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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Toulouse – France

12th ESA Congress - Helsinki, Finland, 20-24 August 2012

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)

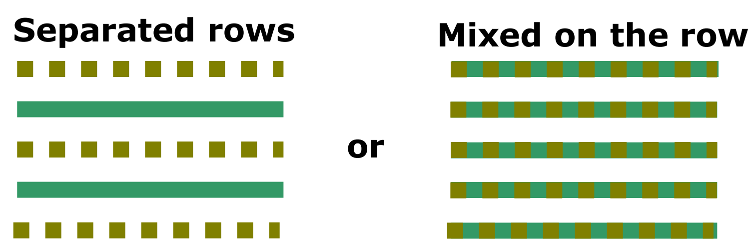
- Intercrops are traditionnaly grown in EXTENSIVE and LOW inputs systems
- In EU, intercrops mainly disapeared from our intensive farming systems EXCEPT, for animal feeding and sometimes in organic farming

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

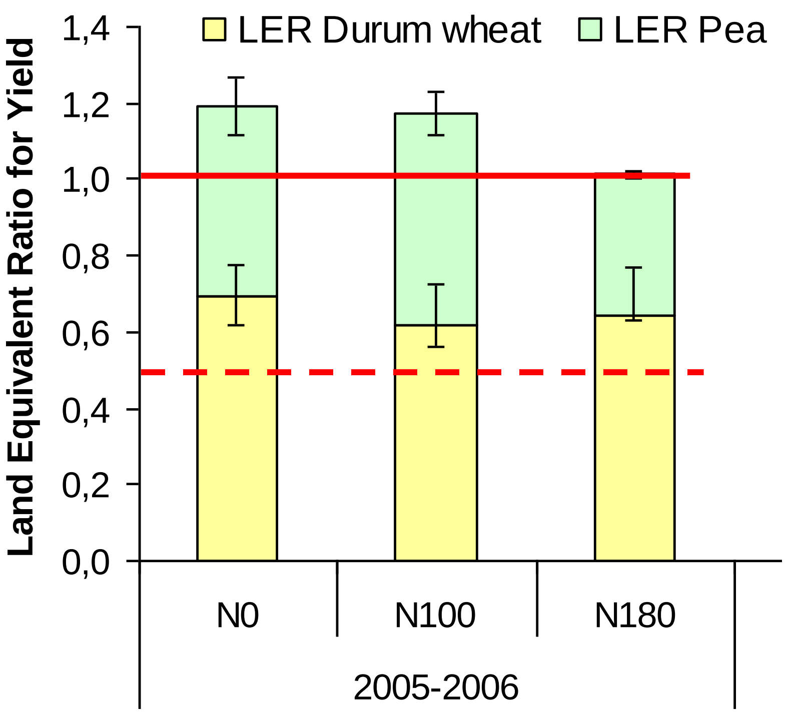
→ Species complementarity could allow a better use of available ressources (water, light, nitrogen…) and agro-ecological services

- 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

Wheat (Nefer) – Pea (Lucy) in 2005-2006 and 2006-2007



(Bedoussac & Justes, 2010a & b)

