Are durum wheat-grain legume and sunflower-soybean intercrops efficient solutions to produce legume in low input systems?

Laurent BEDOUSSAC, Etienne-Pascal JOURNET, Hélène TRIBOUILLOIS, Grégory VERICEL, David CHAMPCLOU, Nathalie LANDE and Eric JUSTES

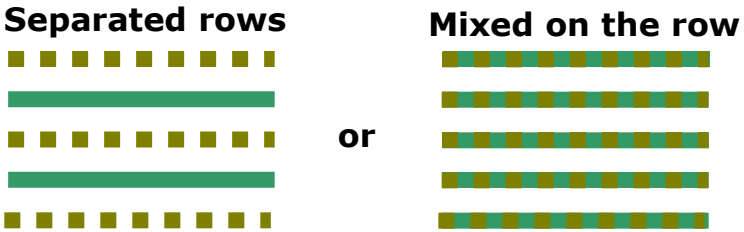
UMR AGIR INRA-INPT
Toulouse – France

1st Legume Society Conference, Novi Sad, Serbia, 9-11 may 2013

Intercrops=Mixed crops: *Simultaneous growing of two or more species in the same field for a significant period without necessarily sowing and harvesting them together (Willey 1979)*

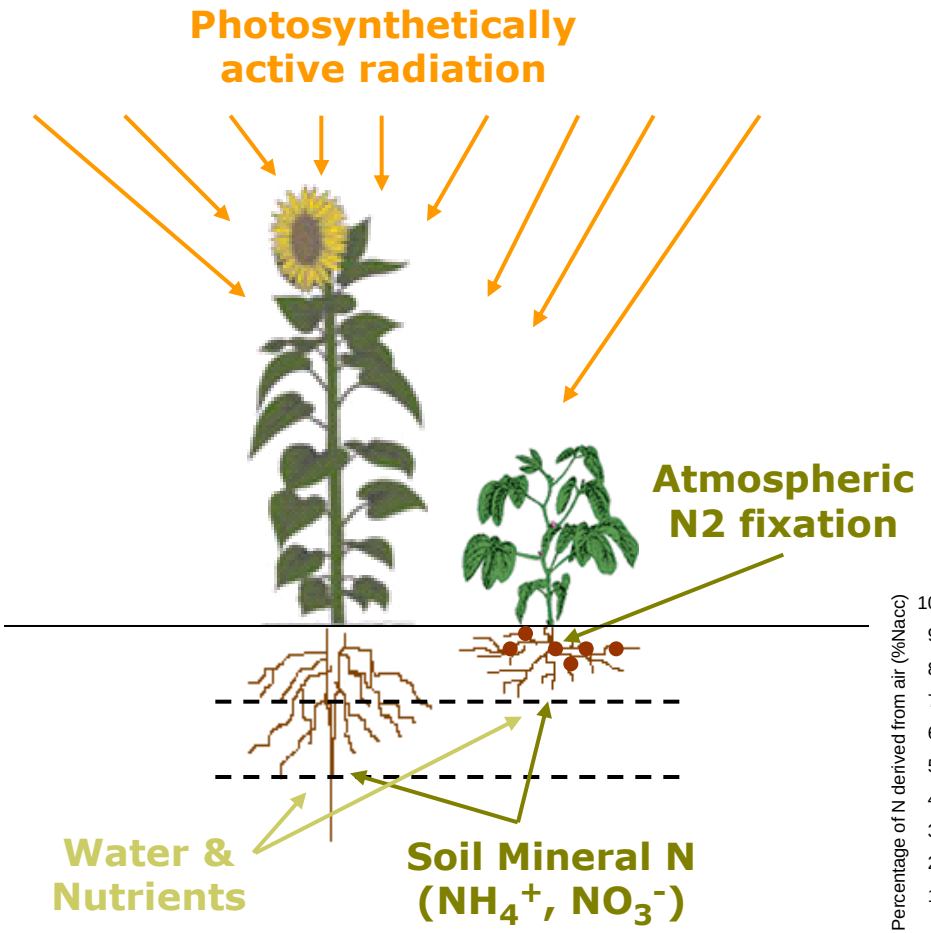
≠ of cover crop during fallow period

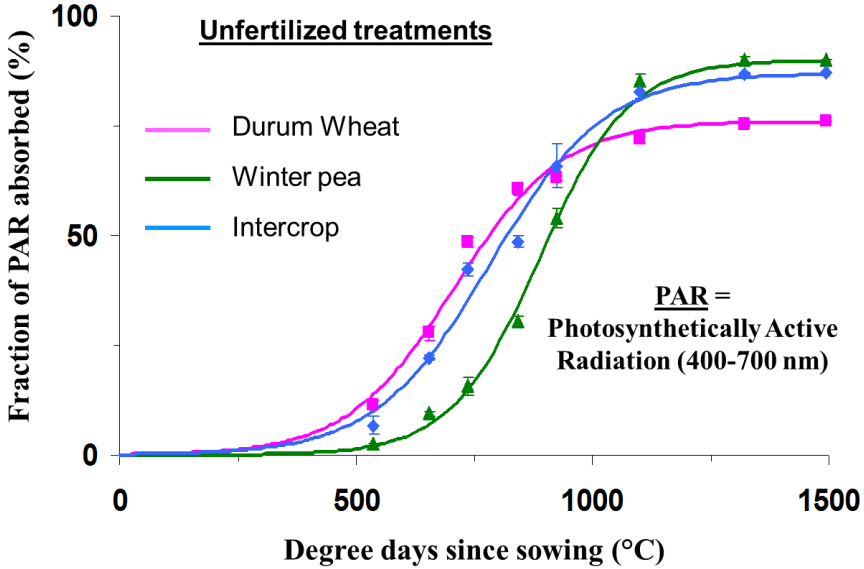
Intercropping is an application of natural ecosystems ecology principles (biodiversity, species interactions, integrated protection…*e.g. Vendermeer, 1989*) *but rarely cultivated except for animal feeding*

