Increasing pea or fababean N 2 fixation by intercropping with durum wheat to improve the cereal grain protein concentration

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Improve agricultural systems efficiency

- Intensification of agriculture in the last 50 years sometimes leads to:
  - **Environmental contamination** (water, soil, air)
  - **Resistance to chemicals** (e.g. Griffon 2006)
- ⬆ **Input costs**
- **Limited resources**
- ⬇ **Energy consumption**

→**Efficiency of agricultural systems needs to be improved**

→ **One of the solutions: diversification of agro-systems** (Malézieux et al. 2008)

• **Intercropping** = the simultaneous growing of two or more species in the same field for a significant period but without necessarily being sown and harvested at the same time (Willey 1979)

Advantages and Disadvantages of intercrops

Cereal – grain legume **spring intercrops** are known to **improve the use of available resources (complementary use of light & N pools)**

(eg. Corre-Hellou 2005; 2006; 2007, Hauggaard-Nielsen et al. 2001; 2003; 2005; 2006; 2009)

- ⬆ Global yield
- ⬆ Cereal grain protein content
- ⬇ Chemicals inputs (**but** contradictory results in the literature)
- Better stability over years

(eg. Jensen 1996, Hauggaard-Nielsen et al. 2001; 2003; 2005; 2006; 2009)

→ **Coherent with actual French agricultural policies:**

"Increase organic farming production by 50% in 2012"
"Reduce pesticides use by 50% in 2018"

→ **Interest for southern France and Mediterranean areas:**

- ⬆ Durum wheat **quality** in low N inputs systems
- ⬆ European **grain legume** production

Adapted to **irregular** and **restrictive climates** (particularly **water**)

But… → **Lack of knowledge and references on winter intercrops**
→ **Technical difficulties**
→ **Necessity to sort grains** (for human consumption)
→ **Industry, cooperatives and farmers hesitation**

Objectives and general hypotheses of our work

Hypotheses:

Intercrop efficiency depends on the balance between competition and complementarity for resource use

- Species :

i) **Growth,** ***ii)*** **Resource needs,** ***iii)*** **Aerial architecture**

- Farming practices :

i) **N available,** ***ii)*** **Date and sowing densities,** ***iii)*** **Sowing pattern,** ***iv)*** **Pesticides...**

- Weather and soil

→ Wide range of possibilities

→ Allowing efficient crop management systems design adapted to specific objectives

Objectives:

1. ***Analyse intercrops functioning in a wide range of competition in particular N availability (amount/dynamic)***
2. ***Determine optimal management to improve IC efficiency***