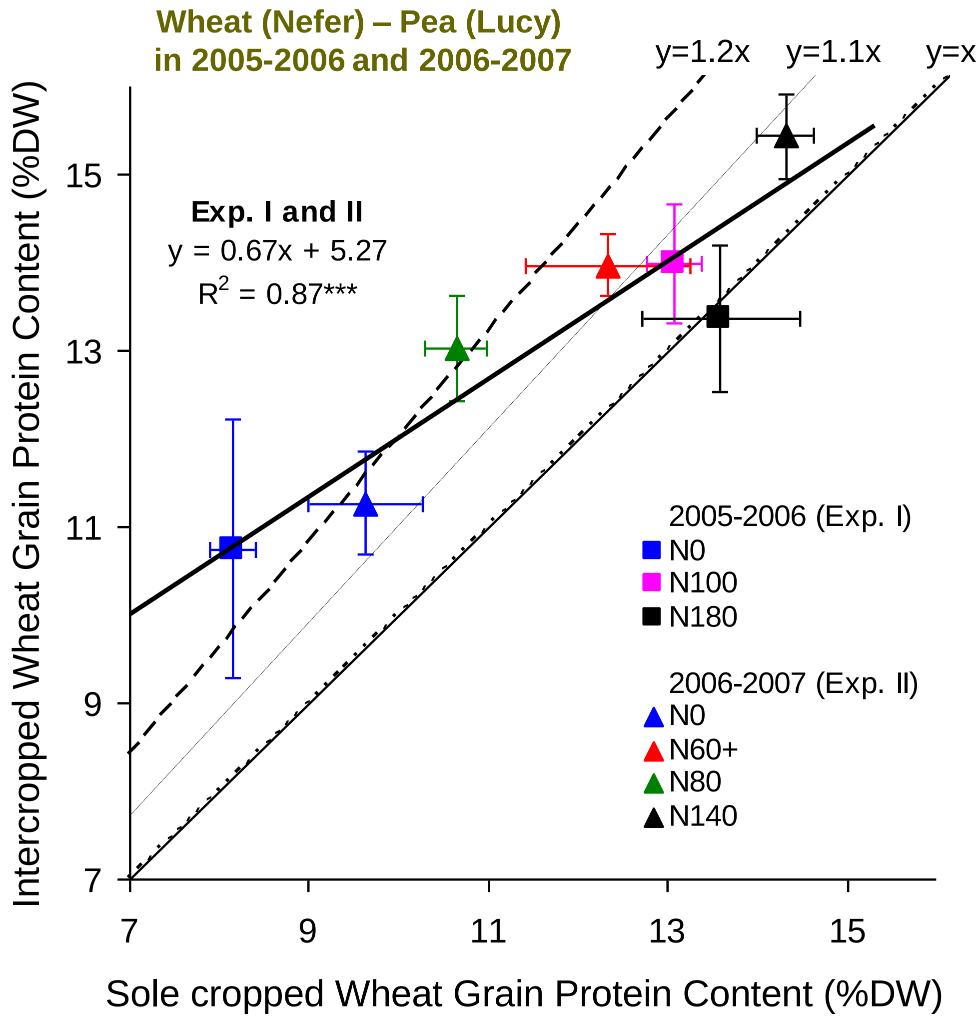
Land Equivalent Ratio (LER) = relative land area under SC required to produce the yield achieved in IC. LER is the sum of partial LER for each specie **(LER_P & LER_W)** as an indicator of their performances in IC (e.g. Willey, 1979). Widely used, and abuse!

$$LER = LER_P + LER_W$$

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

