Designing and evaluating arable systems. Cash and cover crop legumes in sole crop and intercrop to improve nitrogen use efficiency

Laurent Bedoussac, Hélène Tribouillois, Daniel Plaza Bonilla, Etienne-Pascal Journet, Eric Justes

Designing and evaluating arable systems

Cash and cover crop legumes in sole crop and intercrop to improve nitrogen use efficiency

Bedoussac Laurent, Tribouillois H., Plaza-Bonilla D., Journet E.-P., Justes E.
laurent.bedoussac@toulouse.inra.fr

INRA SCIENCE & IMPACT

INP TOULOUSE ENSAT

enfa ECOLE NATIONALE DE FORMATION AGRONOMIQUE TOULOUSE-AUZEVILLE

19th NITROGEN WORKSHOP

Efficient use of different sources of nitrogen in agriculture - from theory to practice

Skara, Sweden 27 June – 29 June 2016

Improving low-input systems with legumes

Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935
Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environment 212, 1-12
Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364

INTRODUCTION

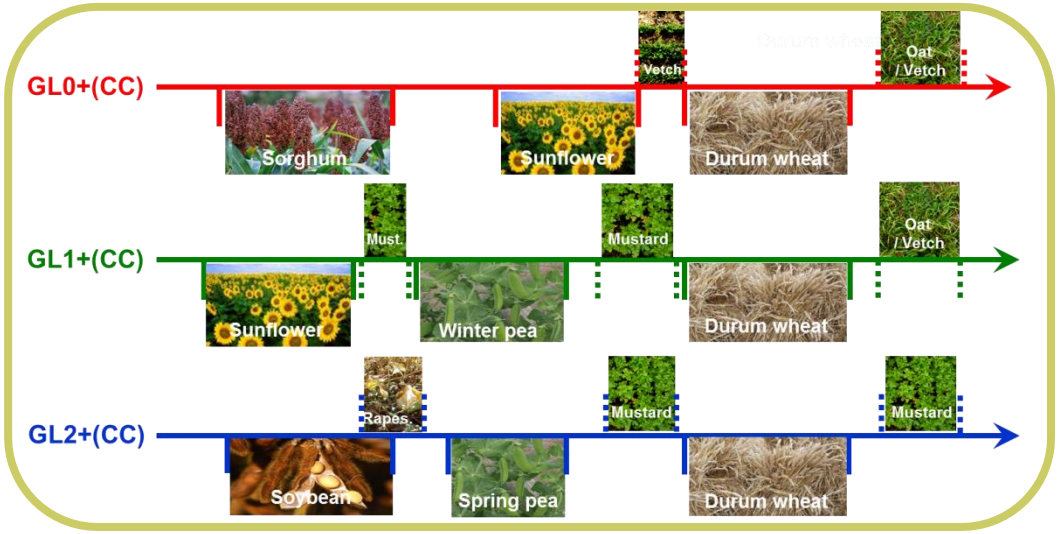
- **Increasing concern about climate change and environment**
  - Requires transformation of cropping systems
- **Crops diversification and legumes are a solution for low-input syst.**
  - Break-crop effects and benefits from N2-fixation
- **Different ways to introduce legumes in low-input cropping syst.**
  - Cash crops and Cover crops
  - Sole crops and Intercrops

- **Objectives : Designing and evaluating low-input cropping systems**
  - Maximizing the benefit from leguminous N2 fixation
  - Reducing environmental impacts
  - Using jointly field experiments and crop modelling
  - Evaluating grain legume intercrops for yield and quality
  - Evaluating cover crops for nitrate capture and green manuring services

1.1) Designing and evaluating cropping systems

From : Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environment 212, 1-12

- **Two 6-year field experiments to study the effects of grain legumes**
  - **A three-year rotation**
  - **Six rotations compared**
    - 0, 1 or 2 grain legume
    - With or without cover crop
    - Each crop grown each year
  - **Crop management based on decision rules**