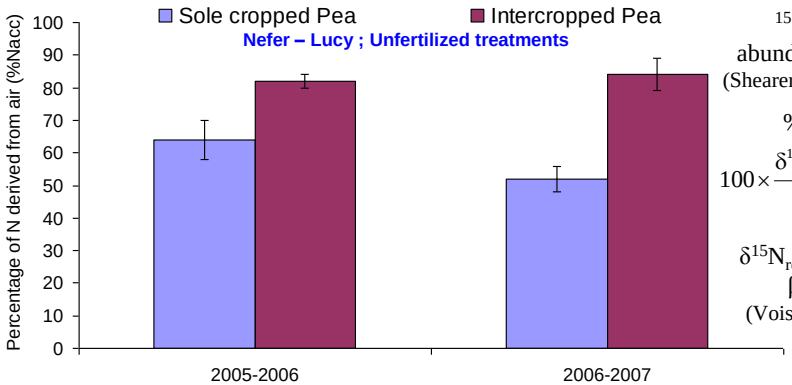


Intercrops and species functional complementarity

→ **Species complementarity could allow a better use of available ressources (water, light, nitrogen…) in time and space**







^{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)

Interests of intercrops for low input systems

- Improve **cereal grain quality** (grain protein content)

(Jensen, 1996; Hauggaard-Nielsen &al 2001a; 2009, Bedoussac & Justes, 2010a)

- Increase **global yield** (compared to low input sole crops)

(Hauggaard-Nielsen &al 2001a; Zhan &al, 2010; Bedoussac & Justes, 2010a)

- Reduce **weeds** (compared to legume)

(Hauggaard-Nielsen &al 2001b, Corre-Hellou &al, 2011)

- Potentially reduce **pests** (e.g.pea aphids) and **diseases**

(hypothesis widely cited, e.g. Vendermeer, 1989; but no demontration published)

- Reduce the **nitrate leaching risk** (compared to sole legumes)

(Hauggaard-Nielsen &al 2003; 2009, Bedoussac & Justes, 2010b)

- Increase **yield stability** (compared to sole crops)

(hypothesis widely cited, e.g. Vendermeer, 1989; but no demontration published)

- Increase or stabilise over years the farmer **gross margin**

(Bedoussac, 2009; Pelzer &al, 2012)

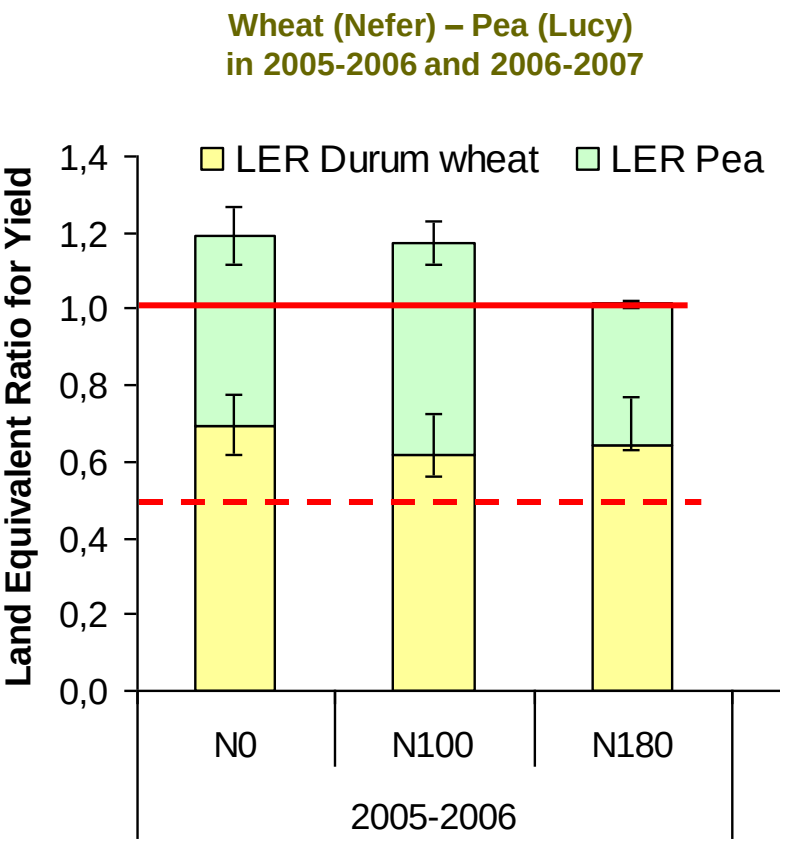
- Improve **football quality**

(Winners of the 2013 legume world cup)

Lots of references for cereal-grain legume IC and few limits highlighted by the scientific community

but only few references for sunflower-soybean IC !!!