Choice of field experiments

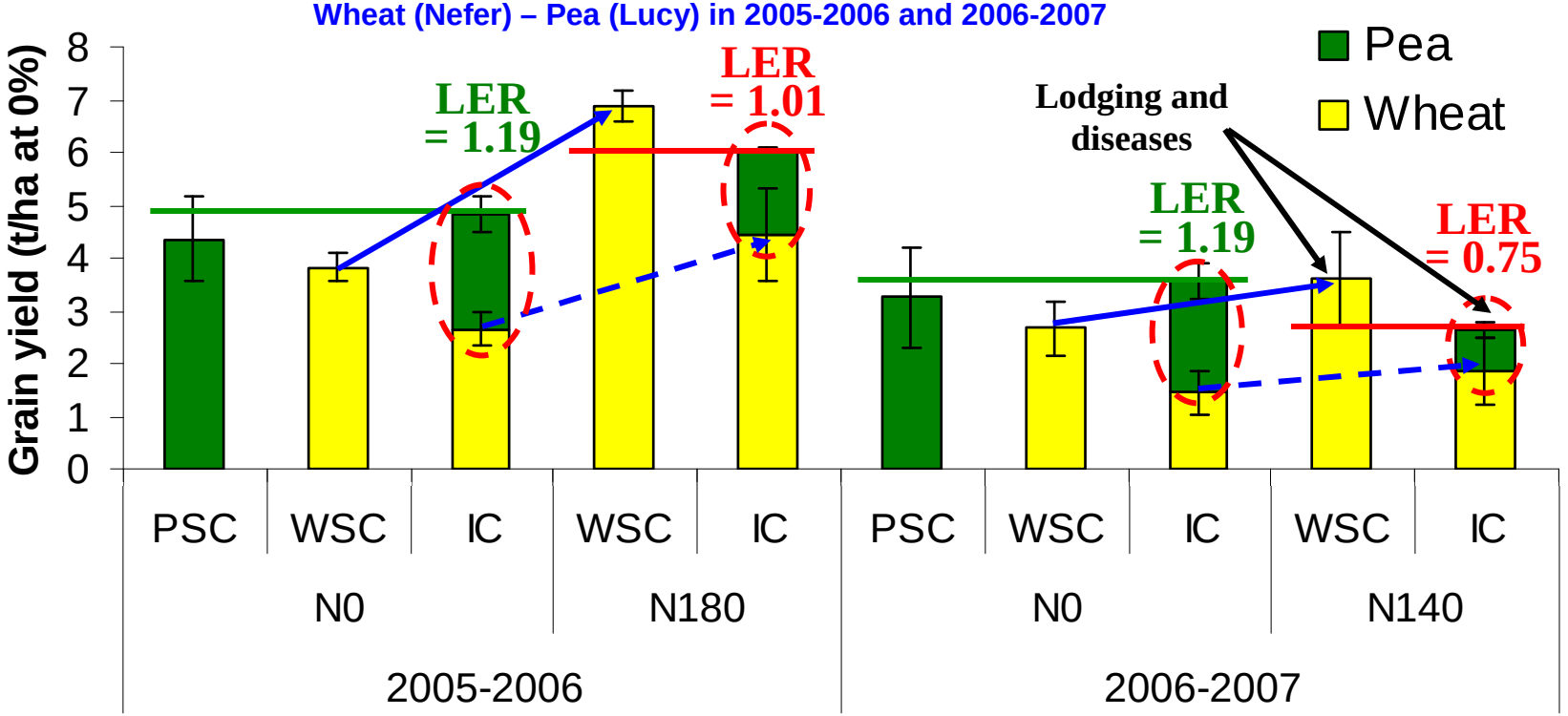
- **Lack of knowledge → choice of field experiments**
- **1 main objective: Evaluate a wide range of competition**
- **3 years experiment = 3 complementary objectives :**

2005-2006: Evaluate hypotheses & potentialities for winter crops
2006-2007: Complete the understanding (functioning & mechanisms) in **dynamics**
2007-2008: Design and evaluate prototypes of crop management systems according to specific objectives in **low input & organic systems**

• 5 wheat cultivars		Intrinsic grain protein content		
		Low	Intermediate	High
HEIGHT	Tall	**Orjaune**	**L1823**	
	Intermediate	**Nefer**		**Neodur**
	Short			**Acalou**