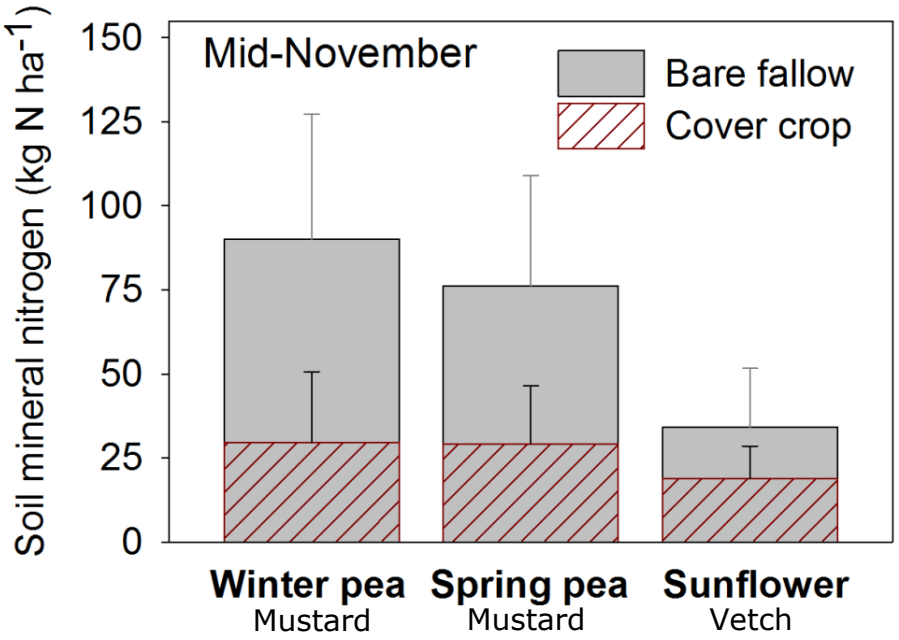


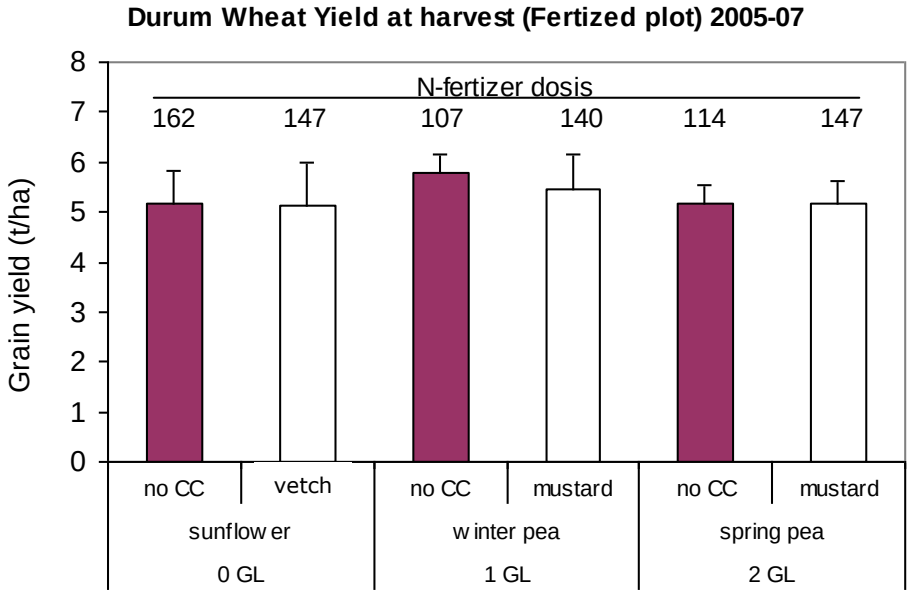
- **Simulations at the rotation time taking into account water and N dynamical budgets**

Soil-Crop Model for legumes and CC
(Brisson et al., 1998; 2020; 2003)

1.2) Effects of legumes and cover crops on wheat yield and soil mineral N

From : Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environnement 212, 1-12





Mineral-N in soil at wheat sowing

- Higher soil N availability after pea: +50 kg N/ha
- Significant effect of CC to decrease mineral-N
- Mustard very efficient to uptake soil mineral-N during few weeks

