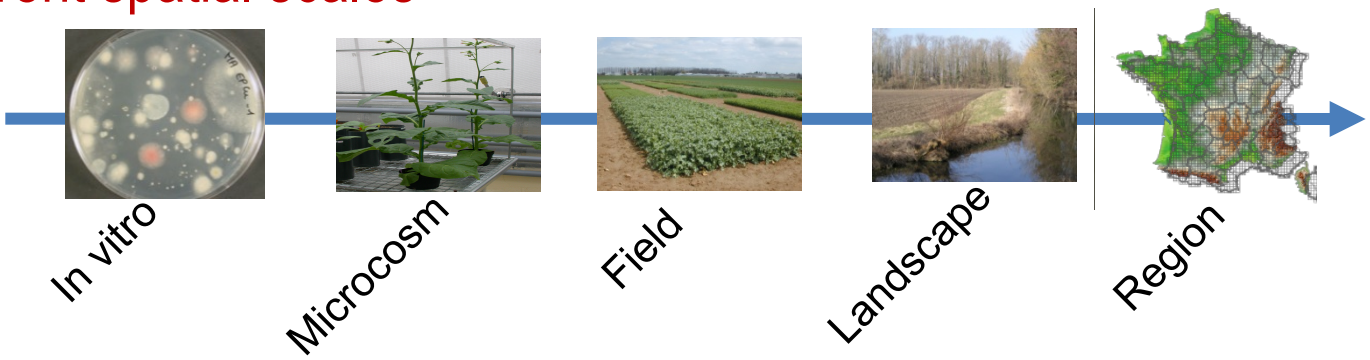
- Design and assess innovative cropping systems delivering agricultural products with a quantity and quality high enough, while preserving the environment quality

Integrating different levels of organisation & spatio-temporal scales

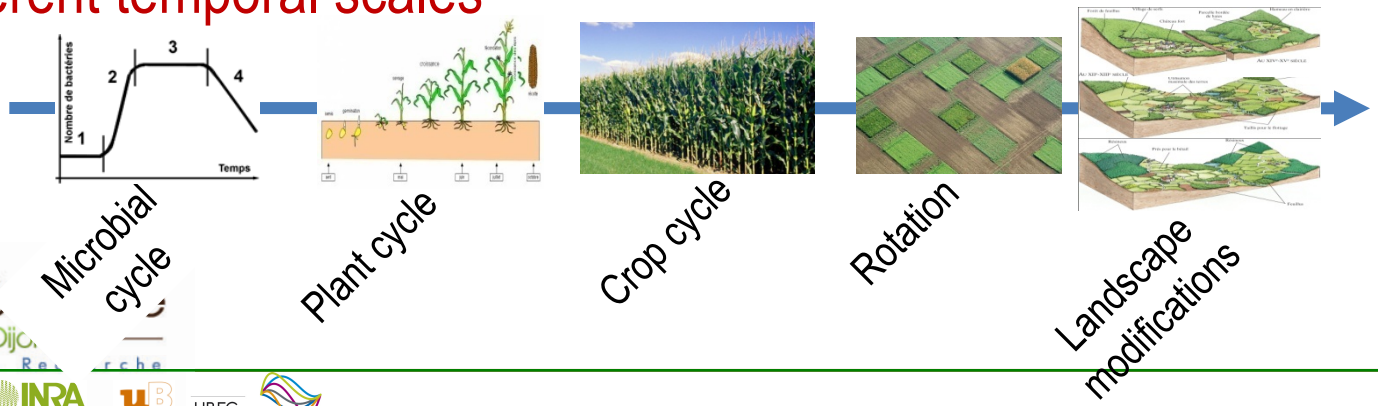
- Different levels of organization



- Different spatial scales

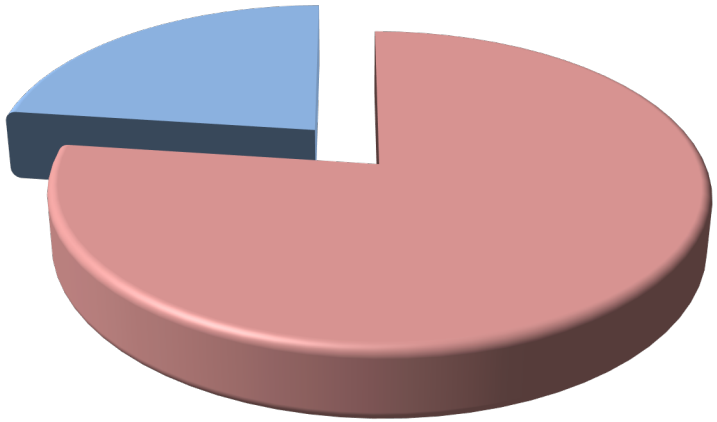


- Different temporal scales



Human Resources

31/12/2017



Total: 330

Non-permanent staff

Permanent staff

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	GEAPSI	IPM	GESTAD
			
Cereals, Brassica	**Mostly legumes, Maize Tomato Cereals**	**Legumes, Arabidopsis, Tobacco,**	**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)	Sustainable Management of Arable Weeds (GESTAD)	Genetic and environmental determinisms of the adaptation of plants to innovative cropping systems (GEAPSI)	Mechanisms and management of plants-microorganisms interactions (IPM)
F. Martin-Laurent	S. Petit-Michaut	C. Salon	S Jeandroz

Platforms & Biological Resource Center

GenoSol	Microscopy	4PMI	Biological Resource Center
S. Mondy	J. Lherminier	C. Salon & C. Bernard	C. Steinberg

Theme-based scientific workshops

Ecology of communities in agroecosystems	Design of agroecological systems	Plants-microorganisms interactions	Ecological engineering	Interactions between modeling and experiments /observations
	Ni. Munier-Jolain	C. Salon & D. Wipf	A. Hartmann	N. Colbach

Platforms & Biological Resource Center

GenoSol

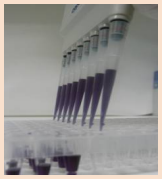
- 4 ETP (3 permanent IR, AI, TR et 1 CDD) from april 2016

Biological resource Centre

11 300 sample ; 1 500 new par year

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 anaysis of microbial diversity
Statistical tools

- An integrated platform

GenoSol PLATEFORME

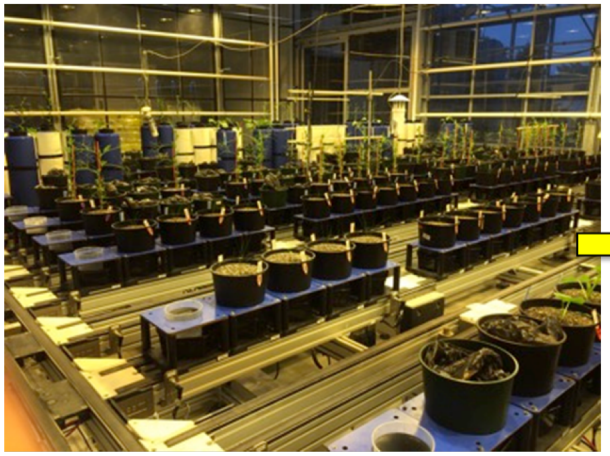
CNOC IBiSA AnaEE France

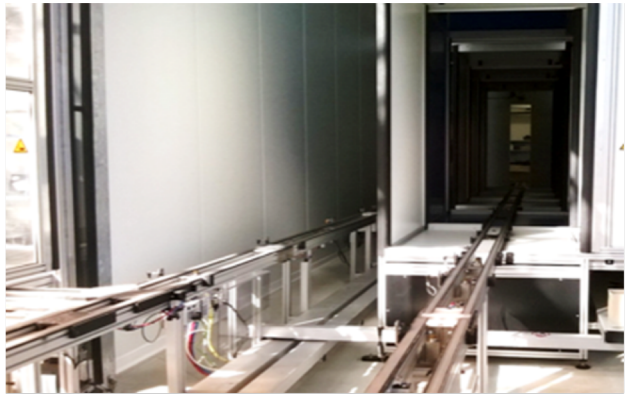
Agroécologie Dijon Unité de Recherche

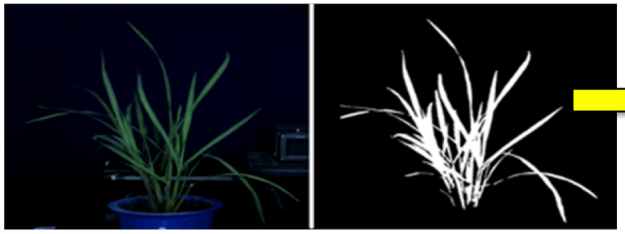
AGROSUP DIJON INRA UBFC

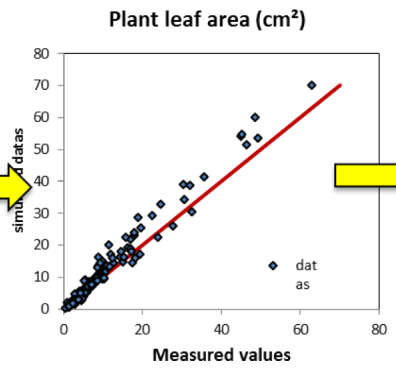
4PMI

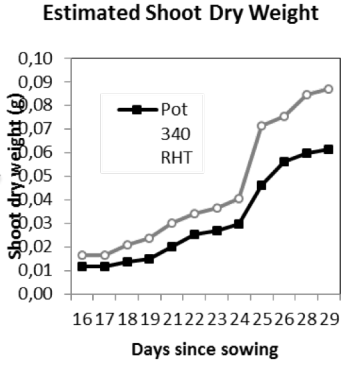
- **Aims:** Develop innovative automated techniques for **high throughput morphometry of plants** produced in controlled conditions with a **focus on plant root-microbe interactions**
- **Staff:** 1 Research Manager, 1,5 Engineer, 1 Assistant Engineer, 6 technicians
- **Equipments:**
  - 4 automated greenhouse and 1 climatic chamber high CO_2
  - High throughput shoot and root phenotyping and their imaging cabins







