Is intercropping an efficient solution to design low input systems ? The examples of durum wheat-grain legume and sunflower-soybean intercrops

Laurent Bedoussac, Etienne-Pascal Journet, Hélène Tribouillois, David Champclou, Nathalie Landé, Eric E. Justes

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Introduction: intercrop or intercropping = mixed crops ≠ cover crop during fallow period

- **Natural ecosystems productivity mainly based on a high functionnal biodiversity and species complementarity**
- **Intercrops, in particular legume-gramineous are commun in these ecosystems (eg. permanant pastures)**

- **Intercrops are traditionnaly grown in EXTENSIVE and LOW inputs systems**
- **In EU, intercrops mainly disapeared from our intensive farming systems EXCEPT, for animal feeding and sometimes in organic farming**

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)*

Intercropping species is an application of principles of ecology

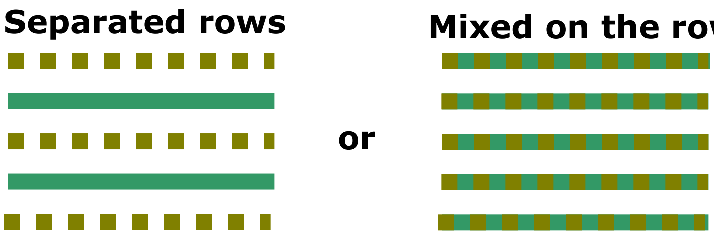
(biodiversity, species interactions, integrated protection…) *(e.g. Vendermeer, 1989)*

→ better valorise natural ressources in time and space (even inside the same plot)









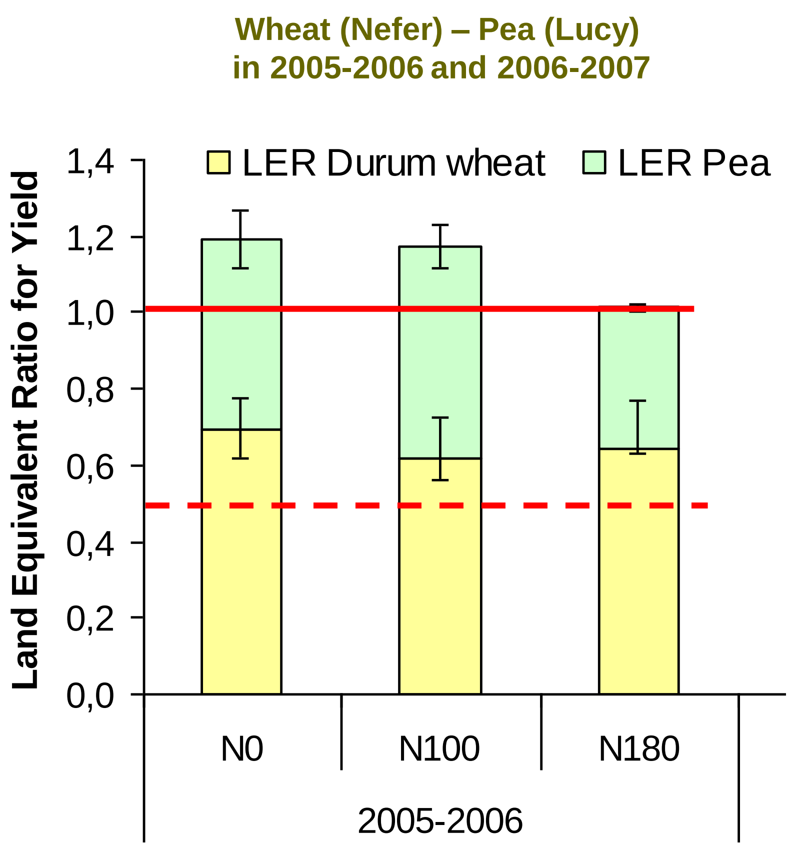
Interests of intercrops for low input systems

→ Species complementarity could allow a better use of available ressources (water, light, nitrogen…) and agro-ecological services