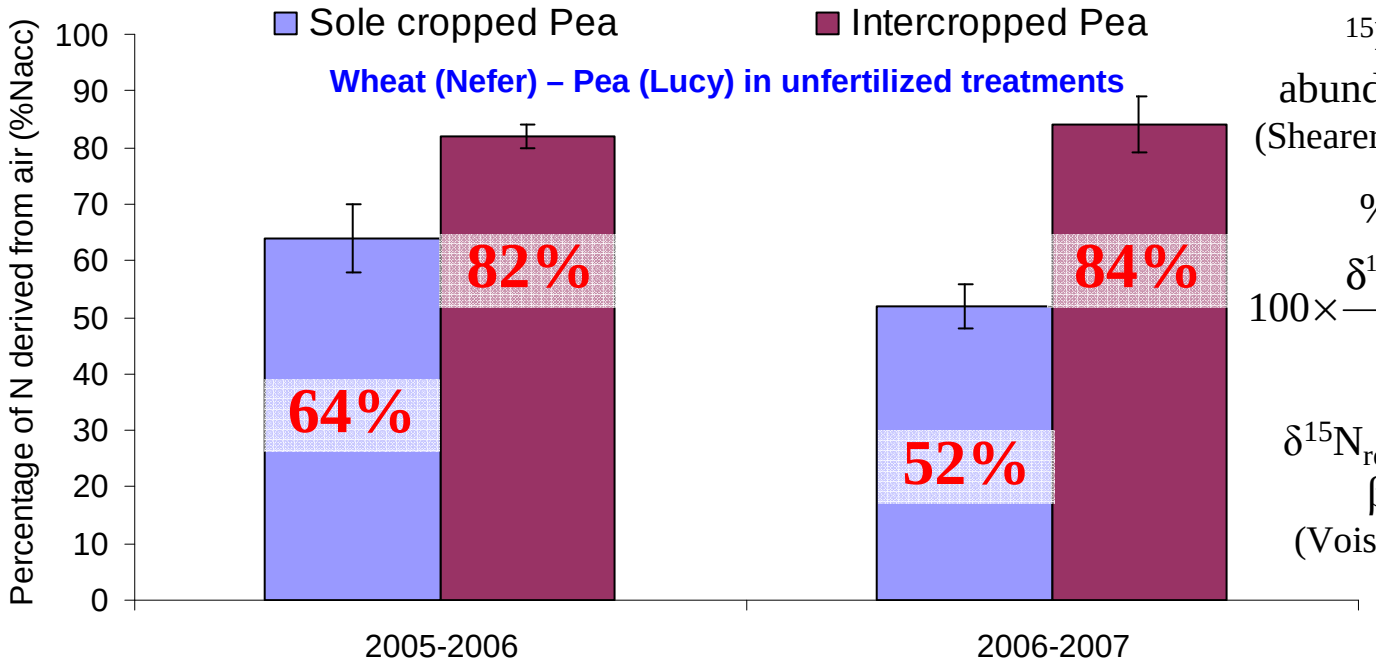
- 2 “winter” legumes: **1 pea (Lucy)** & **1 faba bean (Castel)**
- **Various N availabilities (Amount & Dynamics)**

IC efficiency for yield depends on N availability



- **LER > 1 in low N systems**
  →IC up to 19% more efficient than SC
- **LER ≤ 1 with large amount of N available**
  →IC efficiency depends on N-fertilization & IC more suited to low N
- **N-fertilization slightly increased wheat yield**
- **Pea yield strongly reduced by N-fertilization**

Intercropping increases legume N_2 fixation



^{15}N natural abundance method (Shearer and Kohl 1986)

$$\%Ndfa = 100 \times \frac{\delta^{15}N_{ref} - \delta^{15}N_{pea}}{\delta^{15}N_{ref} - \beta}$$

$\delta^{15}N_{ref}$ = IC wheat

β = -1‰ (Voisin et al. 2002)

