Breeding strategies for legume crops: main challenges

Bernadette Julier
URP3F, Lusignan, France

INRA
SCIENCE & IMPACT

Horizon 2020 of European Union: Call 2016, SFS 44 : “A joint plant breeding programme to decrease the EU's and China's dependency on protein imports”

This project has received funding from the European Union’s Horizon 2020 Programme for Research & Innovation under grant agreement n°727312.

EUCLEG

Breeding forage and grain legumes to increase EU’s and China’s protein self-sufficiency

www.eucleg.eu

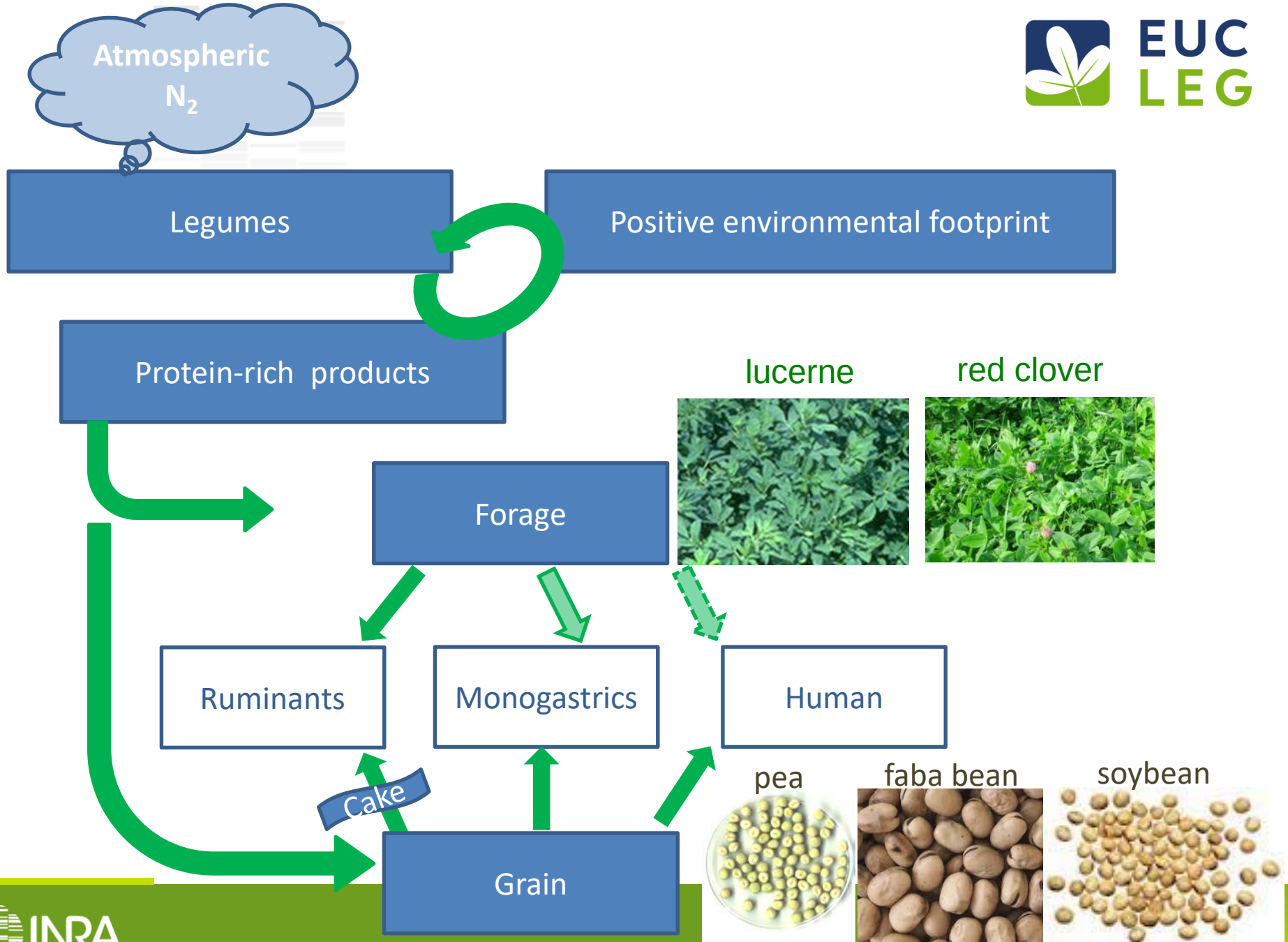
Fabaceae: one family…

- Grain legumes (“pulses”): annual, mainly self-pollinating, large genome
- Forage legumes: perennial, cross-pollinating, heterozygous (and polyploid) genome