- Improve **grain quality** (cereal 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)
- Increase **resiliency** (yield stability compared to sole crops)
(hypothesis widely cited, e.g. Vendermeer, 1989; but no demontration published)
- Reduction of **weeds** (in comparison of legume)
(Hauggaard-Nielsen &al 2001b, Corre-Hellou &al, 2011)
- Potential reduction of **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 or stabilise among years the farmer **gross margin**
(Bedoussac, 2009; Pelzer &al, 2012)

Lots of references for cereal-grain legume intercrops
.... and few limits highlited in the scientific bibliography!!!

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



(Bedoussac & Justes, 2010a & b)

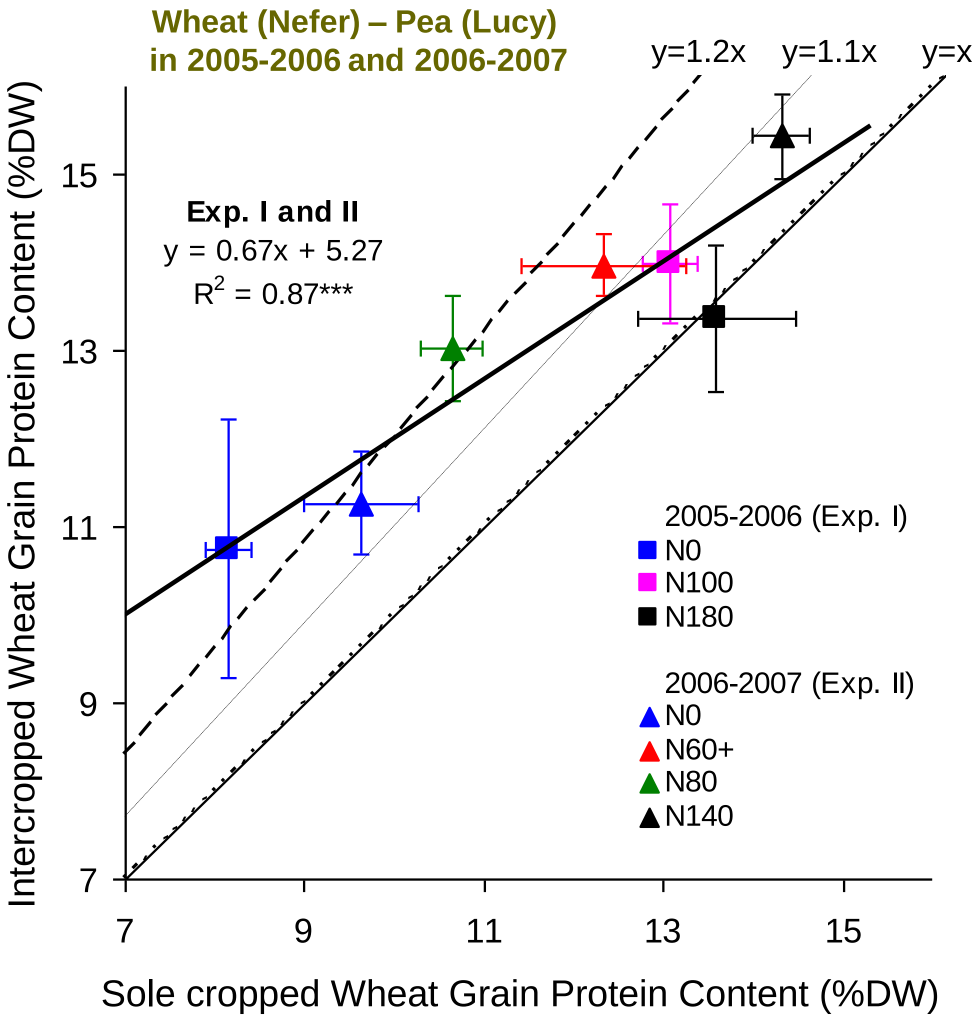
Land Equivalent Ratio (LER) = relative land area under SC required to produce the yield achieved in IC. LER is the sum of partial LER for each specie **(LER_P & LER_W)** as an indicator of their performances in IC (e.g. Willey, 1979). Widely used, and abuse!