- **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

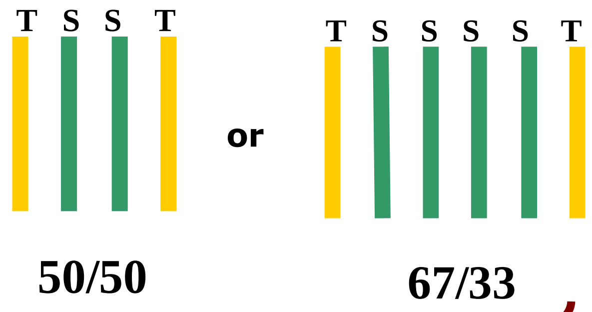
- The lower SC Wheat GPC the larger the increase
→ IC more adapted to low N input systems

- 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

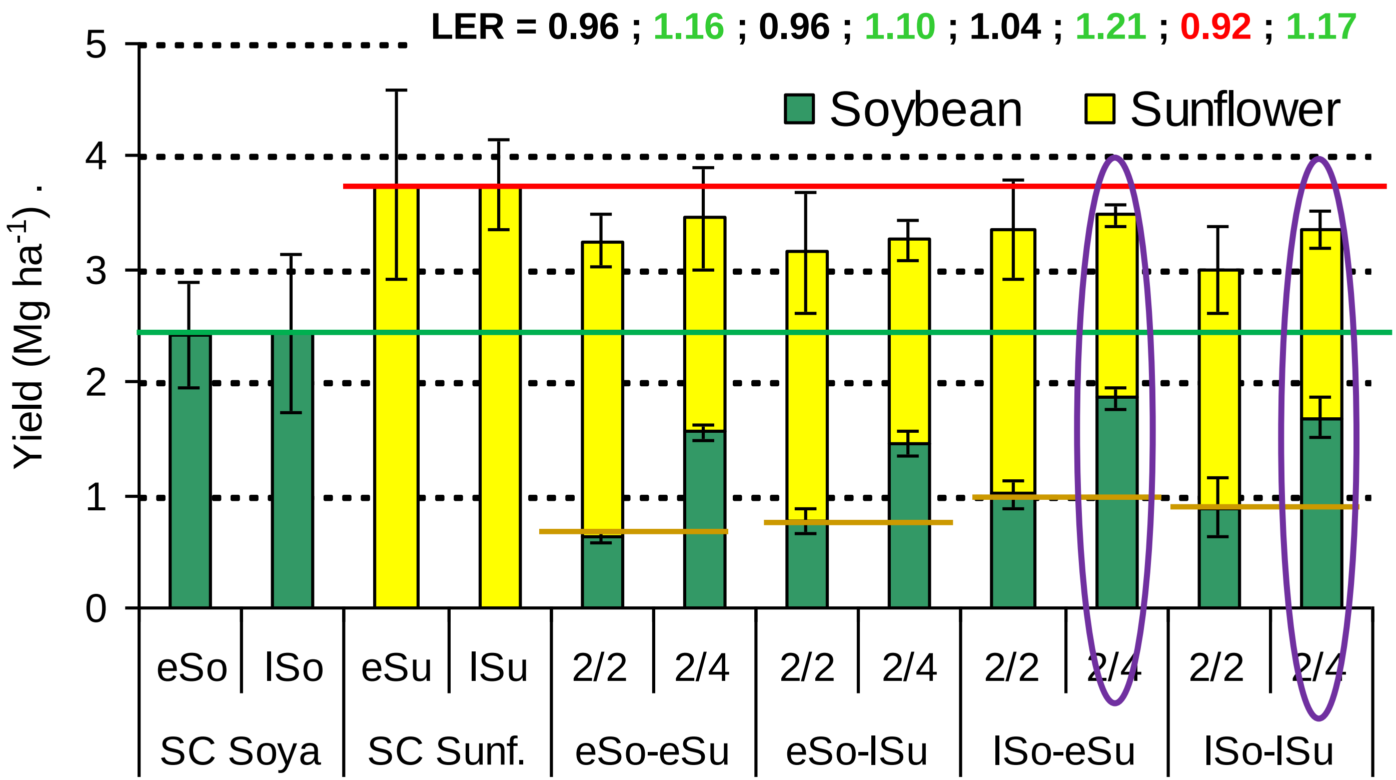
Harvesting in two times :
1st Sunflower : Mid-September
2nd Soybean : End-September / beginning of October