→ different breeding schemes

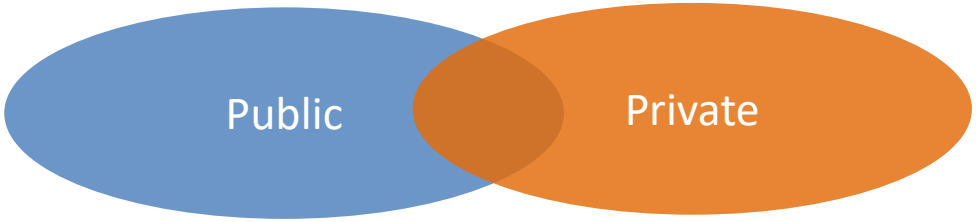
Low number of breeders, limited budget

A few main species, many « minor » species


Atmospheric
N_2
Legumes
Positive environmental footprint
Protein-rich products
lucerne
red clover
Forage
Ruminants
Monogastrics
Human
Cake
Grain
pea
faba bean
soybean

Challenges in breeding research

1. Identify target traits for each crop and set up phenotyping methods
2. Identify, collect and phenotype genetic resources
3. Deliver molecular tools
4. Decipher genetic architecture of traits
5. Renew breeding methods

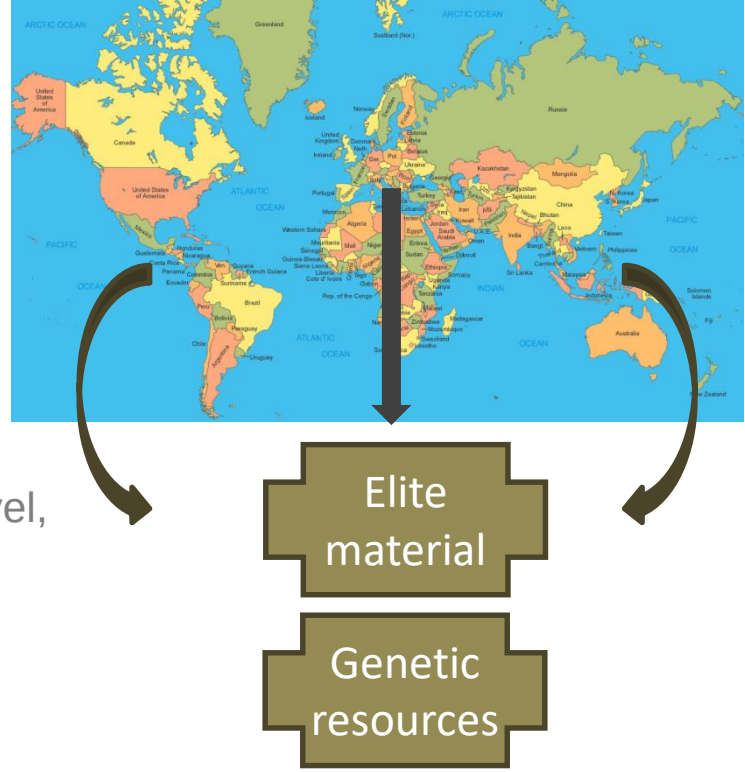


Challenge 1

Identify target traits for each crop and set up phenotyping methods

- « Traditional traits »:
  - Establishment
  - Phenology
  - Forage or grain yield and stability
  - Quality
  - Disease tolerance
- Traits related to climate change
  - Drought tolerance
  - Cold tolerance (extension of crop area cultivation)
  - Heat tolerance
- Traits related to environmental issues
  - Nitrogen fixation
  - Grazing tolerance
  - Adaptation to legume – grass mixtures
  - Persistency
- "New traits" related to processing: increase the use of legume crops in human nutrition
  - Anti-nutritional compounds
  - ...