$$LER = LER_P + LER_W$$

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

- **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 doesn't compare species yields**
  → Other indices more adapted
  (Bedoussac & Justes, 2011)

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



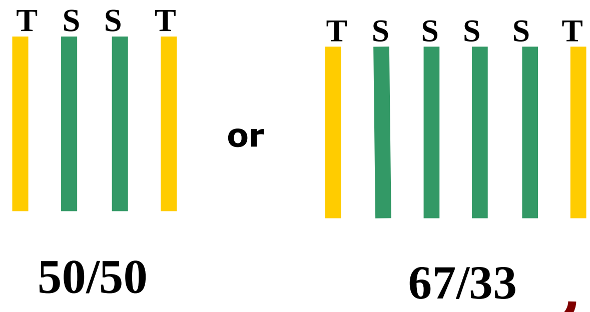
(Bedoussac & Justes 2010a, 2010b)

- 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 ?
→ Less wheat yield but almost same amount of N available (Higher Pea N2 fixation) = **niche complementarity for N sources** ***combined with light competition***

First results for summer crops: **sunflower-soybean intercrop**

Experimental design:

Substitutive design in row : 2 structures



→ *To compensate the inoculation inefficiency*

Cultivar Isidor earlier than Ecudor

Range of precocity: Cultivar ES Ethic earlier than Fabiola earlier than Melody

N & Water non limiting

Site	Year	Soybean cultivar	Sunflower cultivar	Spatial row structure	Cover crops	Irrigation	Nitrogen conditions	
							Fertilization	Initial soil N content
INRA Auzeville	2010	Isidor (Soy1) Ecudor (Soy2)	Fabiola (Sun1) Melody (Sun2)	Soybean sole crop Sunflower sole crop 2/2 2/4	No	No irrigation	Partial fertilization (soybean)	76 kg N/ha
CETIOM En Crambade	2010	Ecudor (Soy2)	Melody (Sun2)	Soybean sole crop Sunflower sole crop 2/2 2/4	No	Irrigation (30mm and 20mm)	No fertilizer	361 kg N/ha
INRA Auzeville	2011	Ecudor (Soy2)	ES Ethic (Sun3)	Soybean sole crop Sunflower sole crop 2/4	C1 : Phacelia/Oat C2 : No	No irrigation	No fertilizer	C1 : 62 kg N/ha C2 : 82 kg N/ha