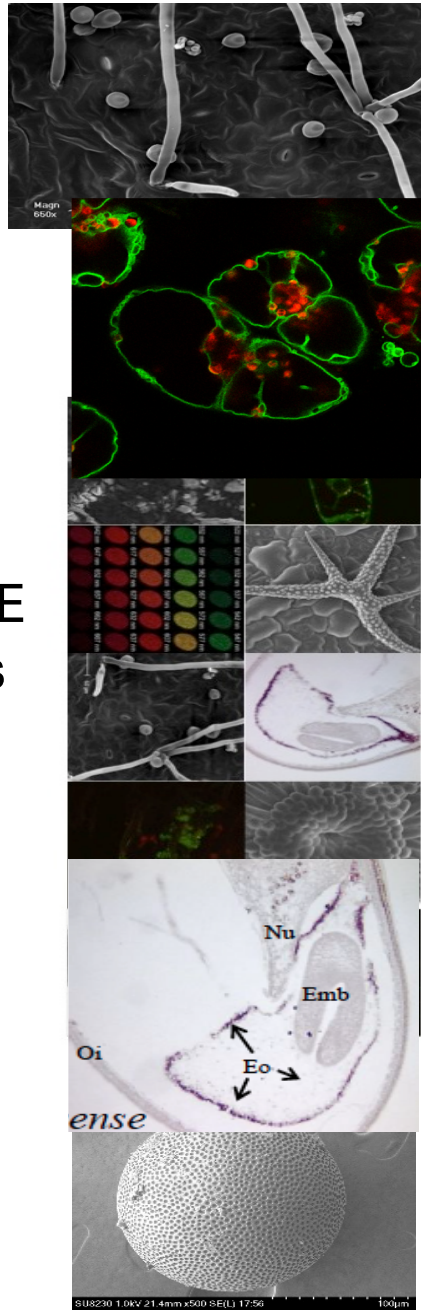




Microscopy platform, part of the Campus Imaging Center

DImaCell
Dispositif Interrégional en Imagerie Cellulaire

- **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

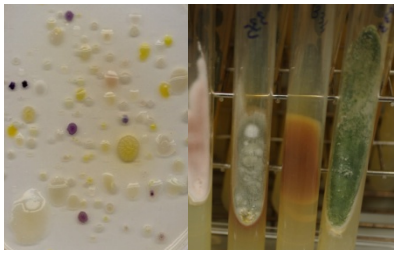


IBiSA

Agroécologie Dijon Unité de Recherche

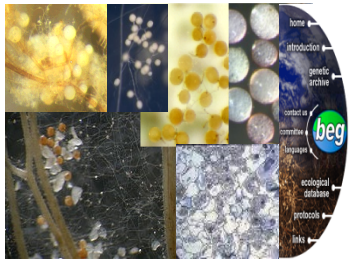
AGRO SUP DIJON INRA uB UBFC

Biological Ressource Centre



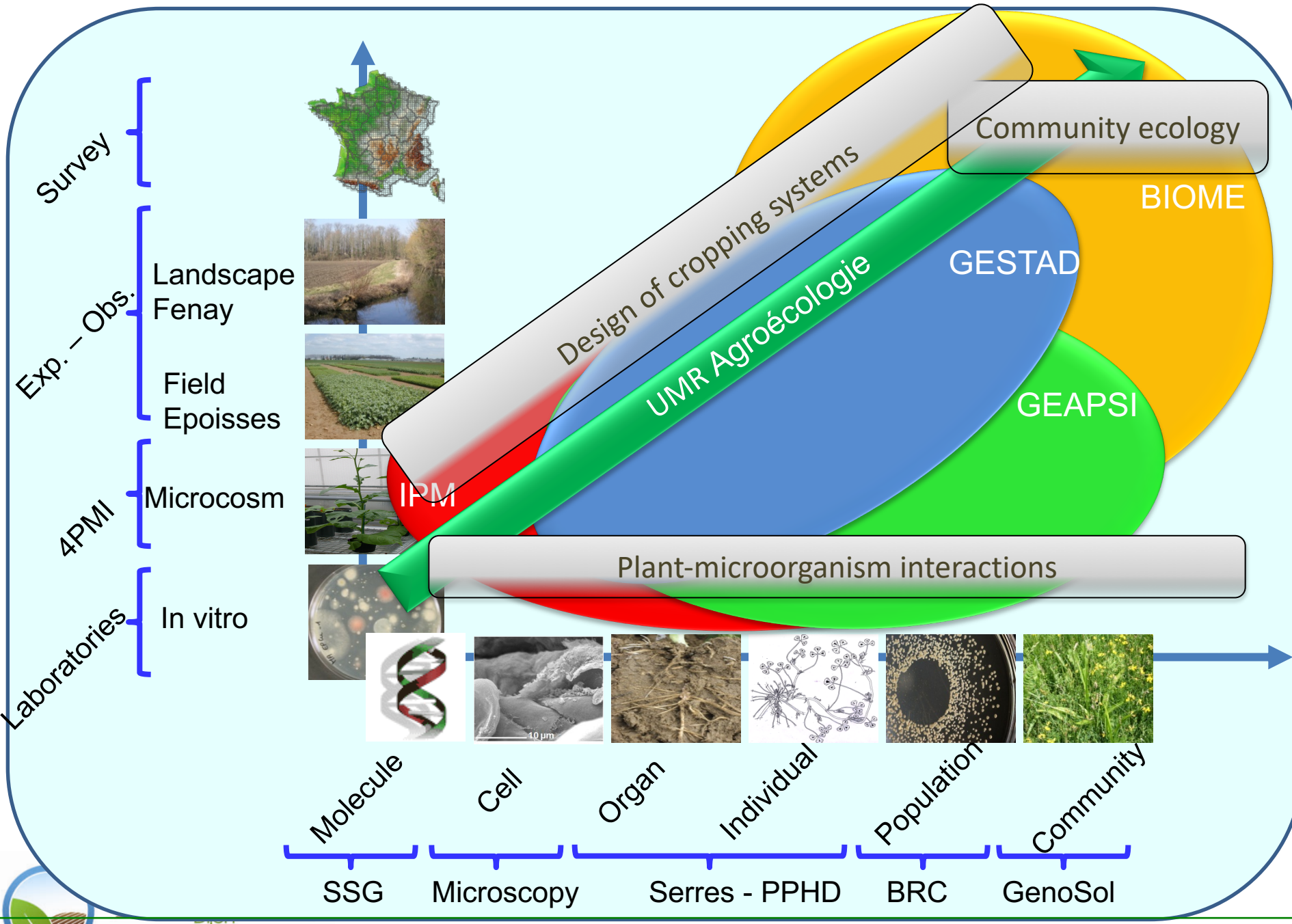
Missions

- 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.

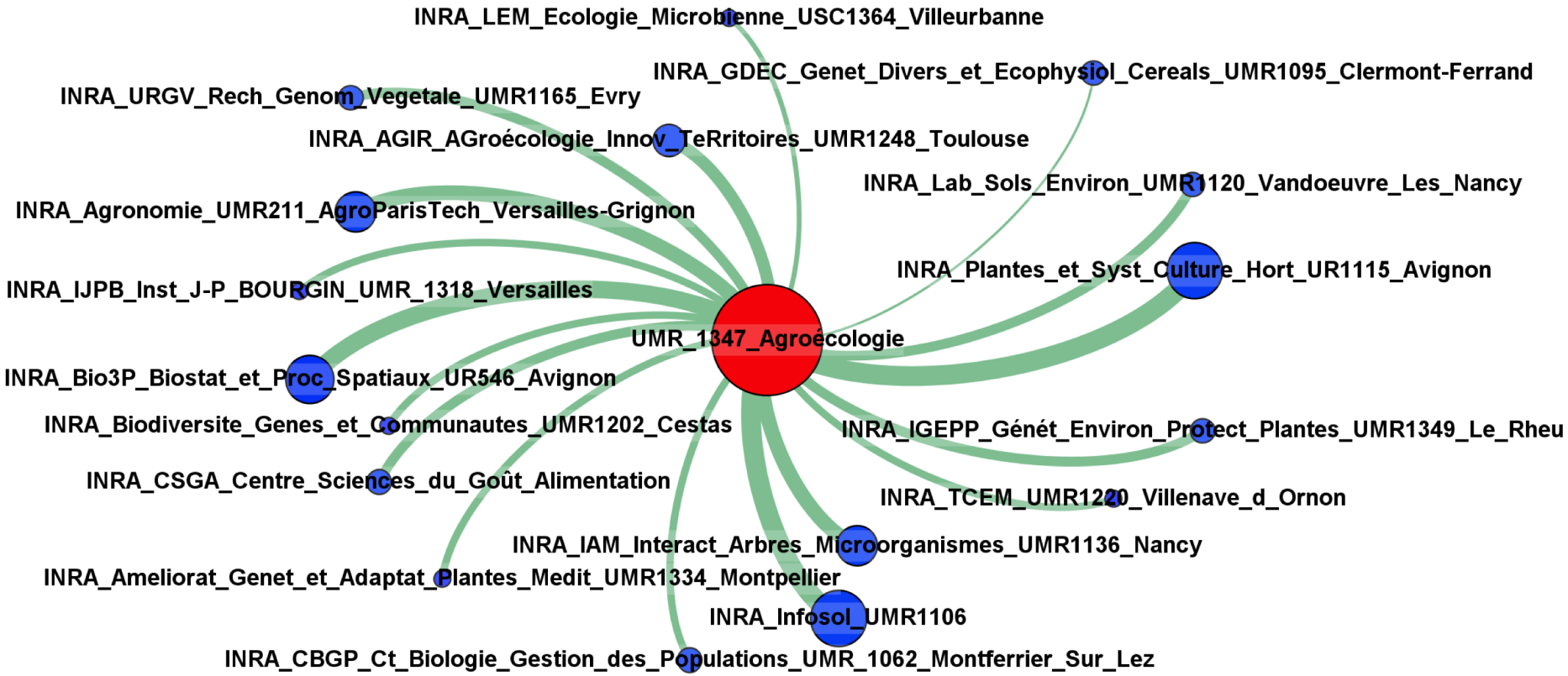

Survey
Exp. – Obs.
Landscape
Fenay
Field
Epoisses
4PMI
Microcosm
Laboratories
In vitro
Community ecology
BIOME
Design of cropping systems
GESTAD
UMR Agroécologie
GEAPSI
IPM
Plant-microorganism interactions
10 µm
Molecule
Cell
Organ
Individual
Population
Community
SSG
Microscopy
Serres - PPHD
BRC
GenoSol