Challenge 2



Identify and collect genetic resources

- **Breeding programmes**
  - Genetic diversity can be narrow at a breeder level,
  - much wider if breeders associate in a project,
  - even larger at the world level
- **Untapped genetic resources**
  - Present in genetic resources centres
  - Wild populations, landraces, old varieties
- **Identify and collect all these resources is practically a challenge !**
  - Data mining (PGR, old and recent variety lists, breeding material)
  - Owner agreement
  - Administrative steps (Material Transfer Agreements, …)
  - Sanitary aspects
  - (Seed multiplication)

EUC LEG

INRA SCIENCE & IMPACT

Challenge 2

Test these genetic resources

- Multi-site field trials
- Controlled conditions
- Chemical composition

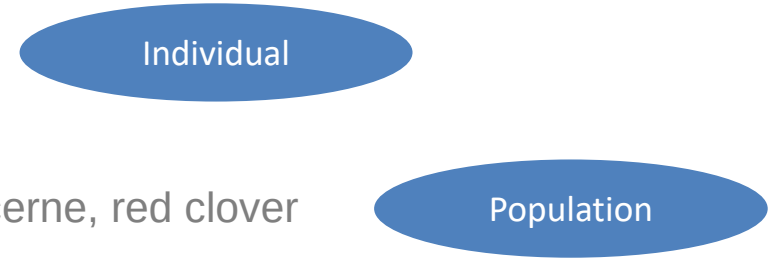
To

- Identify promising accessions
- Measure genetic variation, genotype x environment
- Evaluate genetic correlation, heritability
- Know more about genetic structure

Challenge 3

Deliver molecular tools

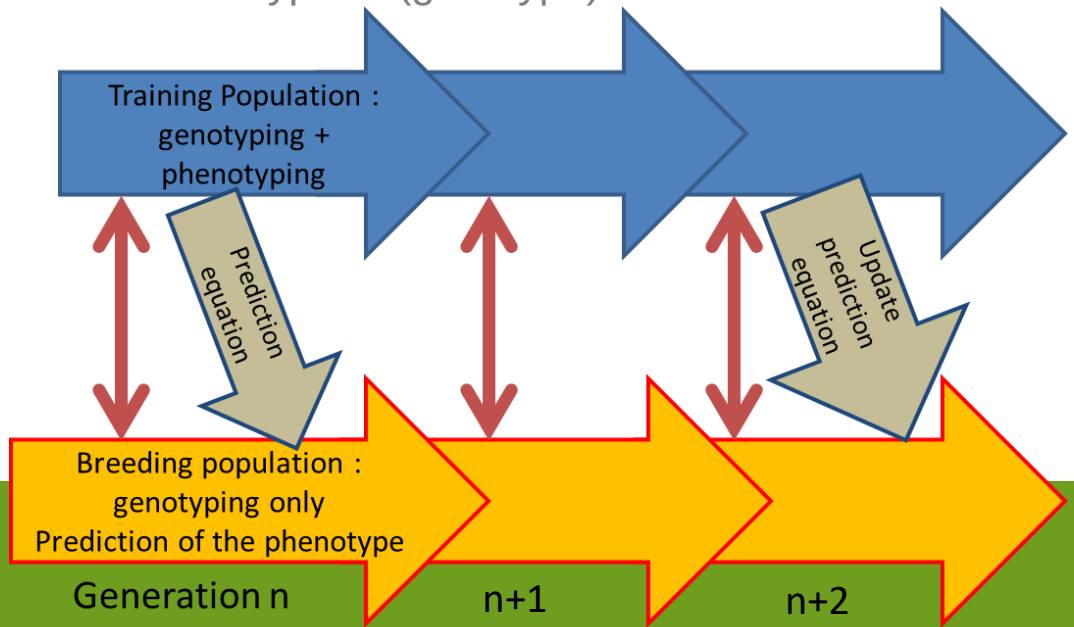
- Reference genome sequence
  - Recently available for some legume crops (red clover, soybean, pea…),
  - Needed for other species (lucerne, faba bean, …)
  - Genome complexity: genome size of grain legumes, heterozygosity / polyploidy of forage legumes
- High throughput genotyping methods
  - SNP array: soybean
  - Exom capture: pea, faba bean
  - Genotyping by Sequencing: lucerne, red clover



Challenge 4

Decipher genetic architecture of traits

- **Genome wide association studies (GWAS)**
  - Direct link between marker and trait polymorphisms
  - Require many markers
  - No preliminary hypothesis on gene control
  - *A posteriori* results on possible involvement of genes or regulatory sequences
- **Genomic selection**
  - Prediction equation: Phenotype = f(genotype)



Challenge 5

Renew breeding methods

- **Consider more traits / more complex traits**
  - More phenotyping efforts
  - High throughput phenotyping
  - Phenotyping in controlled conditions
- **Concentrate on promising genetic resources**
  - Especially for new traits
- **Implement different types of marker assisted selection**
  - Identification of markers or genes involved in trait control
  - Establish prediction equations
  - Set up breeding method(s)
  - Software development to assist in data management and computing

Additional challenges

- Consider all legume species including « minor » ones

- Set up collaborative platform(s) to share genotyping and phenotyping efforts ?