Examples of key results on durum wheat-winter pea intercrops: **Efficiency for yield**



(Bedoussac & Justes, 2010a & b)

Land Equivalent Ratio (LER) = an indicator of IC performances (e.g. Willey, 1979) ; **LER** = relative land area under SC required to produce the yield achieved in IC. LER is the sum of partial LER for each species **(LER_P and LER_W)**

$$LER = LER_P + LER_W$$

$$LER_W = \frac{Y_{W-IC}}{Y_{W-SC}} ; LER_P = \frac{Y_{P-IC}}{Y_{P-SC}}$$

- **LER ≥ 1 in LOW N SYSTEMS**

→ IC up to 20% more efficient

- **LER_W ≥ 0.5 and LER_P ≤ 0.5**

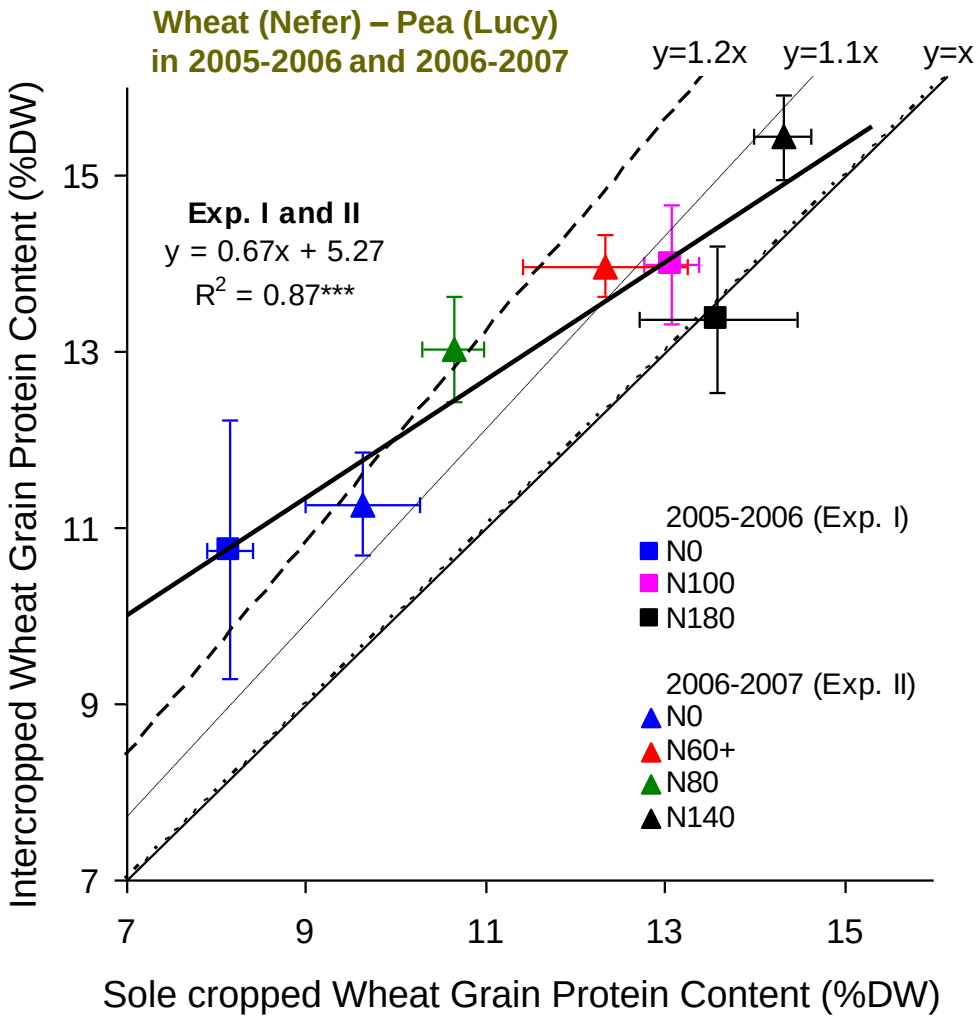
→ Wheat took advantage of IC, not Pea

- **LER widely used and abused while doesn't compare species yields**

→ Other indices more adapted

(Bedoussac & Justes, 2011)

Examples of key results on durum wheat-winter pea intercrops: **Grain quality**



(Bedoussac & Justes 2010a, 2010b)