- Strong international cooperation (54 countries)

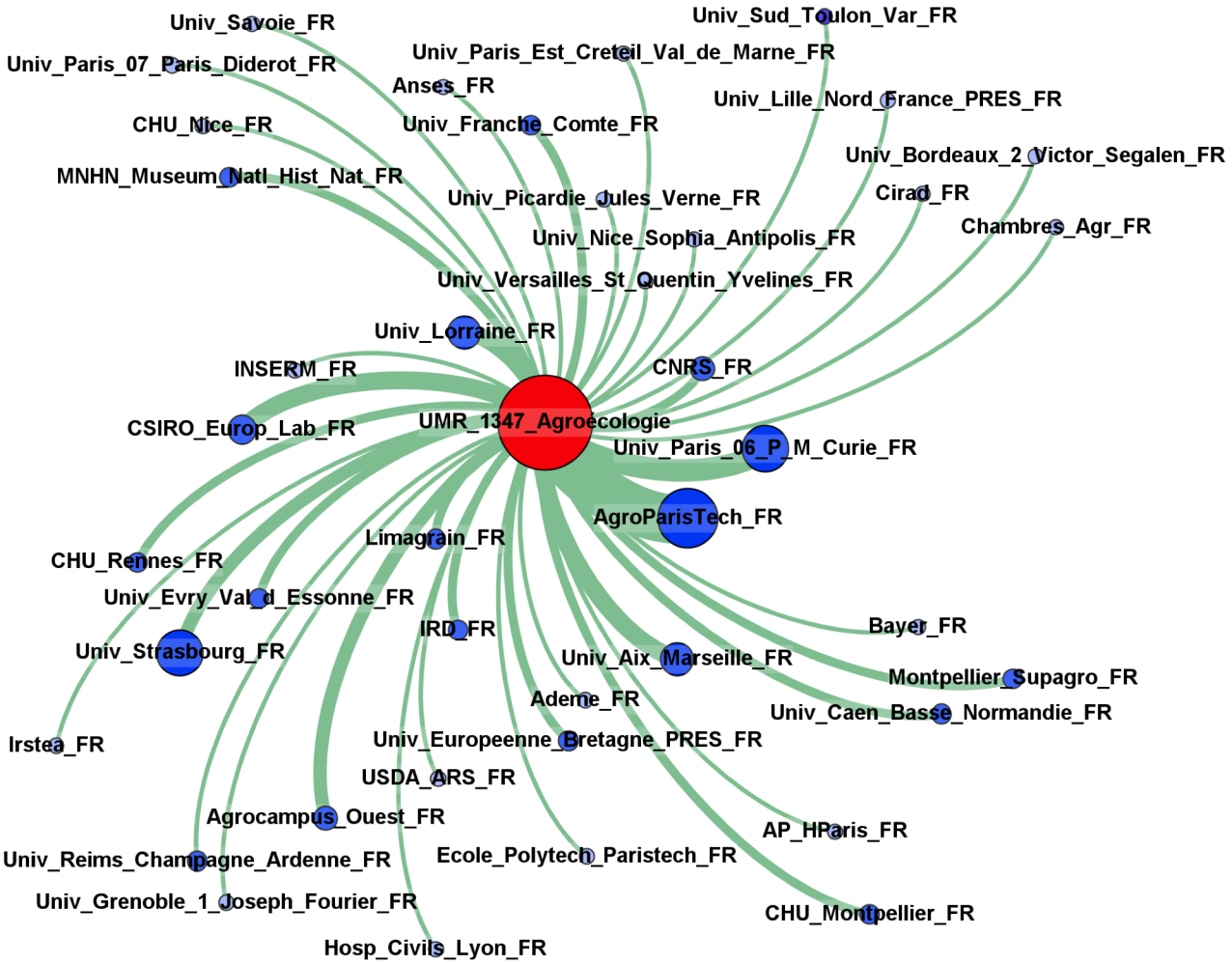
Geographical distribution of UMR publications co-authored with international scientists (47%).

Academic reputation and appeal

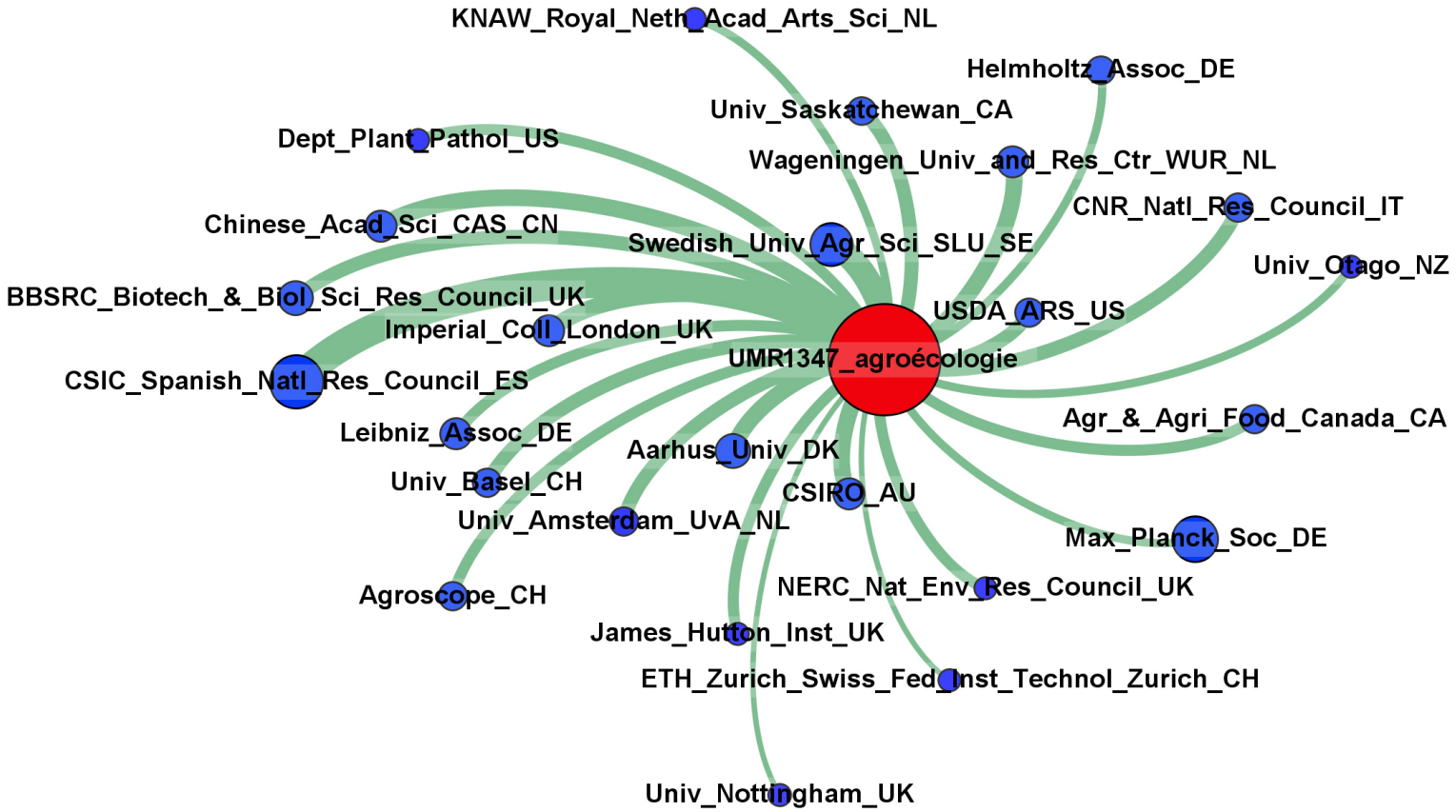
- Collaborations with French Institutes: INRA labs (17 out of 55)



- 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





Agroécologie
Dijon
Unité de Recherche
AGRO SUP
INRA
UNIVERSITE BOURGOGNE FRANCHE-COMTE

Background and aims: objectives

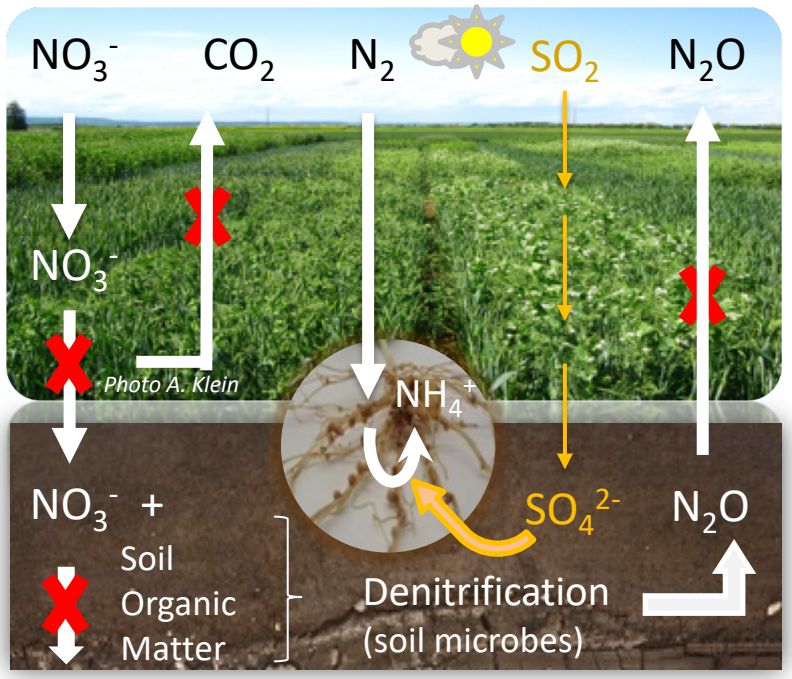
➢ **Scientific objectives**

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)

Background and aims: objectives

- **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**

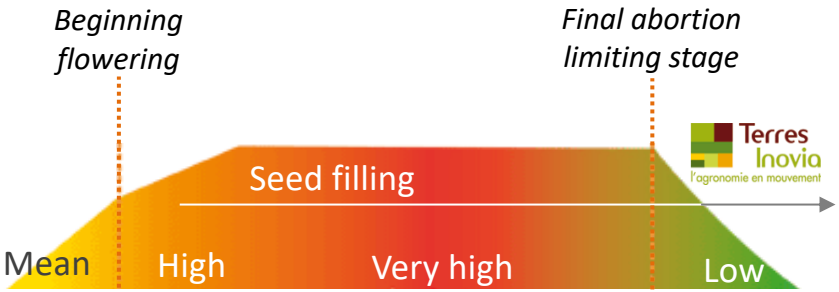
Climate change
➥ **water deficit**

↘ **Symbiotic N fixation**

↘ **yield**

↘ **Seed quality**

Sensitivity of pea to water deficit:



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**.
  - 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).