Practical aspects considered for sowing and harvesting

Sowing at the same time :
Early to End of May

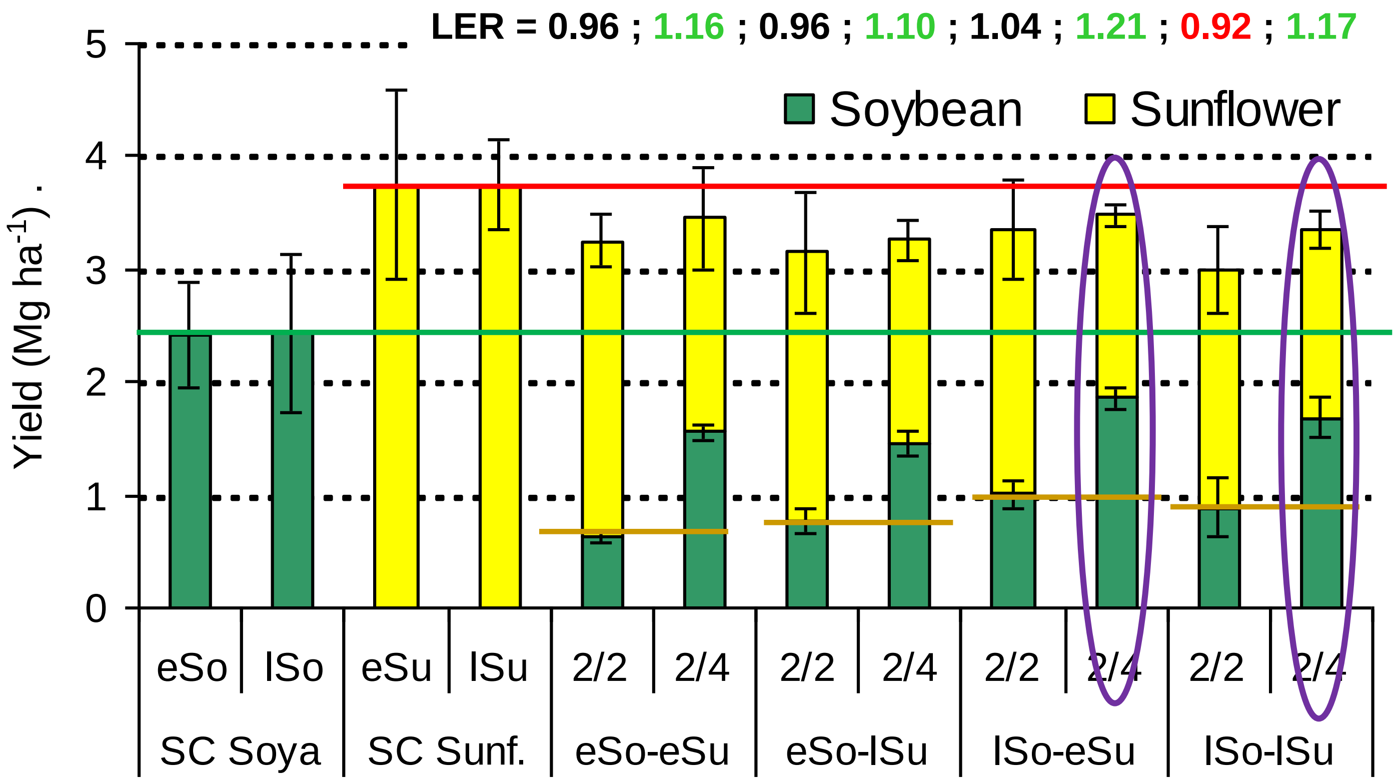
Harvesting in two times :
1st Sunflower : Mid-September
2nd Soybean : End-September / beginning of October

Need to consider the distance between rows and wheels !!!