- **Pea N_2 fixation in IC > SC**

→ **The more wheat N acquisition the more pea N_2 fixation**

→ **Complementarity for N pools use**

- **High pea N_2 fixation in IC (80-85 %Ndfa)**

→ **14 kg N/ha up taken from soil (only 15% of N available)**

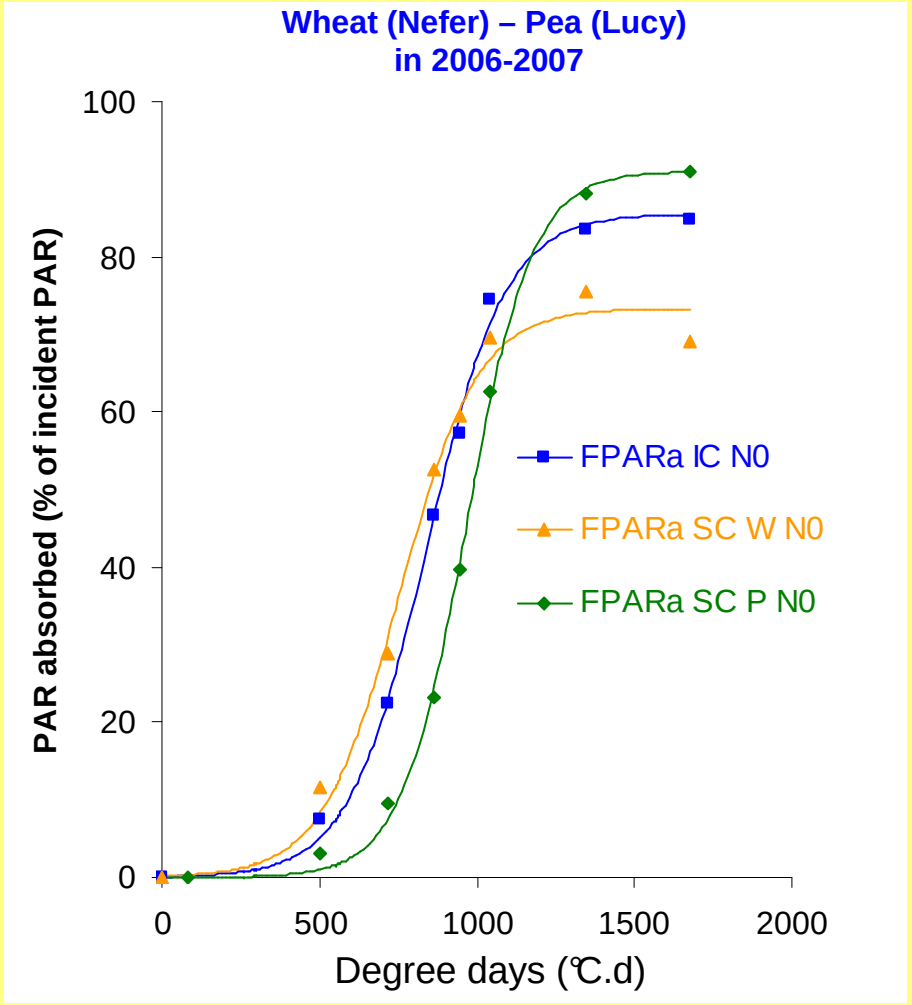
Intercropping improves light absorption

- **Wheat growth earlier than that of pea and then slower**

→ The whole IC absorbed more PAR than the SC

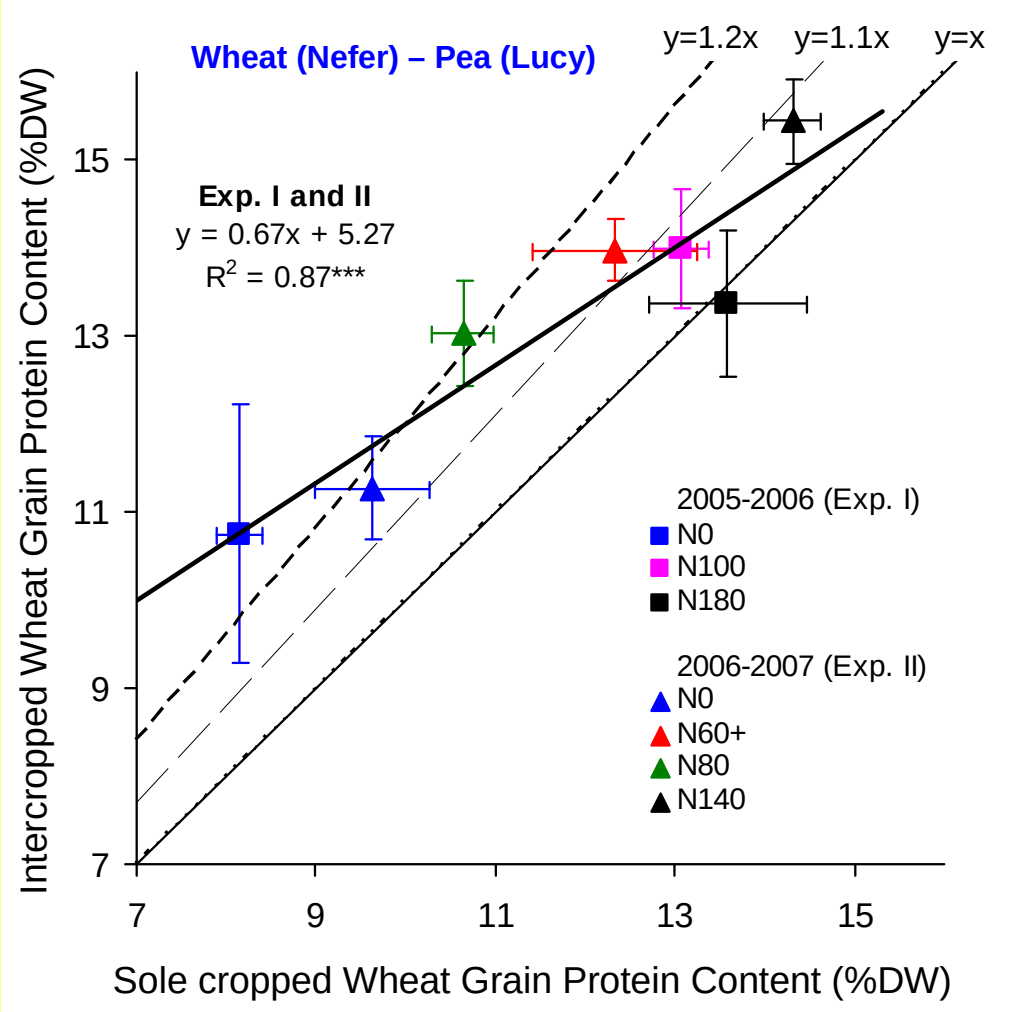
→ **Species complementarities**

→ **≠ in time & height growth**



BUT
IC less efficient than SC wheat with large amount of N

IC improves wheat grain protein content



IC GPC higher than in **SC**

The **lower SC Wheat GPC** the **larger the increase**

→ IC more adapted to low N input systems

Why larger amount of N available per grain in IC ?

Why more N available per grain in IC?

Wheat (mean of Nefer, Neodur, Acalou & Orjaune) – Pea (Lucy) in 2006-2007 (N0)

	Yield	N available	N available /yield unit
SC (reference)	100%	100%	100% (34 kg N/tonne)
SC1/2 (% SC)	92%	100%	109% (37 kg N/tonne)
IC (% SC)	58%	85%	147% (49 kg N/tonne)

Conclusions

- **IC improves the use of available resources (LER>1) in low N input**
  - **Complementary use of N pools**
  - **Complementary light absorption**
  - **Intercrop efficiency reduced with N fertilization**