Background and aims

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- 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 **nutrients deficiencies** (N, S, Fe, others).
- study of the **genetic bases** and processes enabling plant **adaptation to agrosystem** habitats.

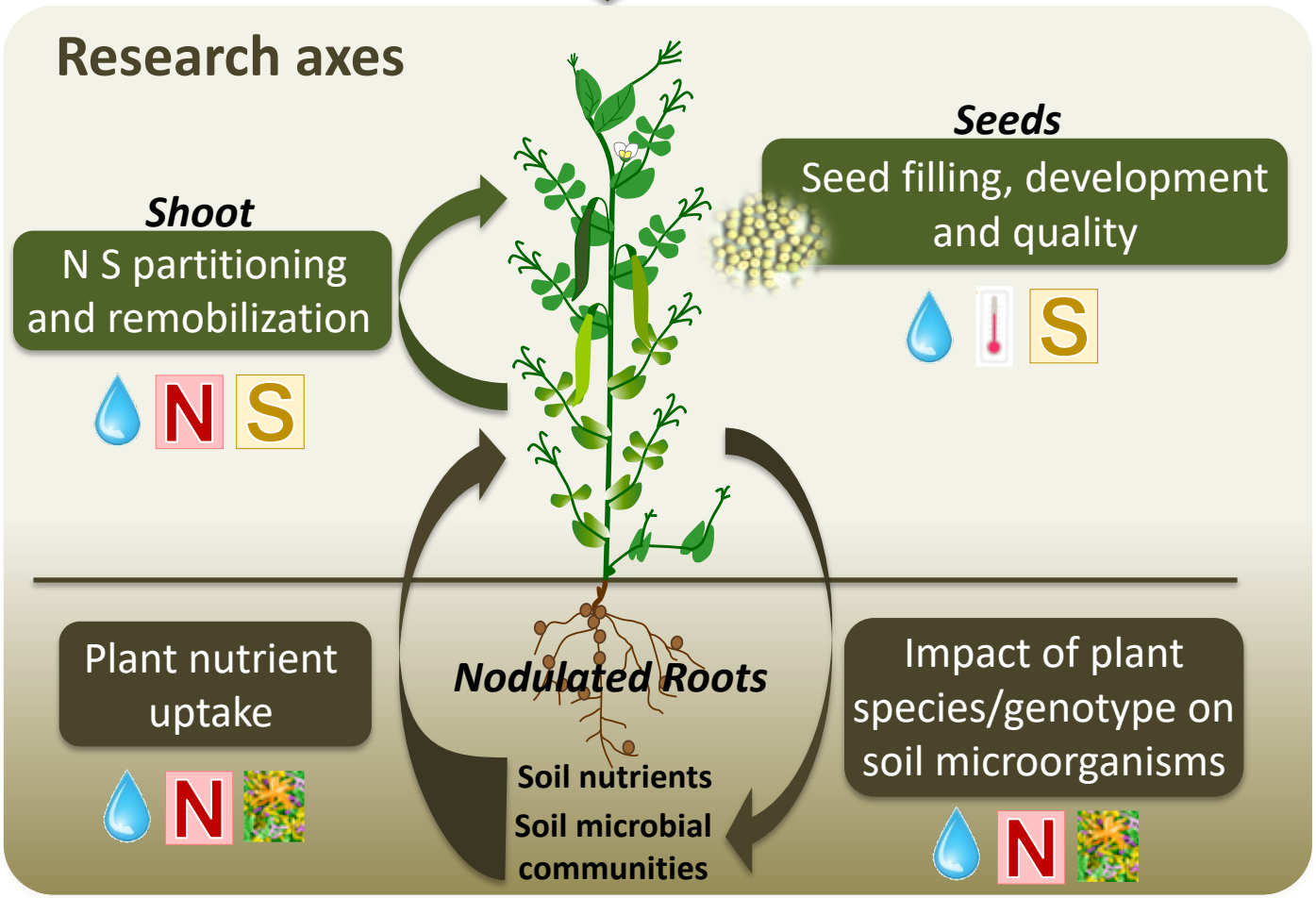
Background and aims

Tools & ressources

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

LEGUMES

Research axes



Environmental factors

Genetic variation

H_2O
Temp.
N Nitrogen
S Sulfur
Soil microbes

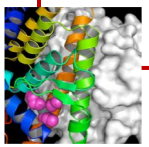
The path…

Tools and methods set up

Building genetic variability for root and nodules development

CONCEPTION of LEGUME IDEOTYPES

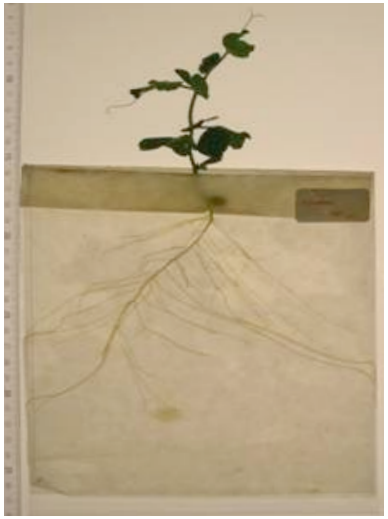
Characterizing mechanisms and molecular basis associated to N nutrition



The path…: Tools and methods

Tools for growth culture and phenotyping

Characterizing root development



Growth pouches, hydroponics

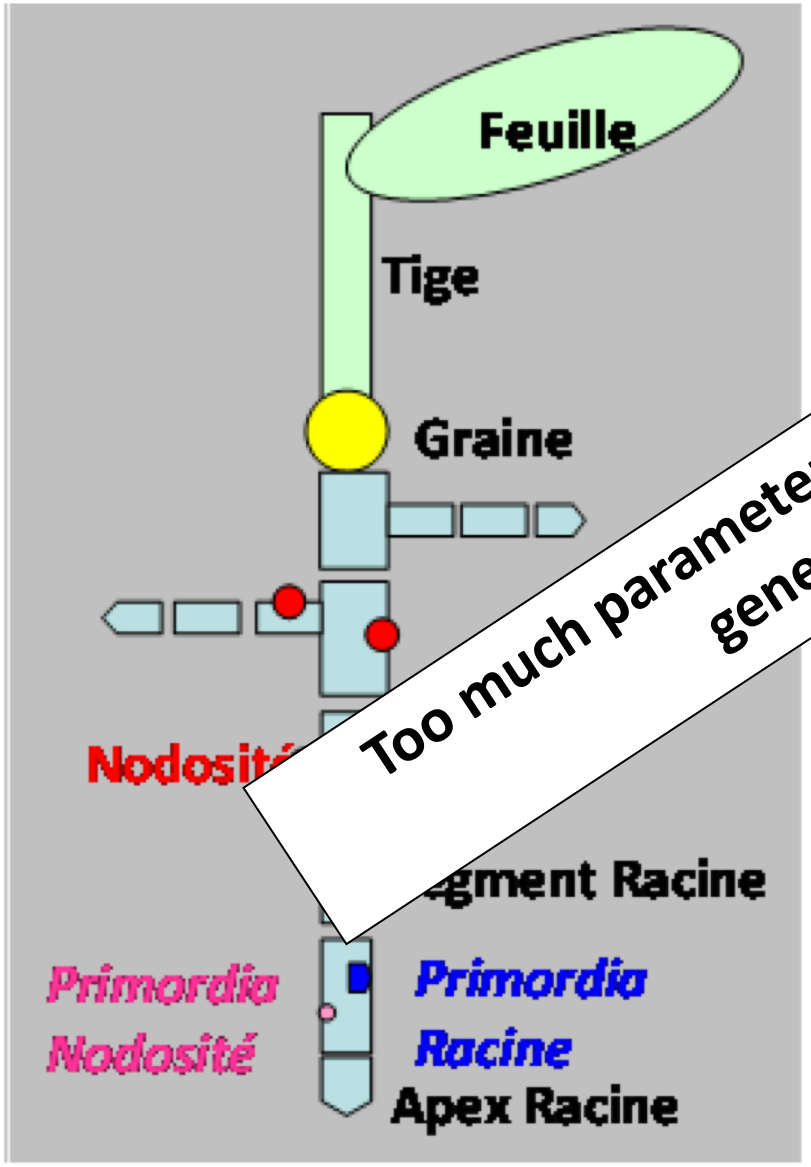
Split root

C, N, S flux measurement

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

The path…: Tools and methods

Mechanistic models : PEA NOD (coll. L Pagès)