Wheat yield & fertilizer-N doses

- Yield slightly higher after w. pea
- Same yield with and without CC
- N release not always compensate pre-emptive competition for soil N
- Rate of fertilizer-N must be increased to reach the same yield

1.3) Designing and evaluating cropping systems

From : Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environment 212, 1-12

- **Grain legume sole cropping not always decrease inputs (except N)**
  - **Sensitivity of pea to pests (aphids, weevils) and diseases (anthracnose)…**
  - **How to chose grain legume cultivars?**

- **Higher N availability after pea must be carefully manage**
  - **To avoid high level of nitrate leaching**
  - **Need to adapt the whole cropping system to valorize N2 fixation**

- **Cover crops are efficient but need to be carefully managed**
  - **To avoid N pre-emptive competition for the succeeding crop**
  - **What about N20 emissions?**
  - **How to chose adapted species?**

Discussion

2.1) Cover crops for nitrate capture and green manure services

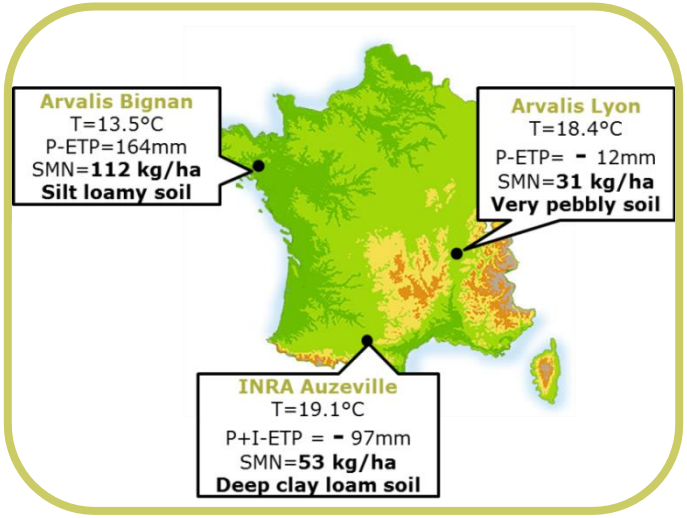
From : Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364

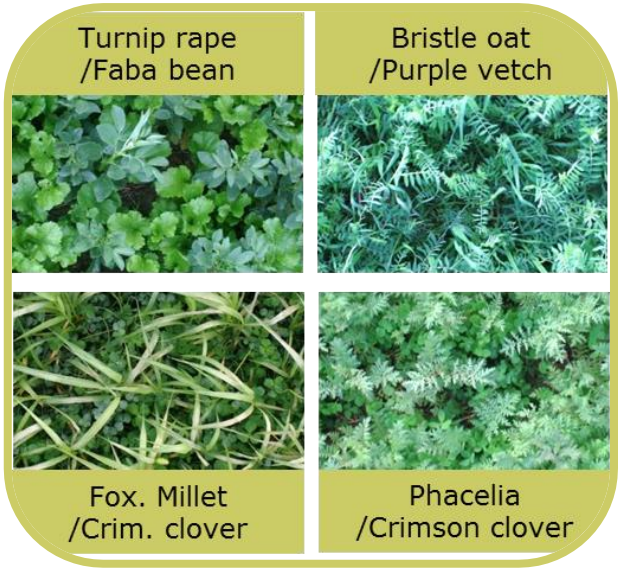
- **A wide range of conditions**
  - **3 sites**
  - **Contrasted pedo-climatic conditions**

- **Mixtures evaluation on 3 sites**
  - **5 fast growing legumes**
    Purple vetch, crimson clover,
    wild lentil, faba bean, forage pea
  - **5 various non-legumes (family, architecture)**
    Turnip rape, foxtail millet, bristle oat,
    Italian ryegrass, phacelia
  - **25 bispecific mixtures**
    (1 leg/1 non-leg ; 50%/50%)