- **IC improves durum wheat grain protein content (GPC) in low N input**
- **IC efficiency reduced with N fertilization**
  - **Early N fertilization ⬆ wheat growth & ⬇ available light for pea**
- **IC functionning & efficiency is function of:**
  - **Dynamic competition & complementarity**
  - **N fertilization, cultivar, species & densities**

→ Design crop management systems adapted to specific objectives

Perspectives

- **Knowledge needs for designing cropping management systems**
  - Which **are the best-adapted legume cultivars and species** ?
  - Effect of **sowing densities and sowing pattern** ?
- **Knowledge needs for pests, diseases and weeds in IC**
- **Technical feasibility, Interannual stability and Effect of phosphorus ?**
- **Intercrop modelling for designing management systems**
- **Next question to resolve:**

How to introduce Durum wheat-Grain legumes IC in the cropping systems and in agrofood chain?

Thank you for your attention

For more details:
http://wwagir.toulouse.inra.fr/agir

Plant and Soil (2010)
Vol. 330, 19:35
Vol. 330, 37:54

Additional results related to IC design

IC-F efficiency depends on plant densities

98 W / 23 F

112 W / 13 F

IC could ⬇ green aphids but not weevils

IC could ⬇ weeds compared to Pea SC

IC could ⬇ wheat septoria and pea ascochyta