Too much parameters for taking into account genetic variability

Understand key … their interactions

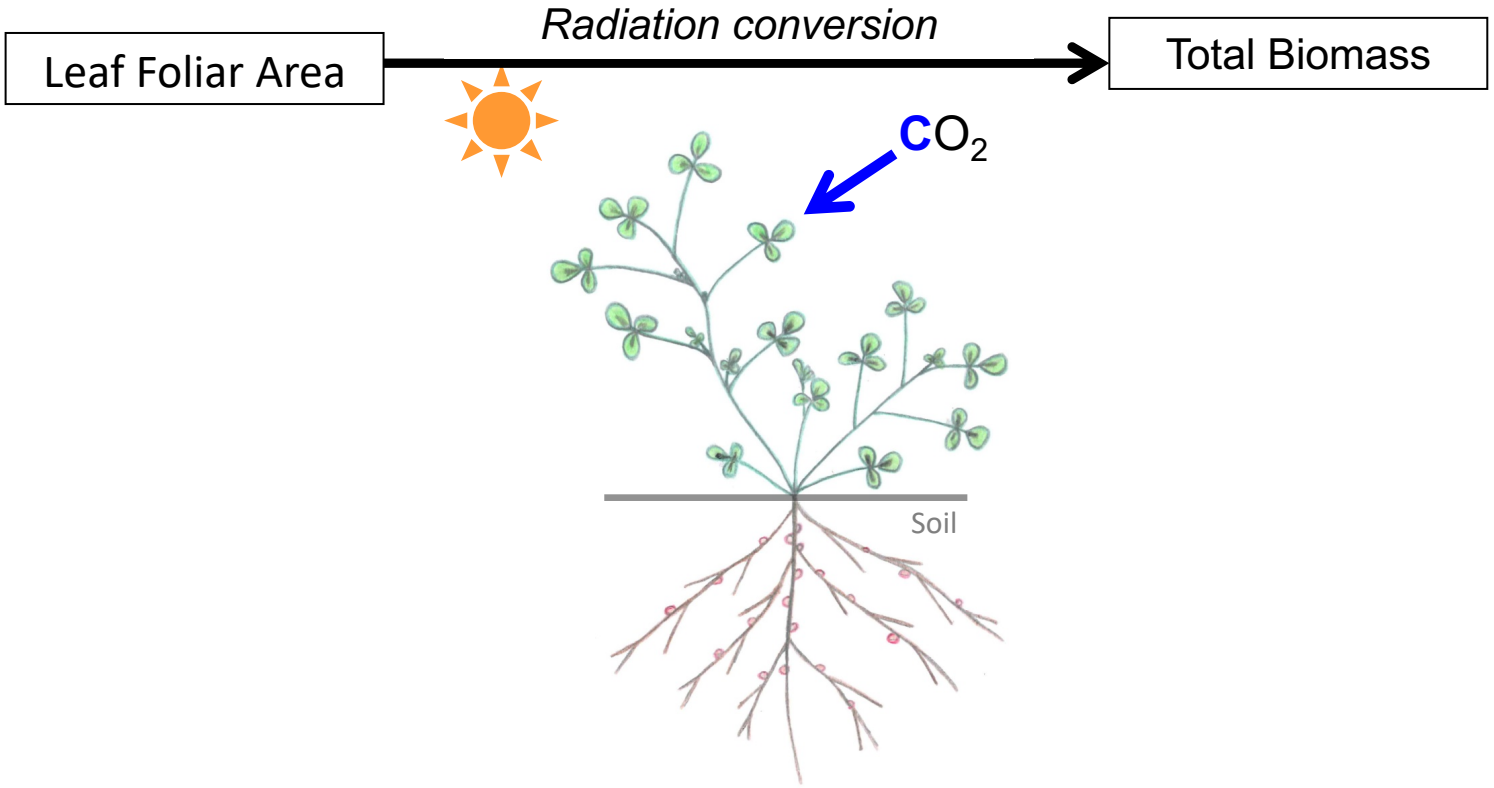
- m… … N interactions,
- …tecture,
- …tuating environmental …variations.

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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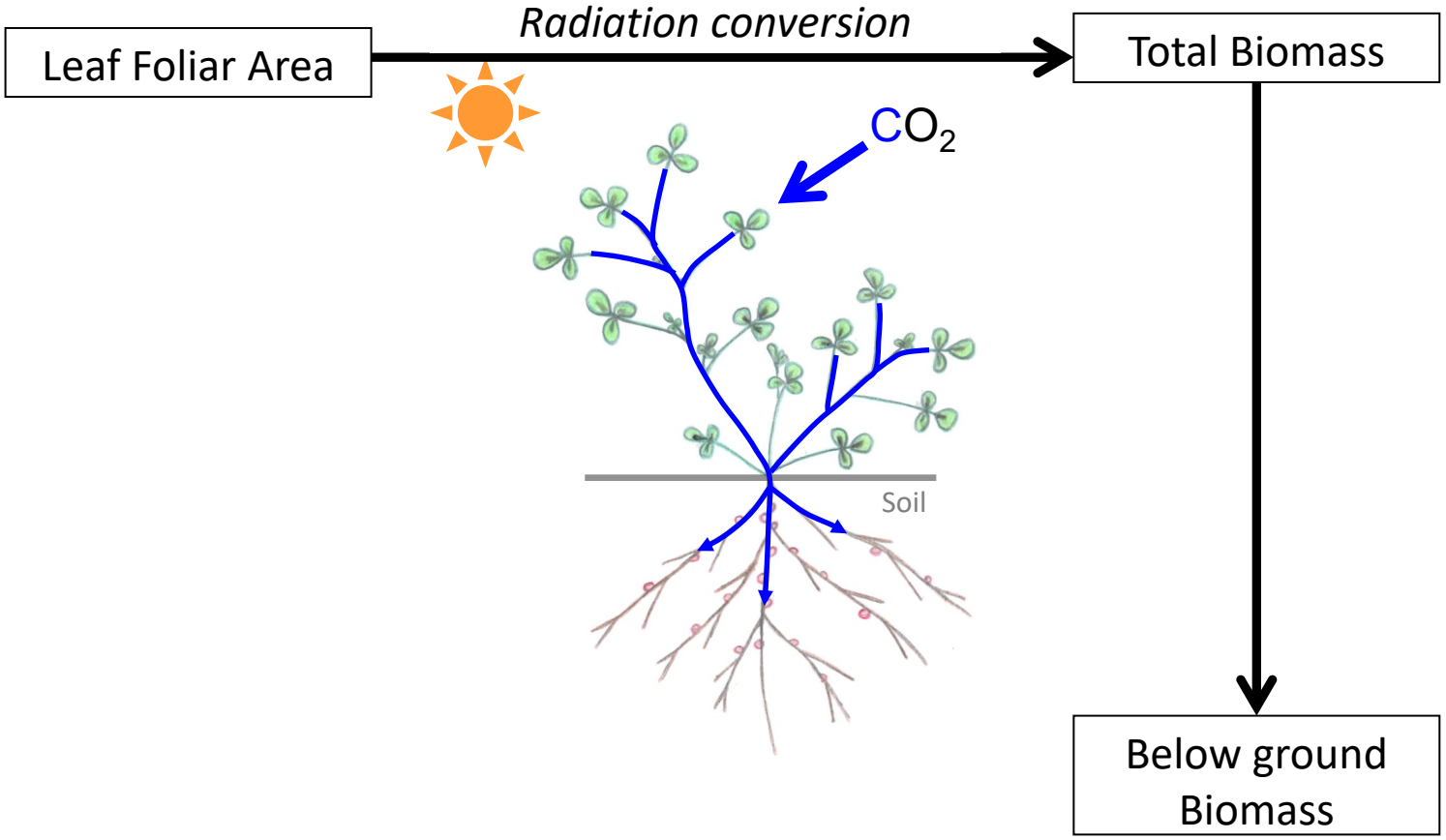

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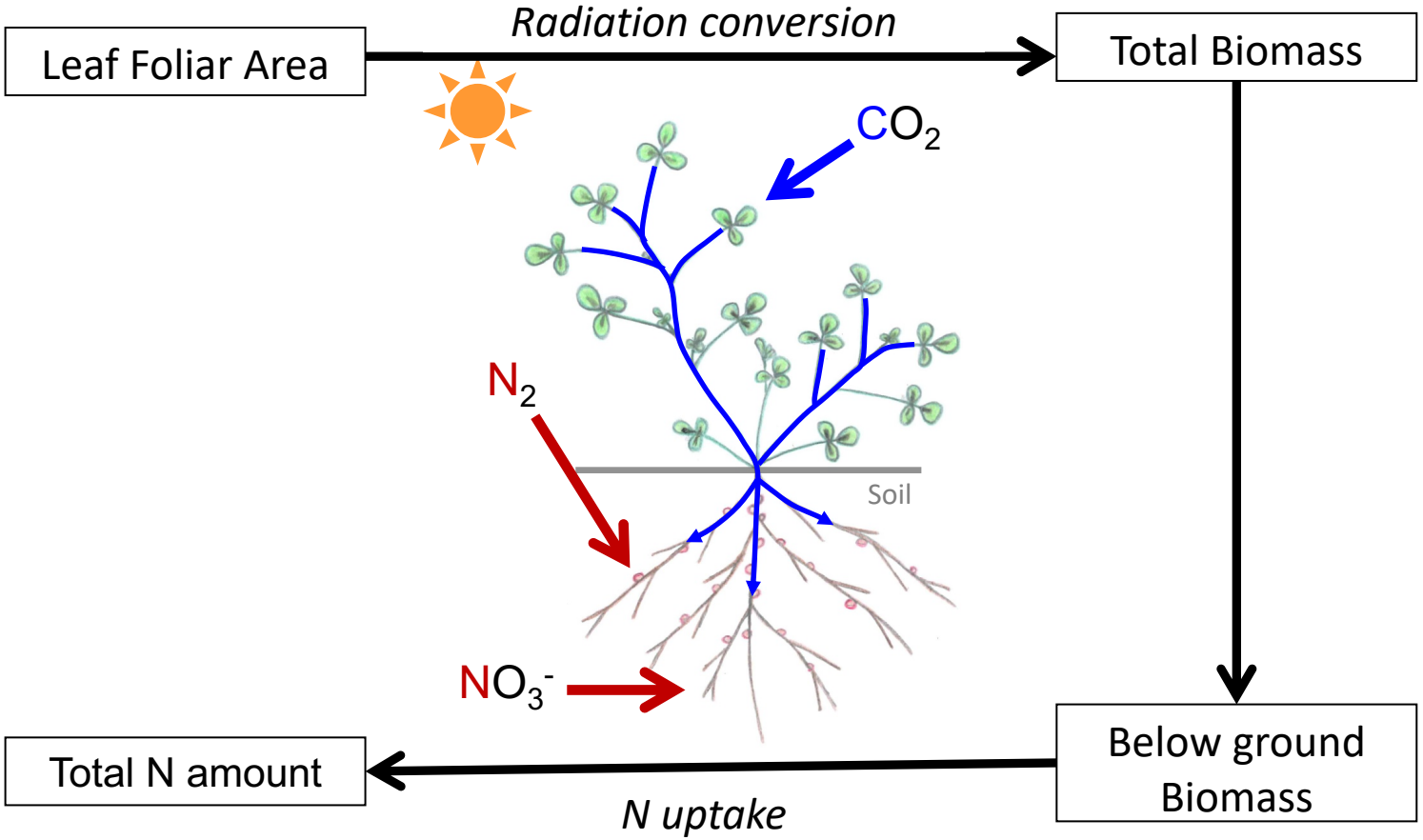