- **Effect of date of destruction on one site for selected mixtures**

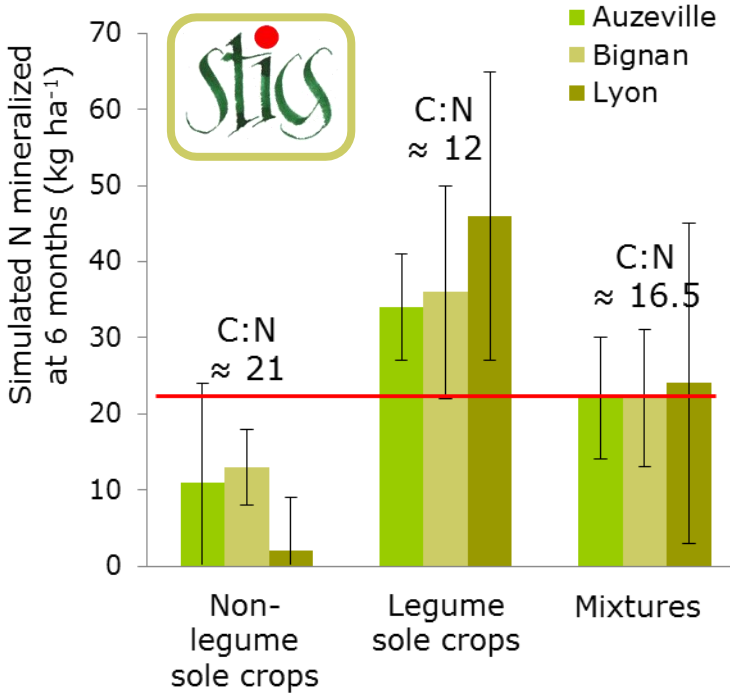
- **N management services assessed with both experiments and models**

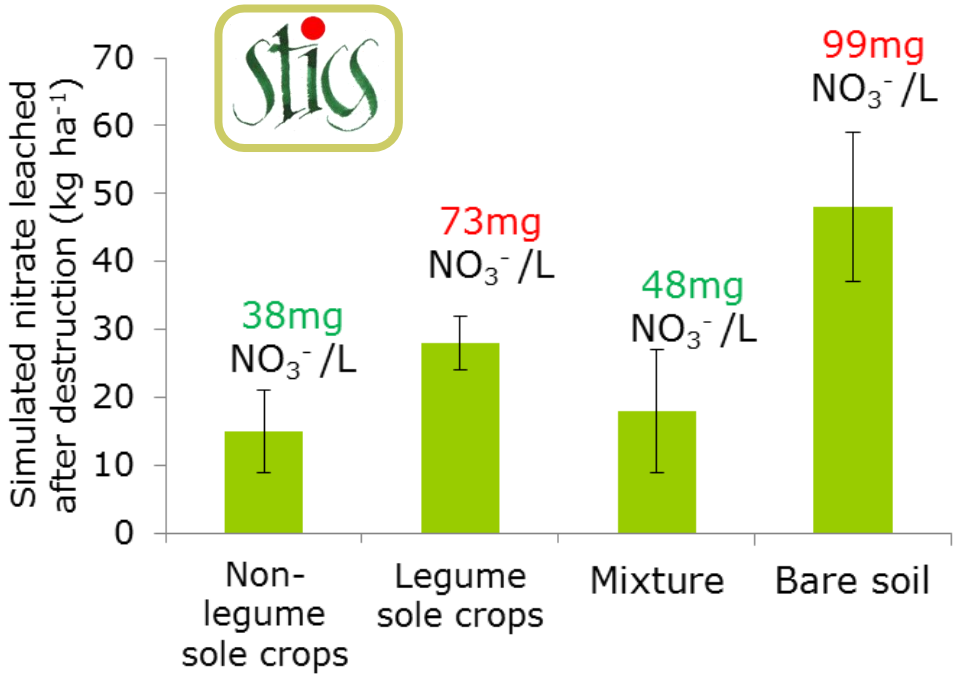




2.2) N mineralization and Nitrate leaching simulation

From : Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364





N mineralization from CC residues

- **N mineralized from residues:**
  Non-leg. SC < Mix. < Leg. SC
- **C:N ratio:**
  Leg. SC < Mix. < Non-leg. SC

Nitrate leaching simulation (destruction after autumn)