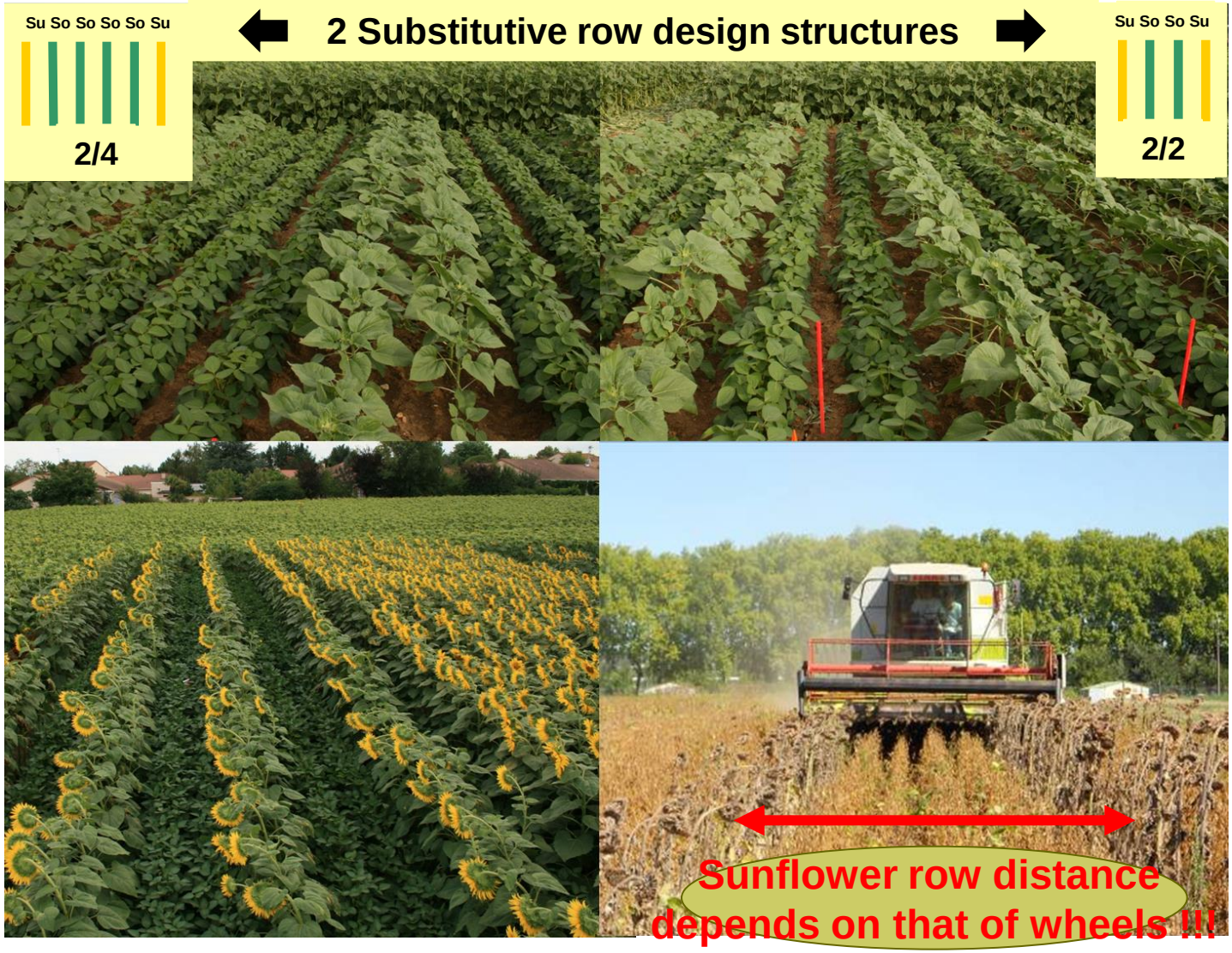
- **IC GPC higher than in SC at the same N level**

- **The lower the 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 ?**
  → Lower IC wheat yield vs. SC but almost same amount of N available (high pea N2 fixation in IC)

→ Niche complementarity for N sources combined with light competition

Summer IC practical aspects :
Sowing once, harvesting twice



Sowing at the same time :

Early to End of May

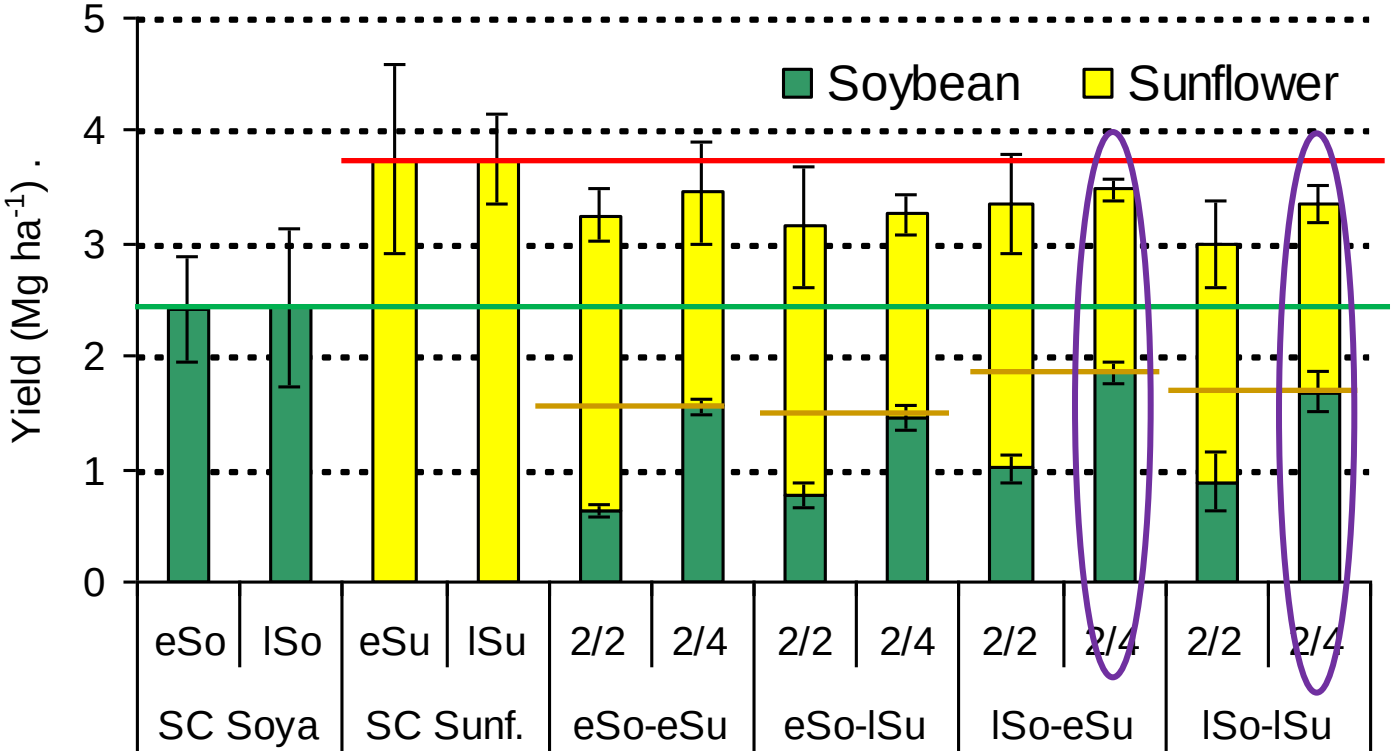
Harvesting in two times :