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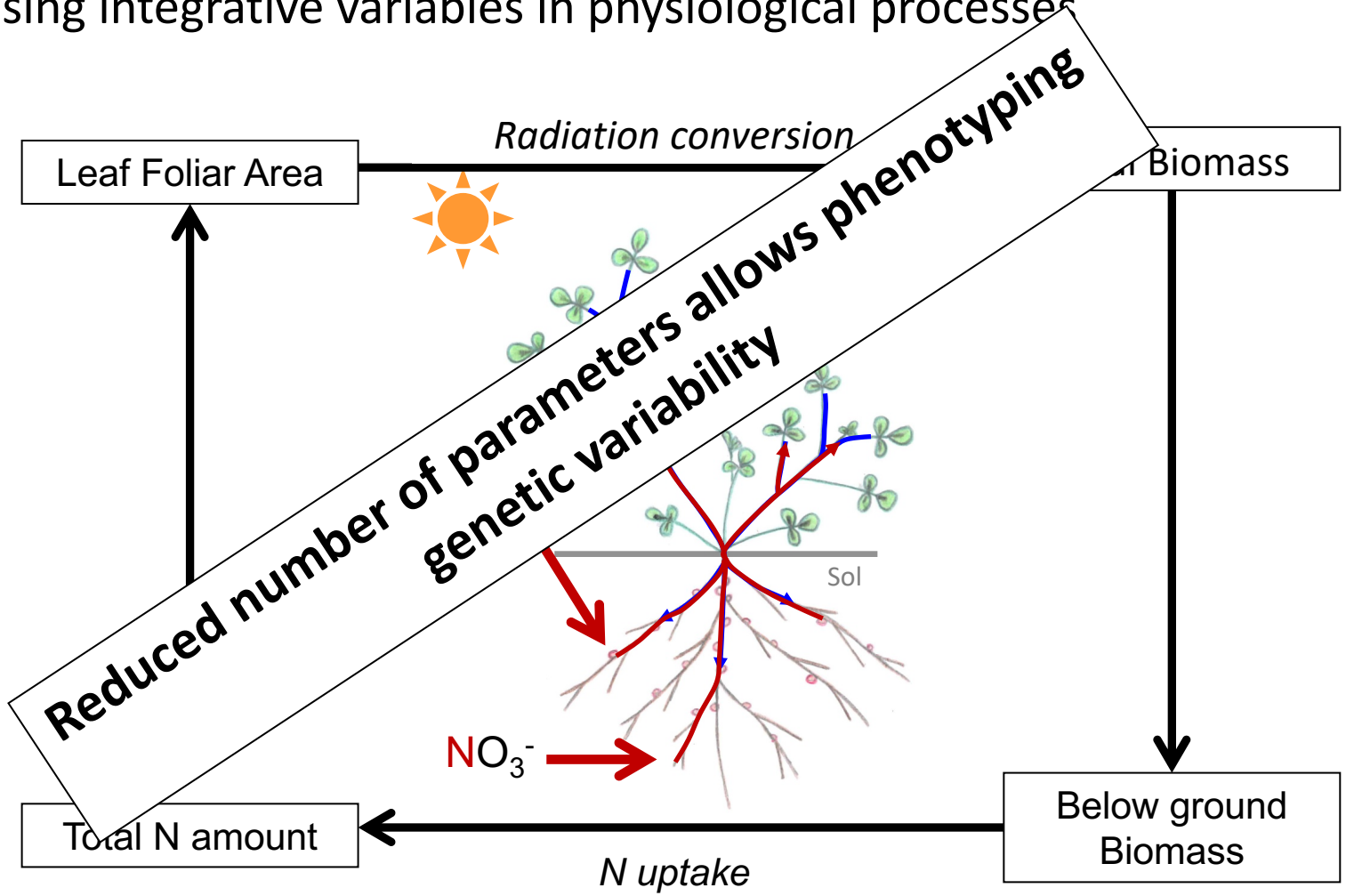
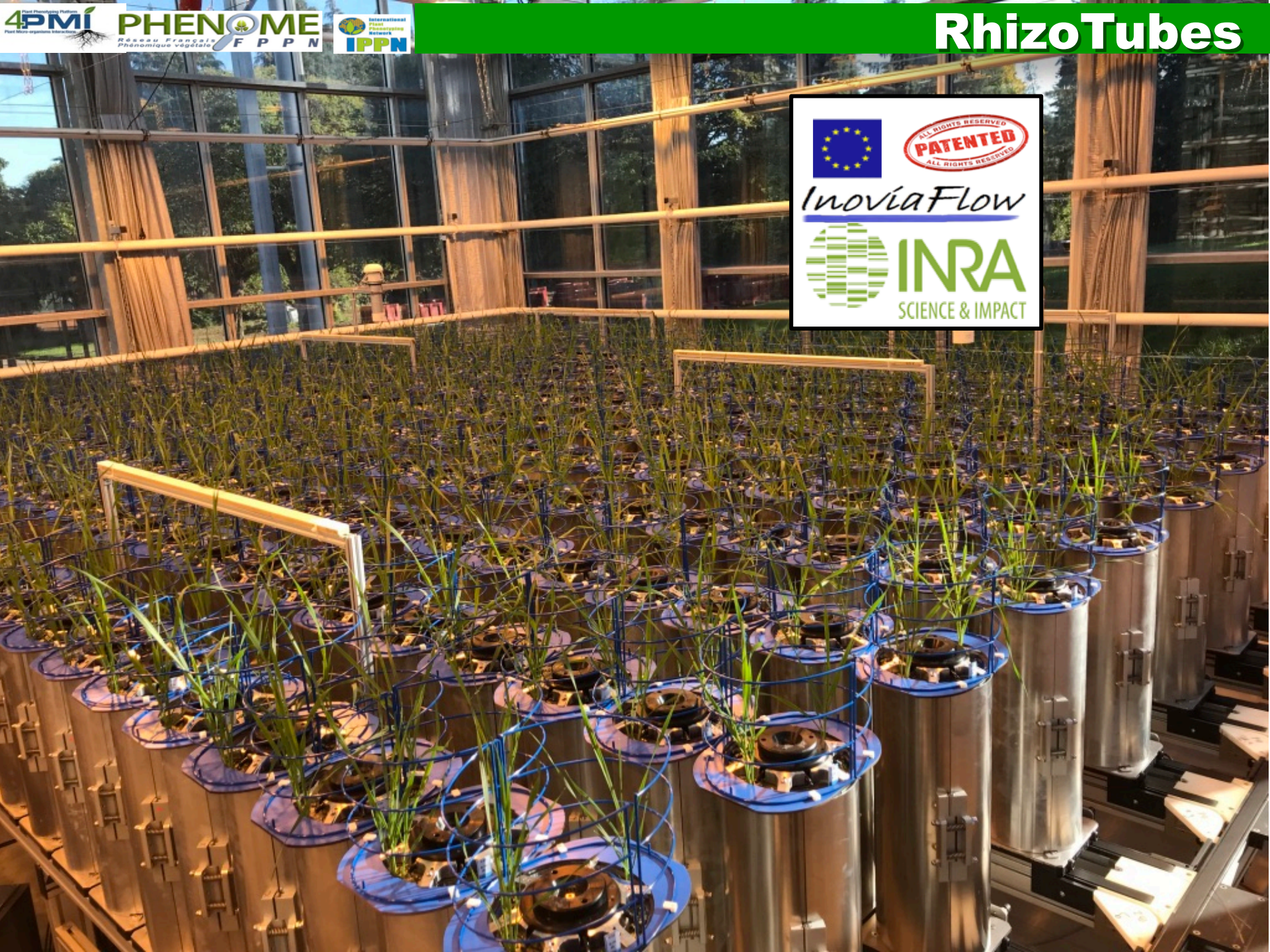