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

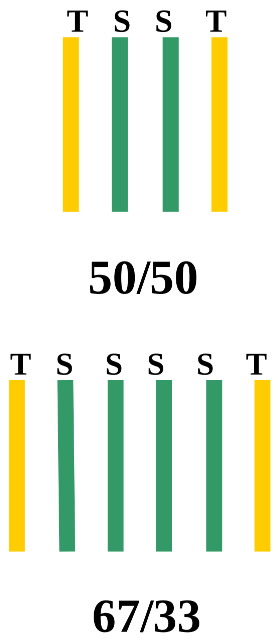
Sunflower – Soybean intercrops

Results: grain yield

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



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

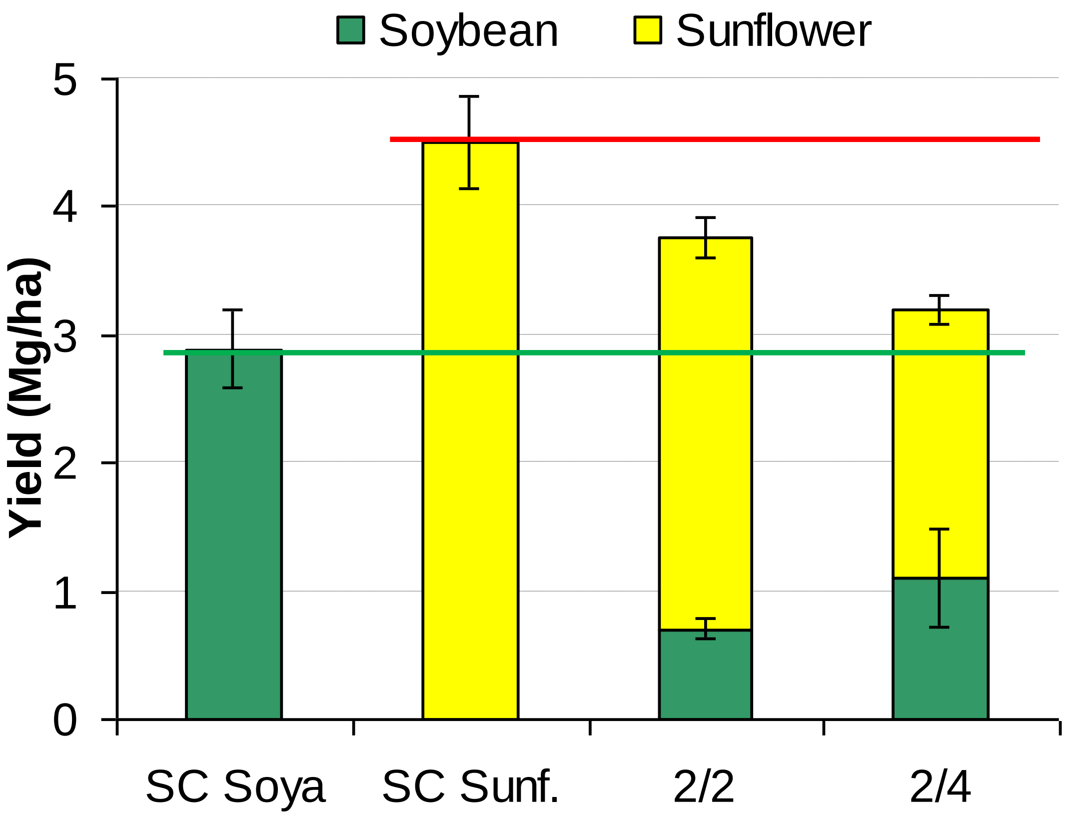


- IC total grain yield > SC Soybean and < SC Sunflower
- More Soybean in the 2/4 and with late cultivar (lSo)
- Always more Sunflower (except 2/4 with lSo)

→ 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)

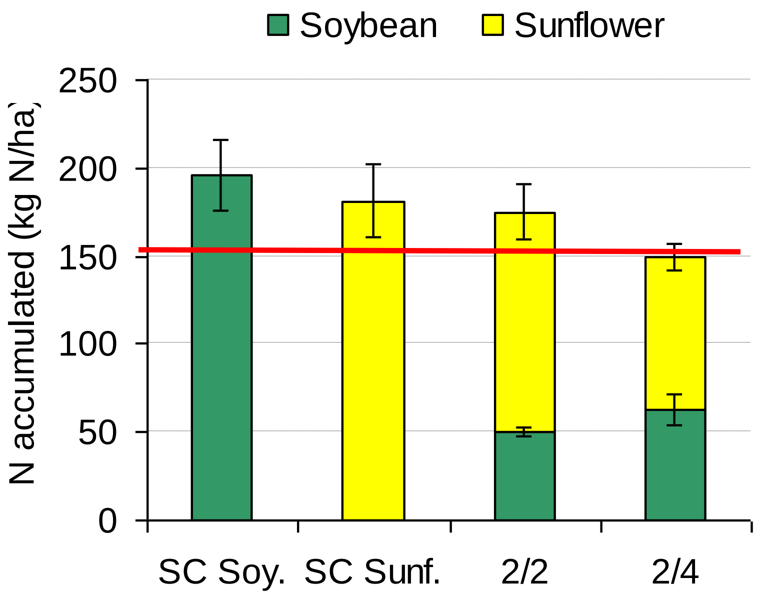
- IC total grain yield > SC Soybean and < SC Sunflower

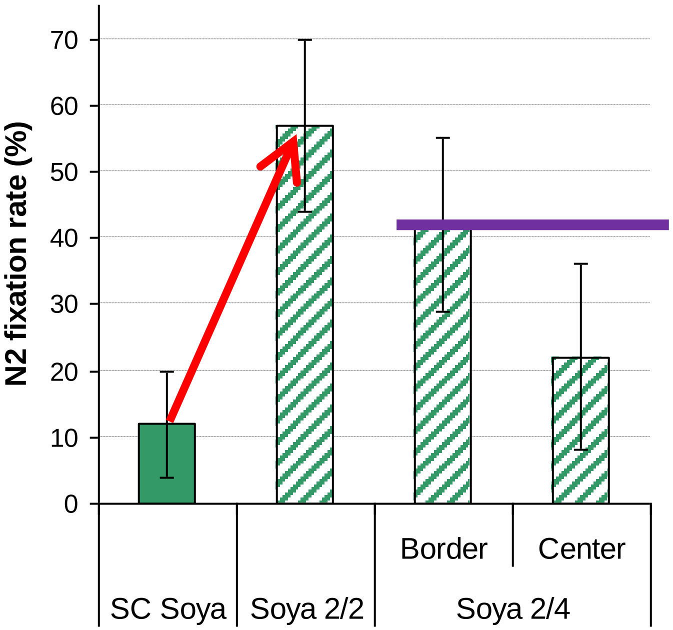
- IC yield higher in 2/2 → N and Water more favorable for Sunflower

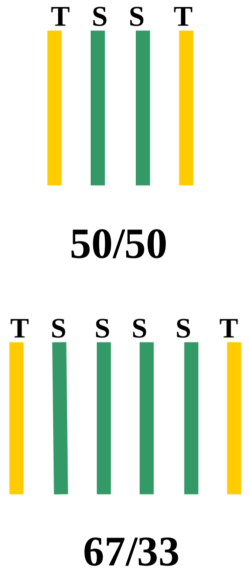
- LER lower than 1 ... → More competition for ressources than complementarity...

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

This work was supported and funded by INRA and ANR (French Agency for Research)

Perfcom project
MicMac-design project

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