- **N leached:**
  Mix.≈Non-leg. SC < Leg. SC
- **[NO3-] in drained water:**
  Mix.≈Non-leg. SC < Leg. SC < BS

2.3) Cover crops for nitrate capture and green manure services

From : Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364

- **Bispecific cover crop mixtures allowed :**
  - **Catch crop effect ≈ non-legume sole crops**
  - **Green manure effect intermediary**
- **The best mixtures depend on the risk of leaching and pre-emptive competition**
  - **Case 1. Low SMN and low drainage (low risk of NO3- leaching, high risk of pre-emptive competition**
    - **Mixture favoring the green manure effect with a destruction at mid-Autumn**
  - **Case 2. High SMN and very permeable soil (high risk of NO3- leaching)**
    - **Mixture favoring catch crop during winter and late destruction at the end of Winter**
- **Need for a dynamic model for bispecific mixtures CC to help for species assemblage and optimizing CC management**

Discussion

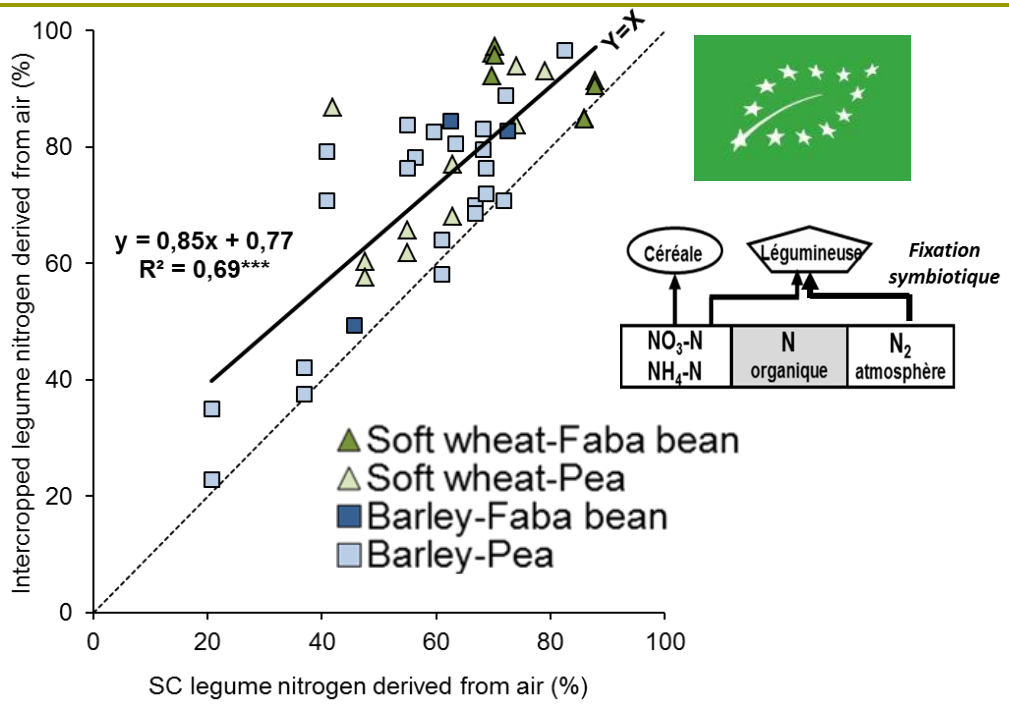
3.1) GL Intercrops to improve productivity and stability by species complementarity