Moreau et al. Plant Cell Environn 2006

Moreau et al. JExp Bot 2008

4PMI: Plant Phenotyping Platform for Plant and Microorganisms Interactions

RhizoTubes


ALL RIGHTS RESERVED
PATENTED
ALL RIGHTS RESERVED
InoviaFlow
INRA
SCIENCE & IMPACT

High Throughput RhizoCab

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ALL RIGHTS RESERVED

InoviaFlow

INRA
SCIENCE & IMPACT

SHAKTI

World wide distribution

Phenoware

Qubit SYSTEMS

PhenoTrait

Trademark

Rhizo

Rhizo tubes

Rhizo cab

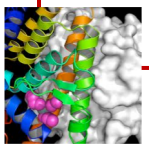
The path…

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

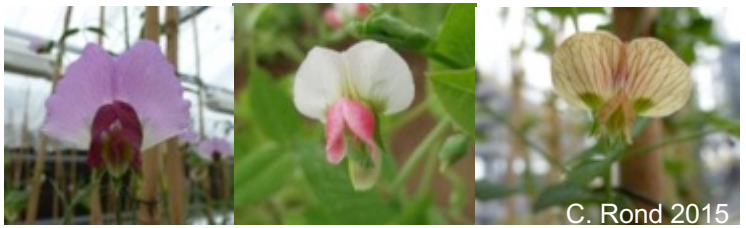


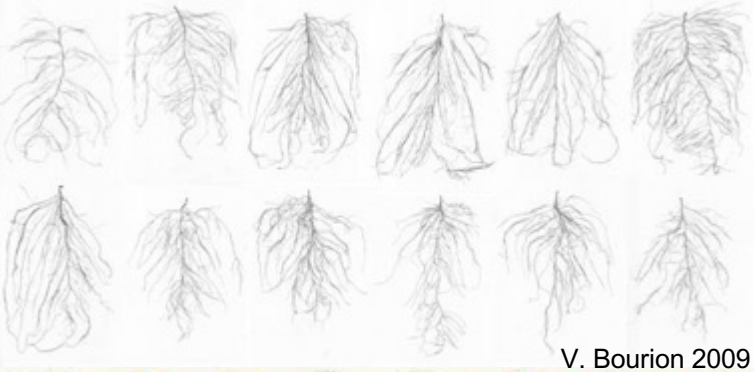
Background and aims : Among available tools

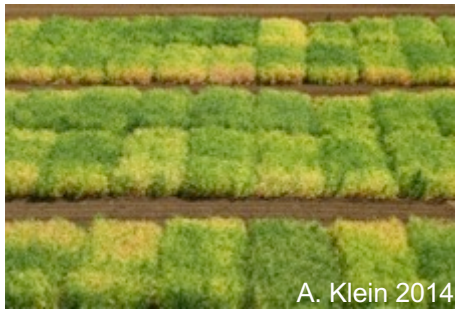
Pea genetic and genomic tools for functional & structural approaches

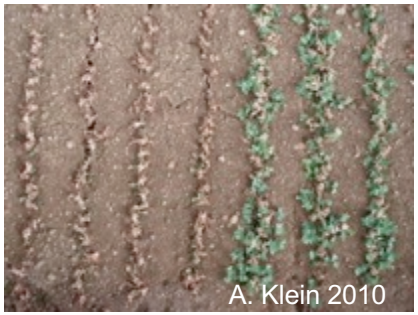
An impressive phenotypic diversity available in the Pisum genus


A. Klein 2013


C. Rond 2015


V. Bourion 2009


A. Klein 2014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INRA

The path…

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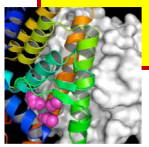
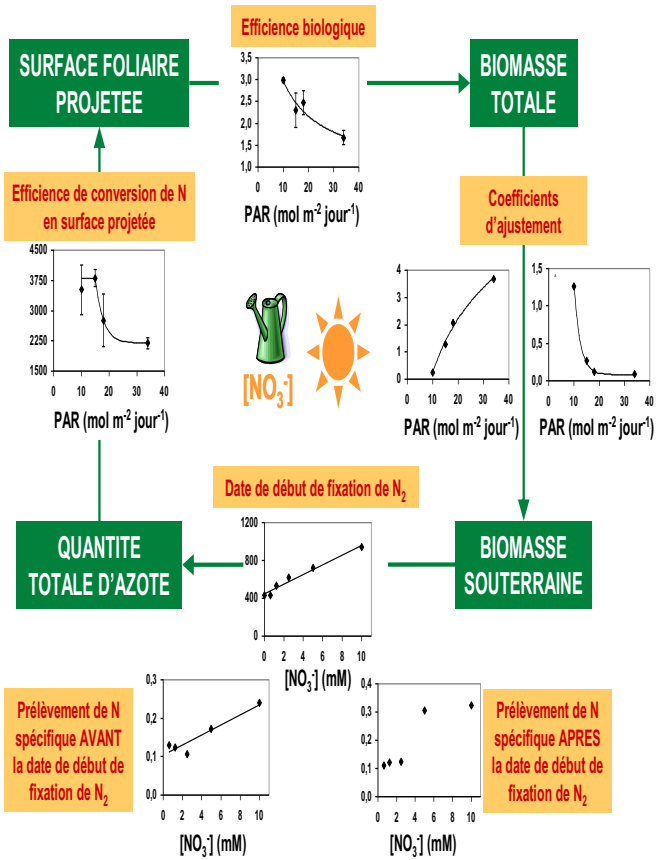
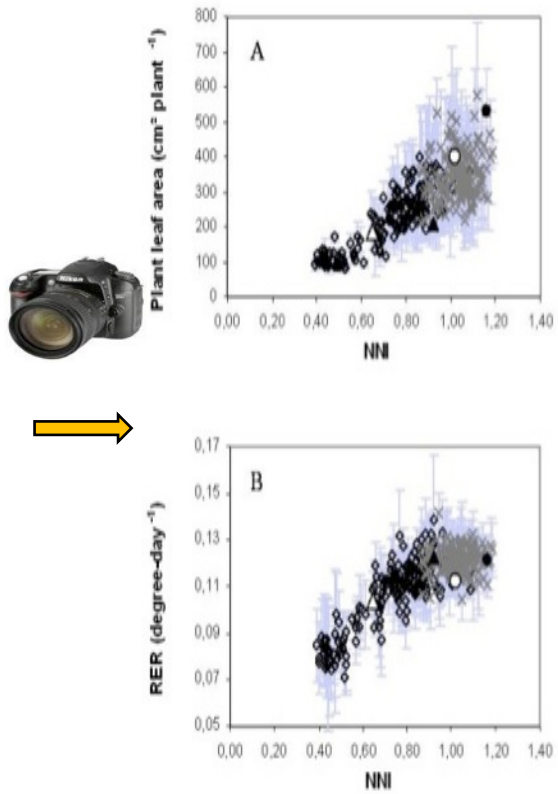


Detect contrasted N nutrition: “archeo phenomics”



Model



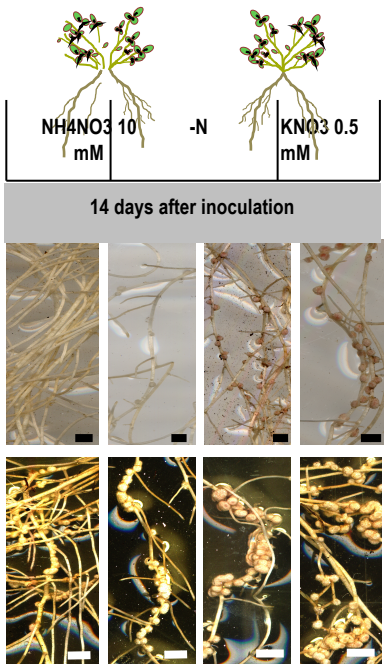
Dynamic leaf area measurement

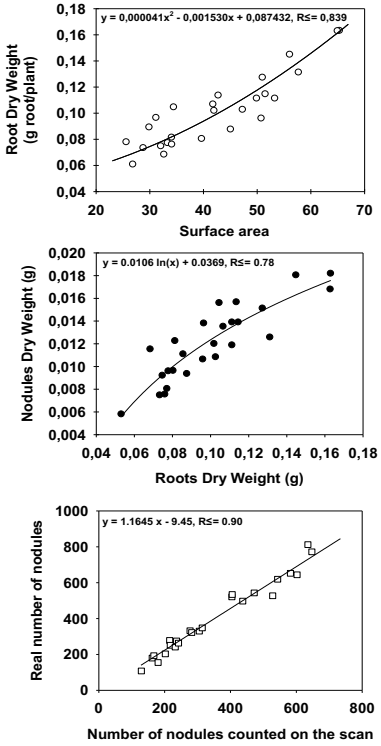
Genotypes of Medicago RIL ranked for ability to uptake N