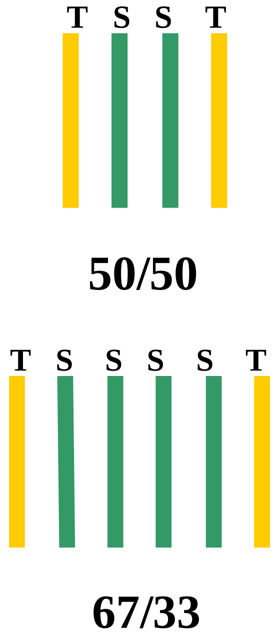
Sunflower – Soybean intercrops

Results: grain yield

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



***Exp. 1*:**
Auzeville 2010

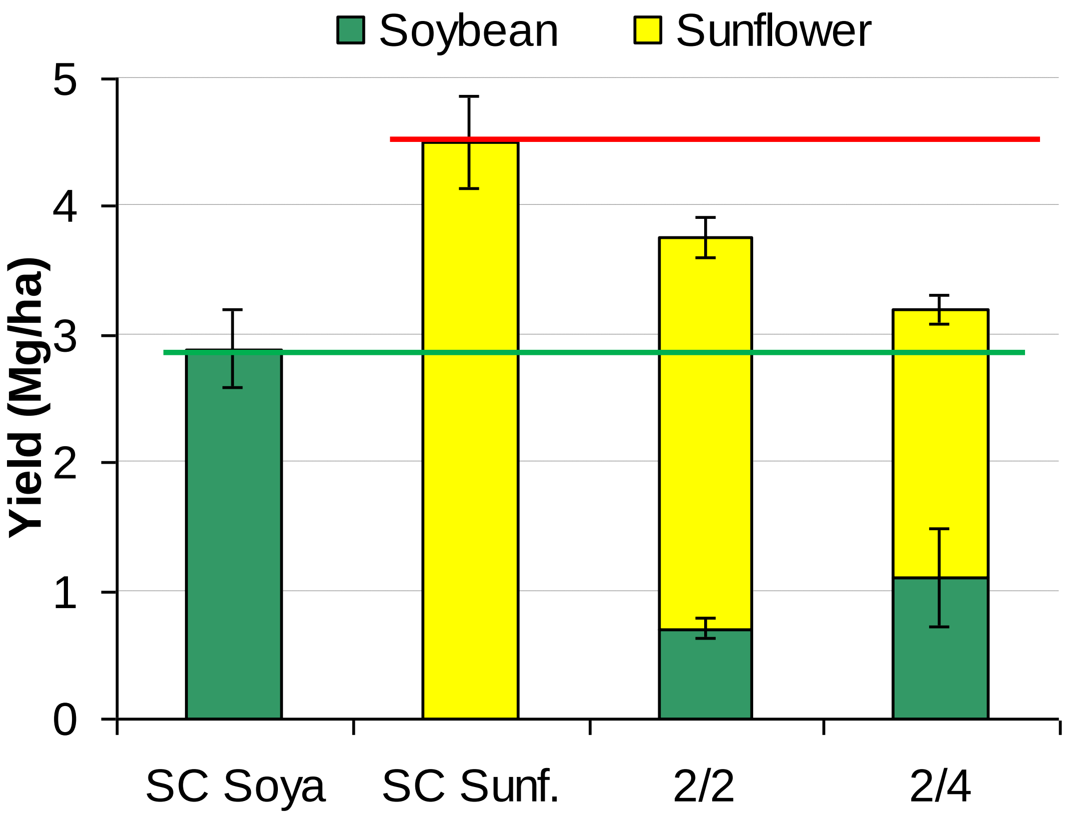


- IC total grain yield > SC Soybean and < SC Sunflower
- More Soybean in the 2/4 and with late cultivar (lSo)
- Always more Sunflower (except 2/4 with lSo)

→ LER always significantly > 1 with the 2/4 design, but not for 2/2

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)

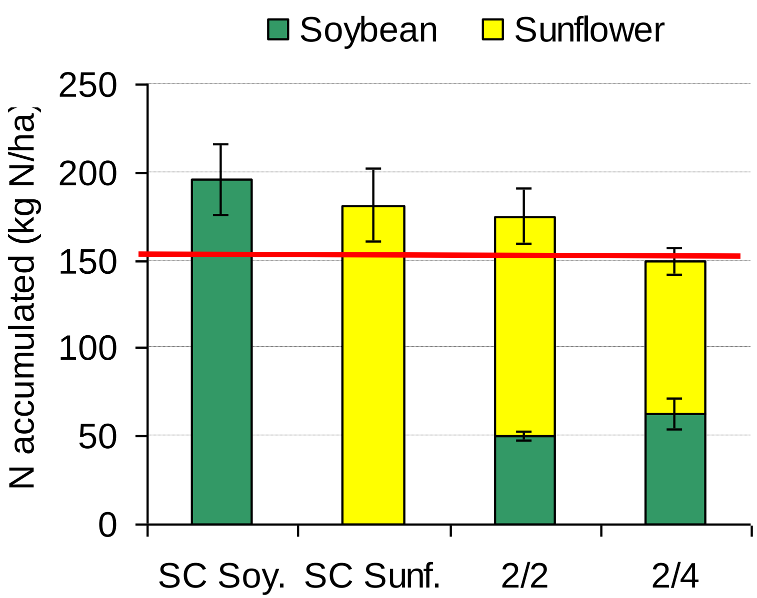
- IC total grain yield
> SC Soybean and
< SC Sunflower