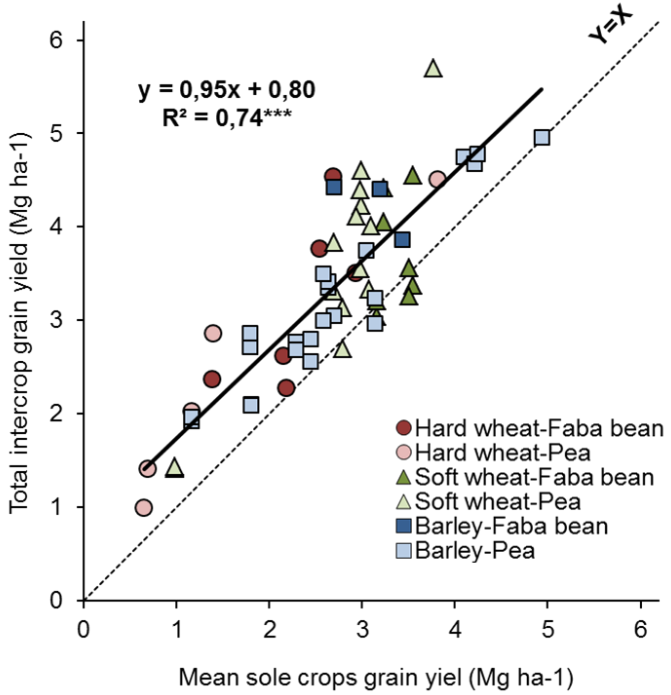
From : Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935

- **10 years of experiments**
  - Various pedo-climatic conditions
  - Conventional and organic farming
  - Experimental station and farm
  - Spring and Winter crops
- **Large range of practices**
  - Cultivars, Densities, Patterns, N, P…
- **Different aims :**
  - Evaluate IC potential advantages
  - Analyze IC functioning

3.2) IC improves yield by complementarity for N Sources (soil mineral N and N2 from air)

From : Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935





- **Higher legume N2 fixation rate in IC (75% vs. 62%)**
  - Niche complementarity for N sources & competition for soil N
  - Most of soil mineral N available for the cereal
  - IC efficiency higher in low N
- **IC yield higher than the mean SC (3.3 vs 2.7 Mg ha-1)**
  - Highest efficiency for low N
- **IC grain yield more stable**
  - Higher resiliency
- **Proportion of cereal > 50%**
  - Cereal more competitive

3.3) GL Intercrops to improve productivity and stability by species complementarity

From : Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935

- **Intercropping is an efficient way to improve yield and grain quality**
  - **Competition for similar resources (in time, space or chemical form) is reduced**
  - **Facilitation process (e.g. P) or niche complementarity (e.g. N)**
- **Intercropping advantages mostly observed in low-input conditions**
- **N transfers between species are limited for annual crops**
- **The best mixtures depend on species, cultivars, fertilization…**
  - **Modelling intercropping systems could be helpful to optimize them and to determine varietal characteristics suited to mixtures**

Towards new innovative cropping systems

Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935
Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environment 212, 1-12
Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364

CONCLUSION

- **Further work is needed to better exploit legume advantages and design new cropping systems :**
  - Better use N availability due to grain legume by sowing cover crop to limit nitrate leaching and increase the N efficiency at the rotation level
  - Analyse the potential of intercrops to reduce grain legume pests and diseases damages which are tedious problems in low-input farming and organic farming
- **A number of factors still needs to be optimized before the full potential of intercropping systems can be expressed such as:**
  - Intercrop efficiency according to N availability in dynamics
  - Species and cultivars adaptations
  - Sowing practice (densities and patterns)
  - Harvest and post-harvest for grain IC: adjustment of beating and grain separation
- **The correct rotational position of intercrops need to be analyzed in order to propose relevant solutions…**

AGIR UMR 1248 INRA / INPT
AGroécologie - Innovations - TeRritoires

Tack för din uppmärksamhet

Designing and evaluating arable systems: cash and cover crop legumes in sole crop and intercrop to improve Nitrogen Use efficiency

Bedoussac Laurent, Tribouillois H., Plaza-Bonilla D., Journet E.-P., Justes E.
laurent.bedoussac@toulouse.inra.fr

INRA SCIENCE & IMPACT

INP TOULOUSE ENSAT

enfa TOULOUSE-AUZEVILLE ECOLE NATIONALE DE FORMATION AGRONOMIQUE

To learn more about this presentation:

Bedoussac, L. et al. 2015. Agronomy for Sustainable Development 35, 911-935
Plaza-Bonilla, D. et al. 2015. Agriculture, Ecosystem and Environnement 212, 1-12
Tribouillois, H. et al. 2015. Plant and Soil 401, 347-364