1st Sunflower : Mid-September

2nd Soybean : End-September / beginning of October

Examples of key results on summer intercrops: **Grain yield**

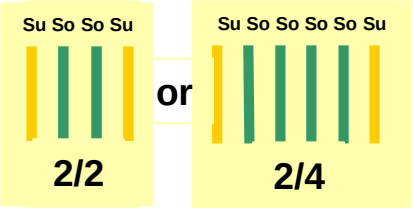
Partial Soybean fertilizaton to compensate inefficient inoculation



LER = 0.96 ; 1.16* ; 0.96 ; 1.10* ; 1.04 ; 1.21* ; 0.92* ; 1.17*

Auzeville 2010

- **2 designs :**



- **4 cultivars :**

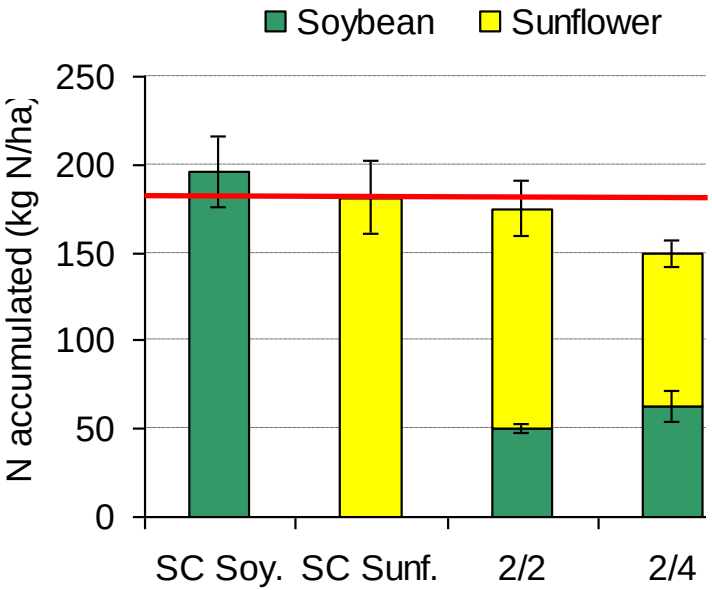
2 Soybean cv. :
Isidor (eSo = **early**)
Ecudor (lSo = **late**)

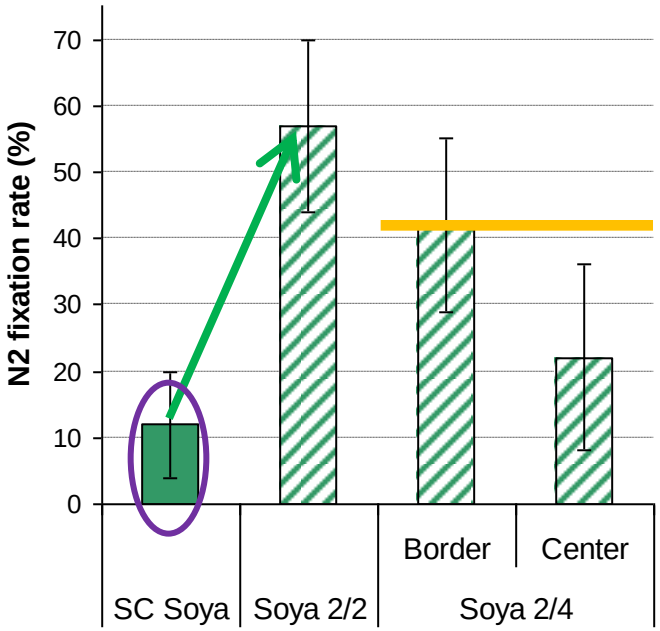
2 Sunflower cv. :
Fabiola (eSu = **early**)
Melody (lSu = **late**)