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 identifcation

Split roots

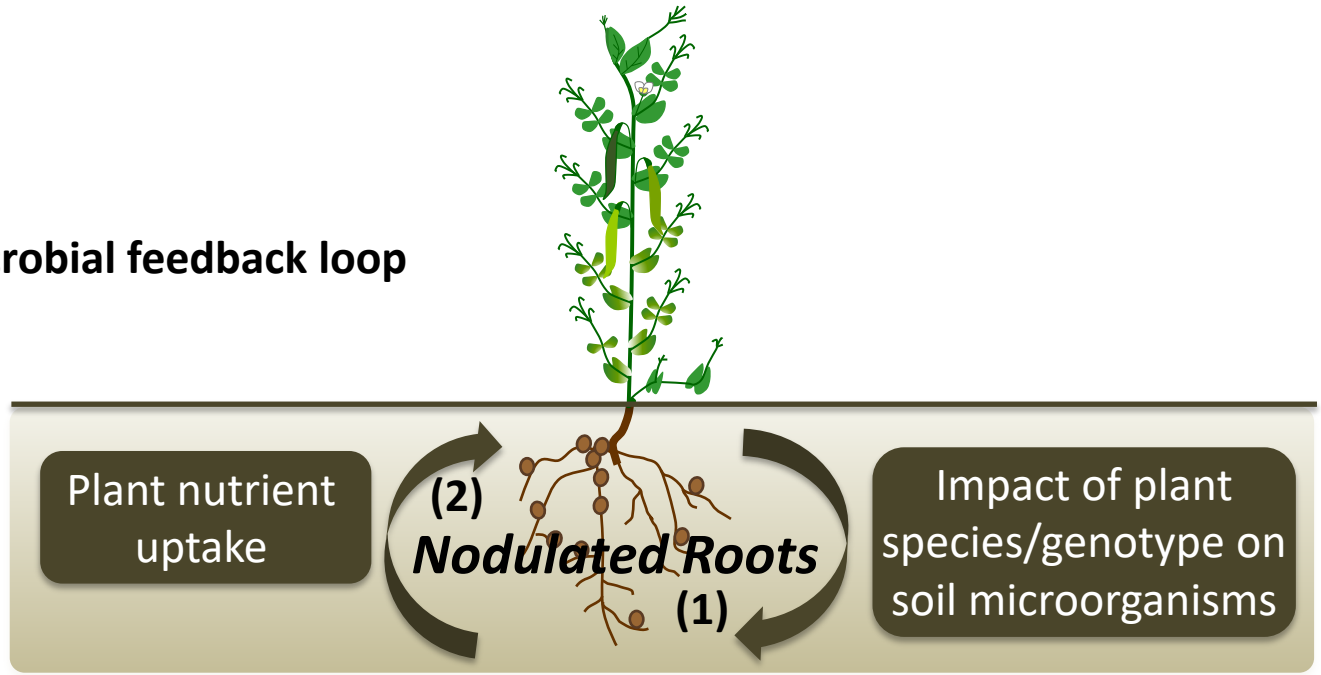
Nodules number and size, appearance

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

Background and aims: among research themes

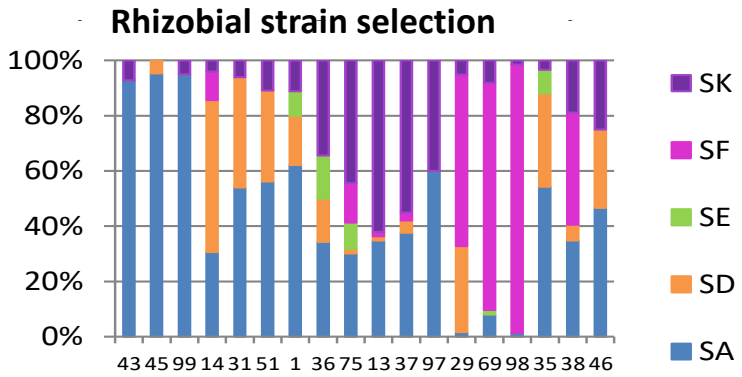
Legume-microbe interactions to optimize plant growth and nutrition

Impact of Pea genotypes on associated Rhizobial symbiotic strains :

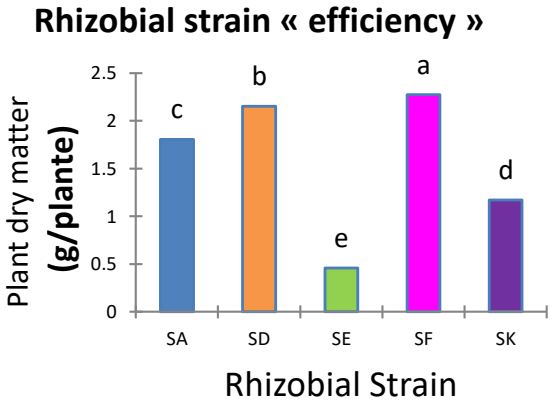
Coll BPMP, Montpellier

INRA SYMBIOPEA project

104 genotypes inoculated with 5 rhizobial strains :



18 genotypes among the 104 tested



Pea genotypes selected different symbiotic strains

Symbiotic strains have different efficicencies

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

Genome Wide Association Study on a wider ranger of plant genetic variability
+ candidate gene approach

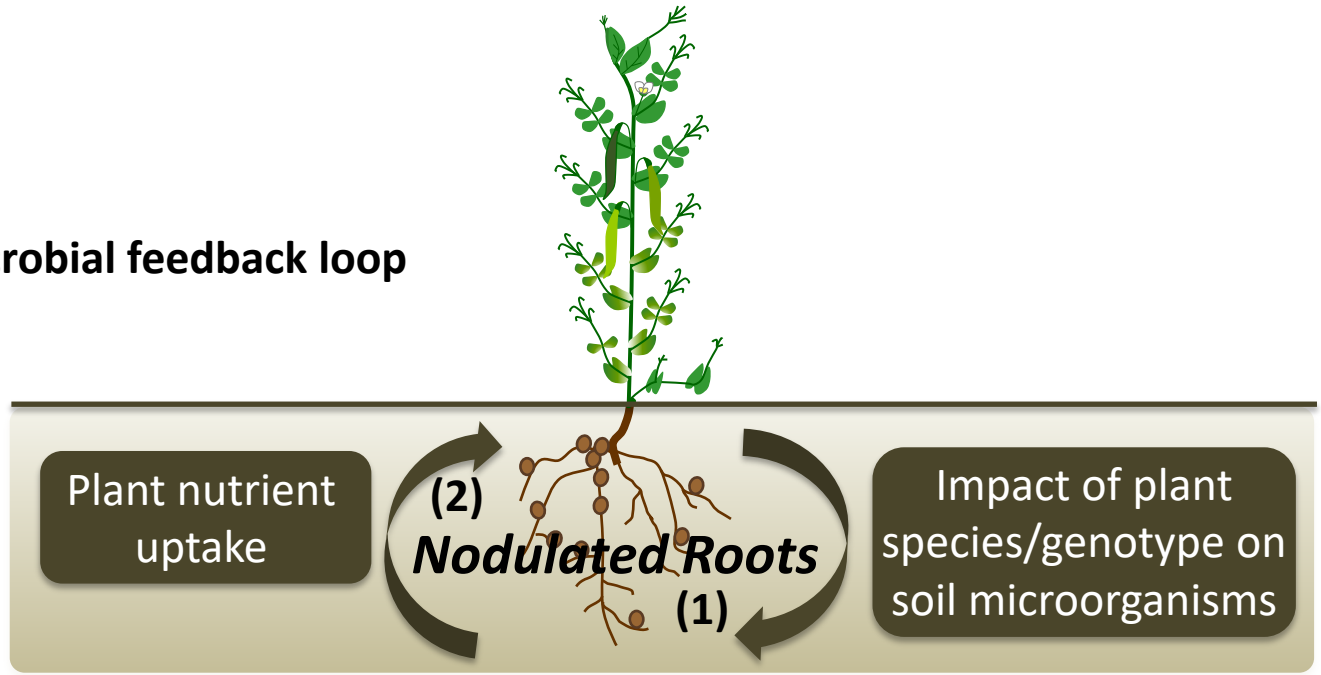
GRASP project (ANR)

➥ **Towards breeding of pea varieties with improved symbiosis for N_2 fixation**

Background and aims: among research themes

Legume-microbe interactions to improve plant growth and nutrition

Plant – Microbial feedback loop



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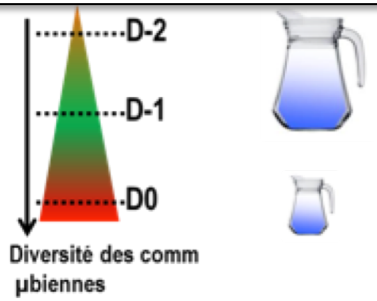
Background and aims: among research themes

Legume-microbe interactions to optimize symbiotic N_2 fixation

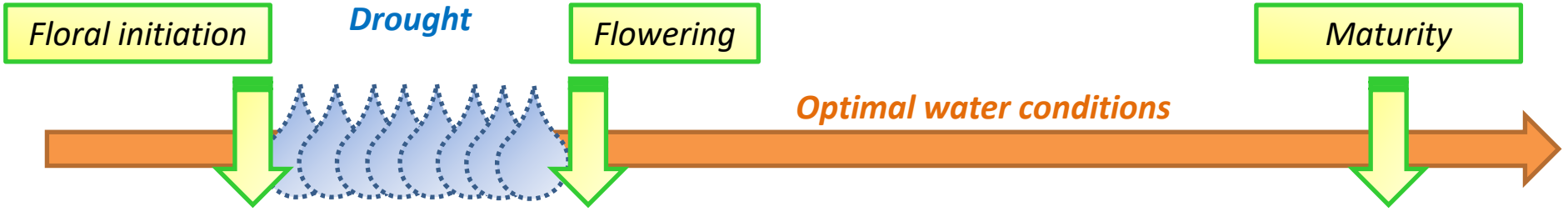
BQR project

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

Varying: level of microbial diversity | Drought extent | Genotype



- **A higher diversity level of soil microbial communities**



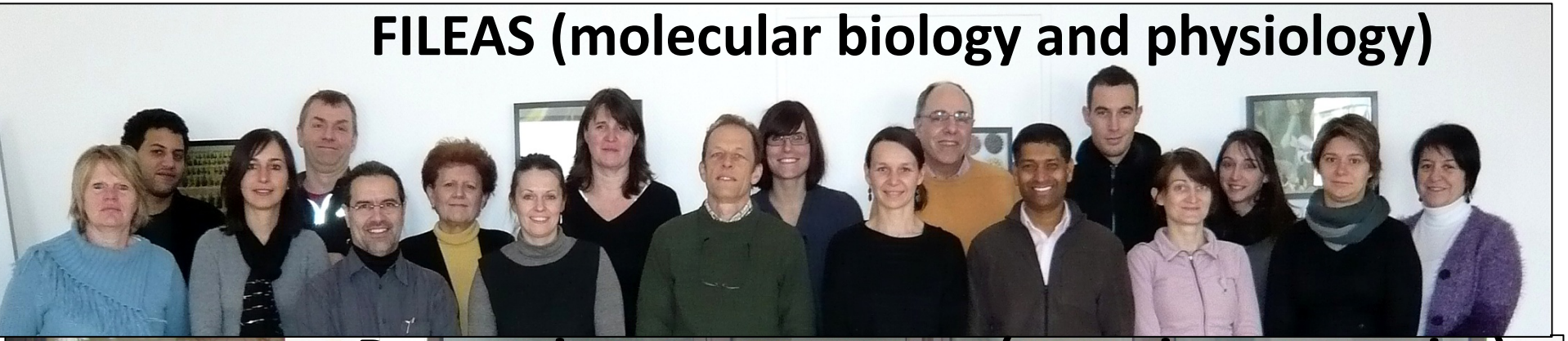
- **has no impact on pea drought tolerance…**

… but provides better pea resilience after stress

- **Similar response with or without symbioses: non symbiotic communities play a role in this response**

The GEAPSI Group…

FILEAS (molecular biology and physiology)



Proteaginous target crop (genetics, genomics)