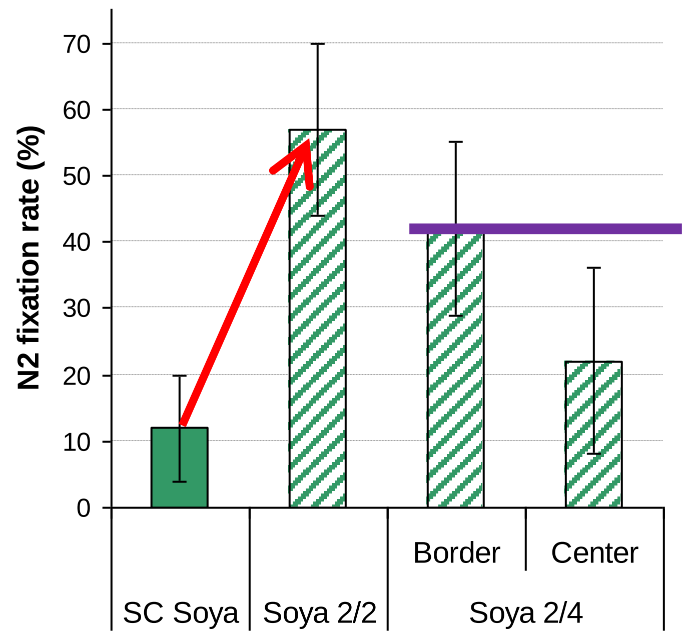
- IC yield higher in 2/2
→ N and Water more favorable for Sunflower

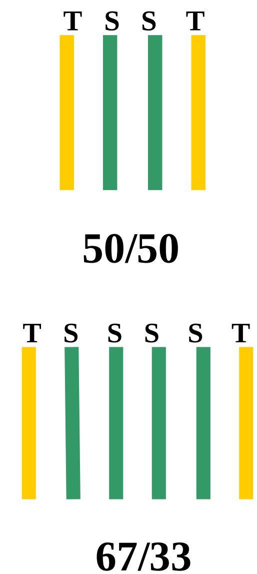
- LER lower than 1 ...
→ More competition for ressources than complementarity...

Results: N acquisition

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







- shoot N accumulated by the whole IC ≤ to that of the sole crops
- SC Soybean N_2 fixation rate low (high initial N soil min. content)
- Higher N2 fixation rate in IC (according to sunflower uptake)
- in particular on the border rows with sunflower

→ Sunflower competition for soil N increased N2 fixation rate

Conclusions and perspectives

- Agronomically, the most efficient sunflower-soybean IC were :
  - 2 Sunflower rows with 4 of Soya (or perhaps 1 Sunf. with 2 Soya.)
  - Early Sunflower with Late Soya (highest time complementarity)
  - Low input systems (no N and no irrigation)

→ Need for more knowleges to develop optimised cropping system designs eccordong to different objectives

- We obtained experimental results non always favorables for intercrops in comparison to sole crops = LER < 1 or = 1, then:
  - A better understanding of dynamical interactions and the effects of cover structure X with pedoclimatic conditions are required
  - In order to complete this work with a modelling approach (first step using the STICS soil-crop model, ever adapated to intercrop)

- IC yield > Mean of the 2 SC yield but grain price quite different...
So an economical assessment was done to complete this analysis

- A key question: How introducing IC in the crop rotation without increasing pests and diseases problems?

Thanks for your attention

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http://www4.inra.fr/micmac-design_eng/

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Results : Half direct margin

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

Without Subsidies

xperiment	treatment	SUNFLOWER seeds	SUNFLOWER harvest	SOYBEAN seeds	SOYBEAN inoculum	SOYBEAN Harvest	PESTICIDES molluscicide	PESTICIDES herbicide	PESTICIDES insecticide	PESTICIDES fungicide	IRRIGATION	Total input costs	Margin (€/ha)	Mean SC Margin (€/ha)
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