- IC total grain yield > SC Soybean and < SC Sunflower
- More Soybean in the 2/4 and with late cultivar (lSo)
- Always more Sunflower (except 2/4 with lSo)
- LER always > 1 with the 2/4 design but not for 2/2

Examples of key results on summer intercrops: **N Acquisition**

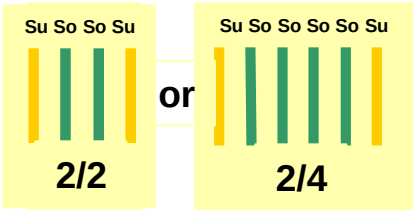
Non limiting resources : 50 mm water ; 360 kg N/ha





CETIOM 2010

- **2 designs :**



- **2 cultivars :**

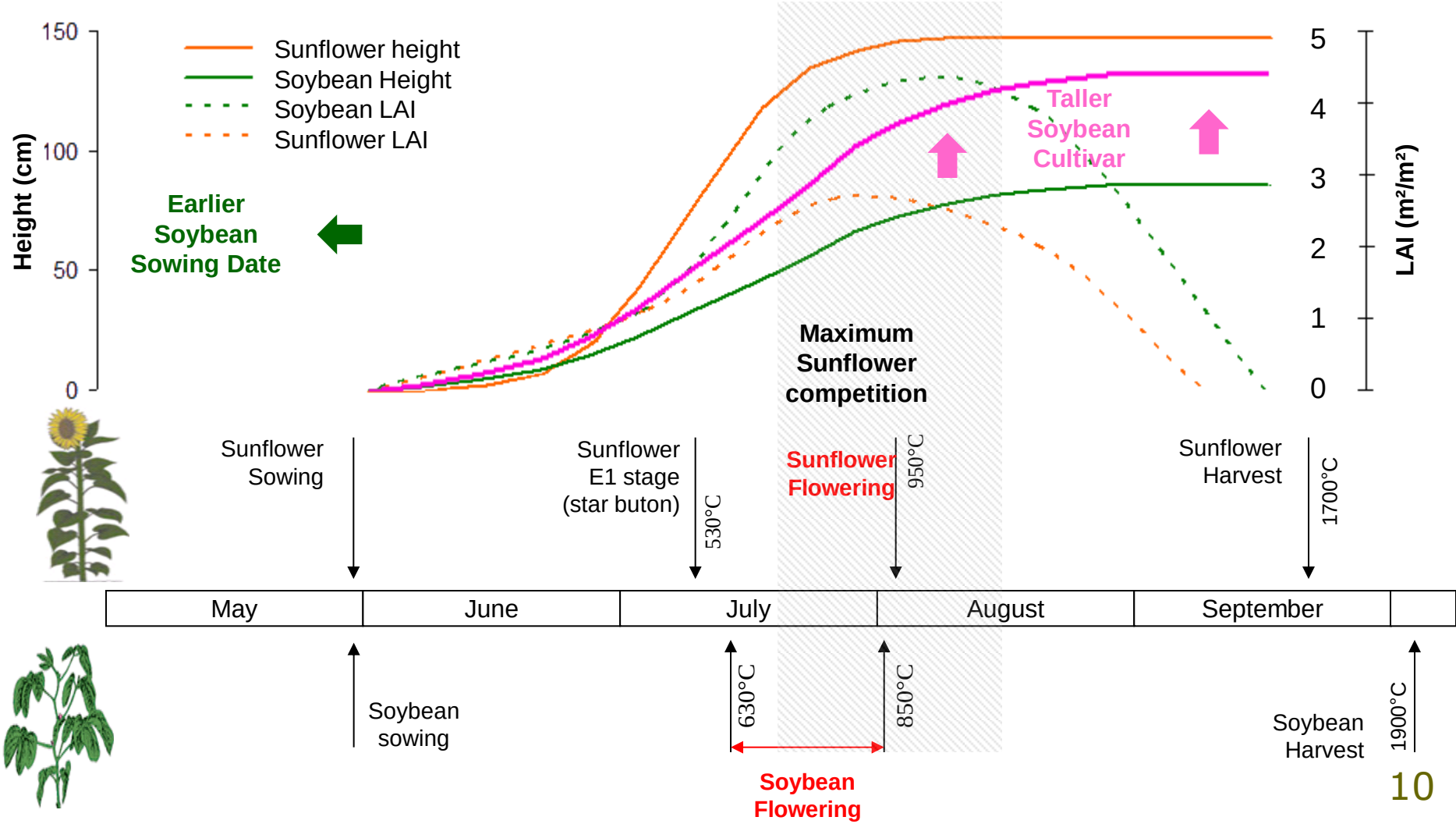
1 Soybean :
Ecudor (lSo = **late**)

1 Sunflower :
Melody (lSu = **late**)

- Shoot N accumulated by the whole IC ≤ to that of the sole crops
- SC Soybean N2 fixation rate low (high initial N soil min. content)
- Higher N2 fixation rate in IC
- Higher N2 fixation rate in border rows