EUCLEG objectives

At the scientific level:

- **Broaden the genetic base of legume crops and analyse the genetic** diversity of European and Chinese legume accessions using phenotypic traits and molecular markers
- **Analyse the genetic architecture of key breeding traits** using association genetics (GWAS)
- **Evaluate the benefits brought by genomic selection** (GS) to create new legume varieties

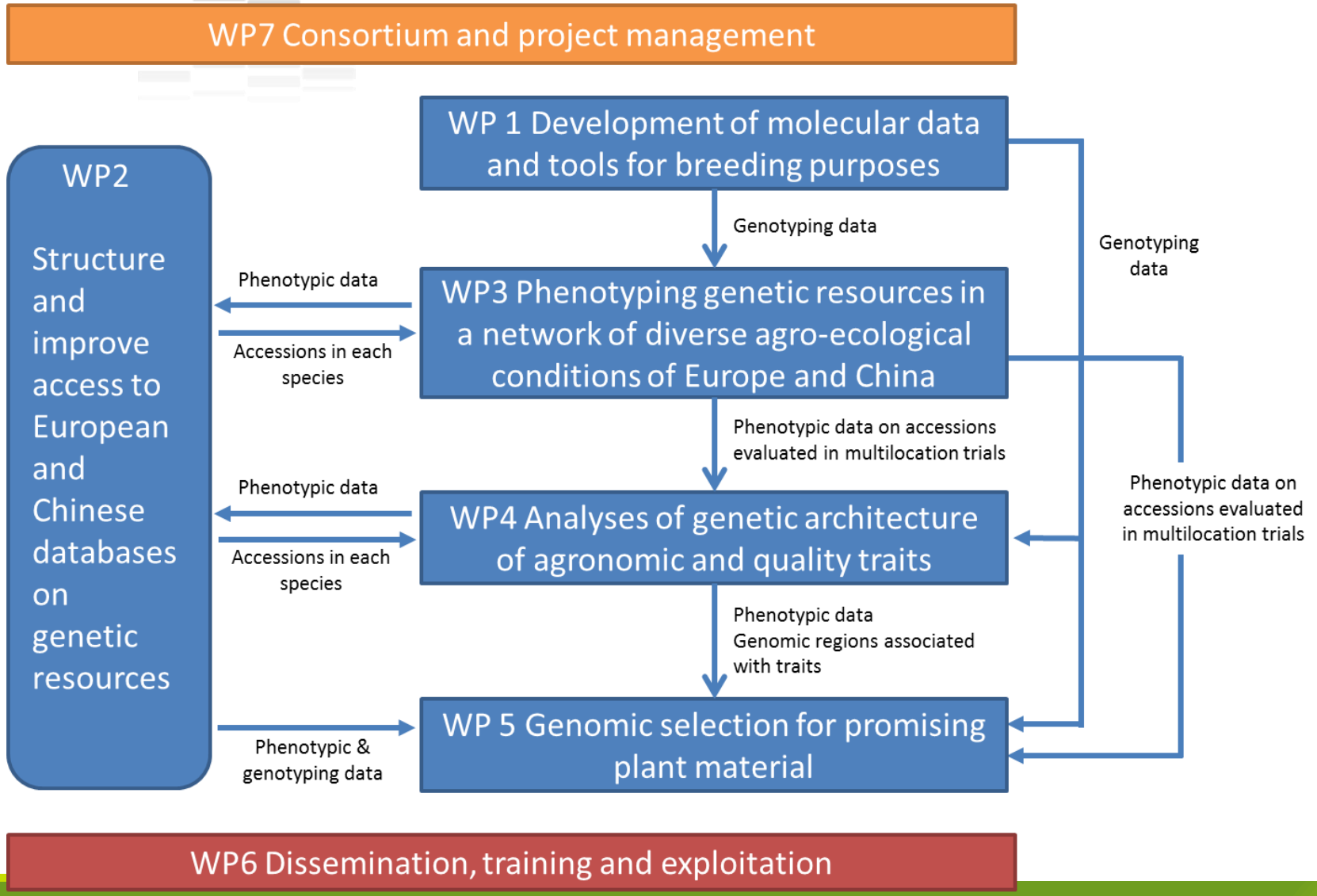
At the technological level:

- **Develop searchable databases** containing passport data, as well as agronomic and genetic features
- **Develop molecular tools and data**

At the applied level (breeding):

- **Develop tools for genotyping**
- Implement **data management and analysis**
- **Explore** the potential for **new uses of forage species for human nutrition**

Project structure



Important points

- Same strategy for all 5 species
  - Use of genetic resources (WP2)
  - Phenotyping (WP3 and 4) and genotyping (WP1)
  - Focus on key phenotypic traits, from establishment to yield and quality, including biotic and abiotic stresses
  - Description of genetic variation, G x E interactions (WP3)
  - Genetic architecture: GWAS (WP4), GS (WP5)
  - Software for data management and analyses (WP2, WP5)
- Strong collaboration with private companies
- Dates : from September 2017 to August 2021 (4 years)

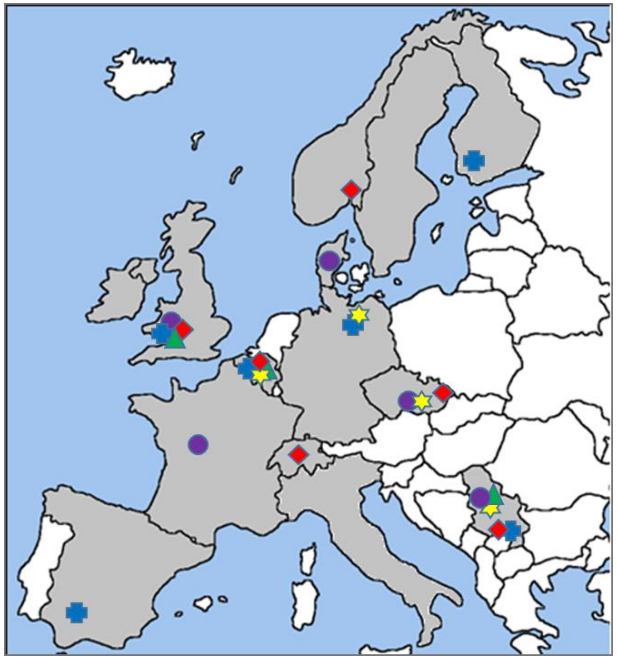


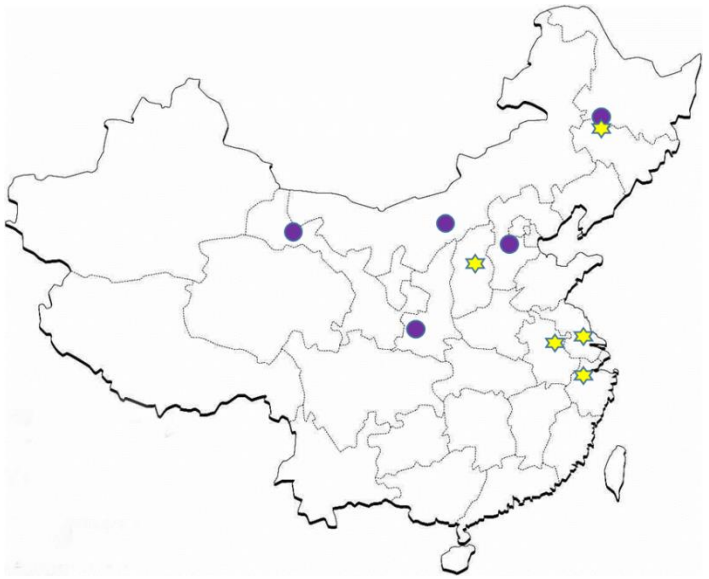


Partnership

38 partners :

- 26 European partners: including 9 breeding companies and 1 SME
- 12 Chinese partners: including 1 breeding company





European Countries participating in EUCLEG project

Field trials:

Alfalfa Red clover Pea Faba bean Soybean