→ according to sunflower uptake and competition for soil N

Increasing complementarity : **Adapting cultivar or sowing date**



Conclusions and perspectives

- **Agronomically, the most efficient intercrops were in low input systems (highest complementarity in time, space & resources)**
  - **No N and no irrigation for the 2/4 sunflower-soybean IC**
  - **No or low early N availability for cereal-legume IC**

→ Need for more knowledge to optimise cropping system designs according to different objectives

→ Need for a better understanding of dynamical interactions and effects of cover structure with pedoclimatic conditions

- **Interest of a modelling approach (first step using the soil-crop model, already adapted to intercrop)**

- **Which legume cultivars for cereal-legume IC ?**
- **Which effects of IC on pests and diseases ?**
- **How introducing IC in supply chain (& rotation) ?**
- **Which economical efficiency ?**

Hvala (thank you)

This work was supported and funded by INRA and ANR (French Agency for Research)
Special thanks for François, Stefano & Alexandra

Perfcom project
MicMac-design project
http://www4.inra.fr/micmac-design_eng/

POSTERS :

- **Reducing biotic stresses in legumes through intercropping with durum wheat.** Laurent Bedoussac, Etienne-Pascal Journet and Eric Justes
- **Breeding legume to improve durum wheat-grain legume intercrops efficiency.** Bochra Kammoun, Laurent Bedoussac, Etienne-Pascal Journet and Eric Justes

ORAL (Session 5) :

- **Agricultural innovative practices and impacts of the supply chain: An ex-ante study of the logistics of agricultural cooperatives to estimate the acceptability of durum wheat-grain legumes intercrops.** Laurent Bedoussac, Marie-Benoit Magrini, Pierre Triboulet

Contacts: Laurent.Bedoussac@toulouse.inra.fr
Eric.Justes@toulouse.inra.fr

Results : Half direct margin

Sunflower : 307 €/t & 357 €/t in org. ; Soya : 281 €/t & 381€/t in org.

Without Subsidies

xperiment	treatment	SUNFLOWER		SOYBEAN			PESTICIDES				IRRIGATION	Total input costs	Margin (€/ha)	Mean SC Margin (€/ha)
		seeds	harvest	seeds	inoculum	Harvest	molluscicide	herbicide	insecticide	fungicide				
CETIOM experiment (high input)	2 Su/ 2 So	50	95	96	15	120	20	86	26	28	30	566	624	767
	2 Su/ 4 So	33	95	128	20	120	20	86	26	28	30	586	491	663
	sunflower	100	95	-	-	-	20	86	0	28	30	359	1080	
	soybean	-	-	192	30	120	20	86	26	0	0	474	454	
Org. Prices INRA experiment (low input)	2 Su/ 2 So	50	95	96	15	120	20	14	0	0	0	410	680	831
	2 Su/ 4 So	33	95	128	20	120	20	14	0	0	0	430	791	739
	sunflower	100	95	-	-	-	20	14	0	0	0	229	1108	
	soybean	-	-	192	30	120	20	14	0	0	0	376	555	

- IC margin > SC Soya but < SC Sunflower
- IC margin < Mean SC margin (except 2/4 INRA)
- IC costs > SC costs mostly because of double harvest

→ need to produce 12 to 16% more yield in IC for the same margin

How to improve complementarity ?

Lucy

Nordica

Isard

Irena

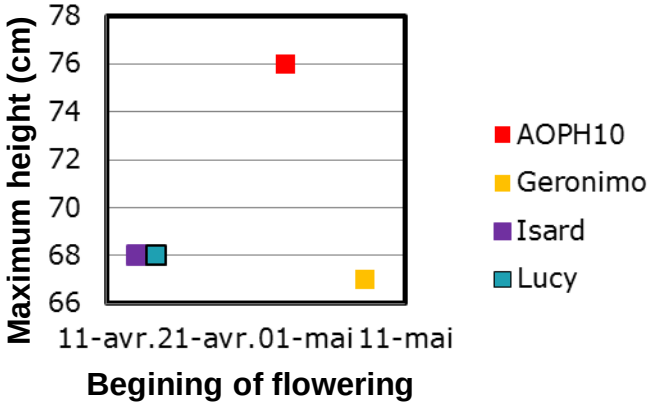
Geronimo

Diver

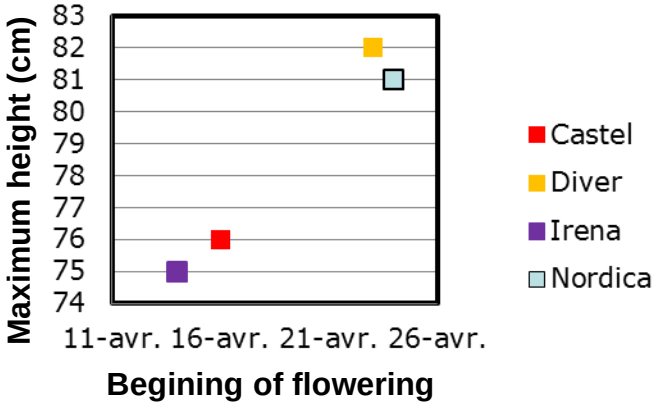
AOPH10

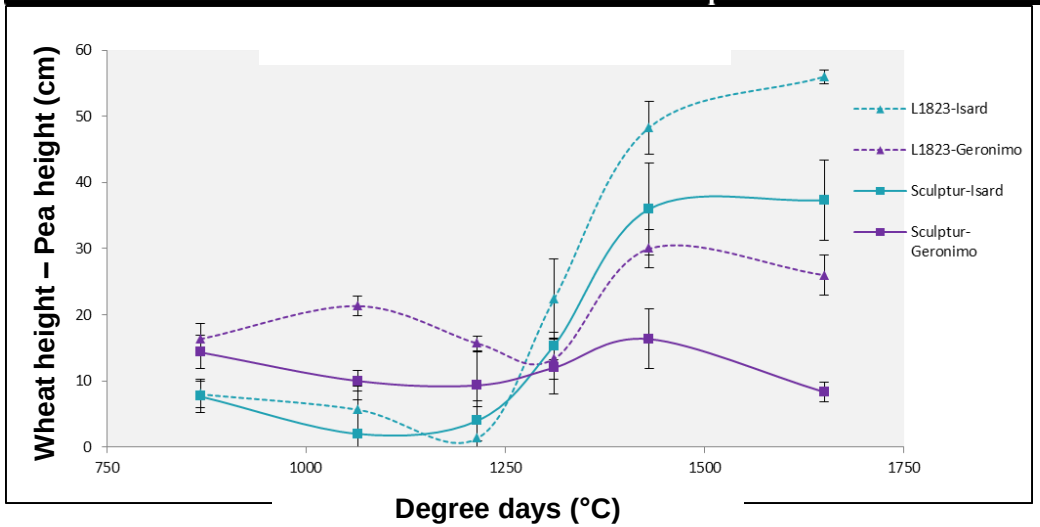
Castel

Pea cultivars



Faba cultivars





27%

26%

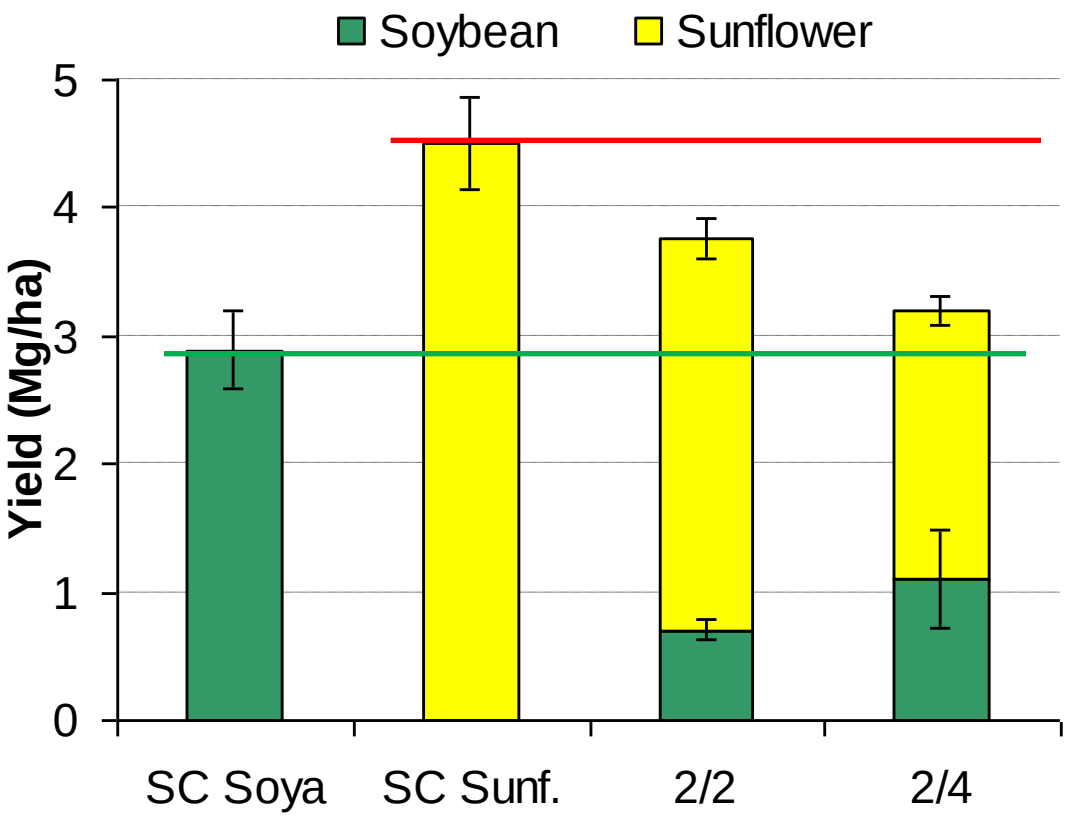
52%

62%

% of SC1/2 yield

Results: grain yield

Isidor (eSo = early Soybean) ; Ecudor (lSo = late Soybean)
Fabiola (eSu = early Sunflower) ; Melody (lSu = late Sunflower)



LER = 0.92 ; 0.85

Exp. 2
CETIOM 2010
(N and Water non limiting)

- IC total grain yield > SC Soybean and < SC Sunflower

- IC yield higher in 2/2 → N and Water more favorable for Sunflower

- LER lower than 1 ... → More competition for ressources than complementarity...