Evaluating economic and technical performances of sunflower-soybean intercrop in French farming systems

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ABSTRACT

- Researches on sunflower/soybean intercrops are mainly focused on their agronomic functioning and their efficiency (Calvino and Monzon, 2009) with few considerations for economic assessment. In particular most of researches tried to identify the most efficient row patterns in order to improve resources use efficiency (e.g. nitrogen, water, light) and consequently to increase their agronomic performances (e.g. yield). The aim of our study was to carry out both agronomic and economic evaluation of sunflower-soybean intercrops compared to their respective sole crops as a key point before proposing this cropping system to farmers.
- In spring 2010, we implemented two field experiments under two agricultural contexts in South West France: i) a low input unirrigated farming system (INRA experiment) and ii) a high input irrigated farming system (CETIOM experiment). For each experiment, two patterns of sunflower-soybean intercrop were evaluated: i) 2 sunflower rows alternated with 2 soybean rows (2 Su / 2 So; ratio 50/50) and ii) 2 sunflower rows alternated with 4 soybean rows (2 Su / 4 So; ratio 33/66). Intercrops were compared to their corresponding sole crops sown at recommended density. In intercrop, the density of each specie on the row was the same as that in sole crops (see Tribouillois *et al.*, 2012 for details). For these 4 treatments, grain yield was measured and micro-economic evaluation was performed calculating gross margins. We also carried out simulations in order to identify the interest for farmers in adopting this innovating cropping practice: i) estimating the yield needed in intercrop to reach the same relative gross margin as in sole crops; ii) estimating sunflower and soybean prices needed in intercrop to reach the same relative gross margin as in sole crops and iii) estimating the intercropped yields to reach the same gross margin of the best sole crop for different agricultural practices scenarii.
- Our experimental results indicated that the sunflower-soybean intercrops reached lower yields than sole crops, except, not significative, for the 'low inputs' conditions and for the 2 sunflowers/4 soybeans design. This combination was also found to be economically efficient because its yield performance was high enough to compensate the increase in input costs required by both crops. For the three other treatments, the gross margin performances were worse than those based on grain yield due to higher input costs. For these three treatments, we estimated that a minimum of 12% to 16% yield increase was required in intercrop to reach the same relative gross margin as in sole crops. Moreover, for the past five years, price context was only favourable for the combination '2 sunflowers/4 soybeans' in the 'low input' conditions. Finally, comparing intercrops conducted in actual French farming systems (scenarii), we concluded that the 2 sunflowers/4 soybeans intercrop design could be efficient both on yield and economical results.
- In conclusion, our experiments showed that the 2 sunflowers/4 soybeans design in 'low inputs' system presented the best performances based on yield and gross margin. Sunflower/soybean intercrop might also be economically efficient in other cropping systems depending on the scenarii. However, our simulations were based on data collected from a single year experiment and considering the French technical and economic context which was defined by higher prices than world market and higher yields for sole crops. Thus, we need to confirm these results in others pedoclimatic and price contexts altogether with another field experiment.
- Economic and agronomic scenarii simulation provided a complementary approach to experiments and agronomic analysis which could help to assess the changes for farmer's to these innovating practices.

Key words: economic, intercrop, land equivalent ratio, sunflower, soybean, yield

INTRODUCTION

Promoting a novel cropping system such as sunflower-soybean intercrops towards farmers needs previously to assess their economic performances. Generally, papers dealing with sunflower-soybean intercrops focused on yield performances of sunflower-soybean intercrops (Olowe and Adebimpe, 2009; Echarte *et al*, 2011) or on economic advantages (Shivaramu and Shivashankar, 1992; Mondal *et al*, 1998). These studies try to identify the most efficient rows patterns, plant densities or agricultural practices (e.g. N-fertilisation). The objective of our work was to go further by comparing both yields and gross margins of sunflower-soybean intercrops with those of their sole crops for various selling prices and farming practices.

MATERIALS AND METHODS

Two field experiments were carried out in South-West of France under semi-oceanic climate, in 2010: i) on the CETIOM experimental fields in En Crambade (43° 25' 26''N; 1° 39' 17'' E) and ii) on the INRA experimental fields in Auzeville (43°31'40''N, 1°30'19''E). CETIOM experiment was carried out under non-limiting soil conditions for water and nitrogen altogether with full chemical treatments to control pests and diseases. INRA experiment was carried out in low input conditions (no irrigation and only spraying herbicide and molluscicide at sowing). See Table 1 for detail on soil characteristics and agricultural practices of each experiment.

Table 1. Description of soil characteristics and agricultural practices of each experiment.

Experiment	Soil characteristics and agricultural practices
CETIOM experiment (high input)	Soil of 150 cm depth: calcareous clayed, mineral nitrogen at sowing = 361kg/ha, water capacity = at least 230mm, pH = 8,3 Agricultural practices: soil tillage (x3), molluscicide (x1), herbicide (x2), insecticide (x1), fungicide (x1), irrigation (50mm) Sunflower: Melody, 6.4 plants/m², sowing date : 30/04, harvesting date : 23/09 Soybean : Ecudor, 37 plants/m², sowing date : 02/06, harvesting date : 05/10
INRA experiment (low input)	Soil of 120 cm depth: silty clay loam, mineral nitrogen at sowing = 76g/ha, water capacity = 180mm, pH = 8,4 Agricultural practices: soil tillage (x3), molluscicide (x1), herbicide (x2) Sunflower: Melody, 6.2 plants/m², sowing date : 02/06, harvesting date : 06/10 Soybean: Ecudor, 33 plants/m², sowing date : 02/06, harvesting date : 05/10

Sunflower and soybean were grown in sole crop as control treatment and compared with two intercrop row designs: i) 2 sunflower rows adjacent to 2 soybean rows (2 Su/2 So; land crop ratio: 50% sunflower – 50% soybean) and ii) 2 sunflower rows adjacent to 4 soybean rows (2 Su/4 So; land crop ratio: 33% sunflower – 67% soybean). For each specie, plant density on the row was similar in intercrop and sole crop. For both experiments treatments were randomized with three replicates for each treatment. Grain-yield was measured at maturity. Gross margins were calculated for each treatment multiplying the grain yield by their prices based on the past five years mean in France (table 2) and subtracting the input costs defined as the sum of all inputs costs (seed, pesticides, irrigation, harvesting; table 3). Note we considered organic prices for the low input system (INRA experiment) because these pesticides were not necessary considering the pedo-climatic conditions and the agronomic diagnosis initially done on the experimental field.

Table 2. Crop prices (euros/t) used for gross margin calculation

crop	minimum	maximum	mean
sunflower*	224	497	**307**
organic sunflower**	274	547	**357**
soybean premium ***	220	327	**281**
organic soybean**	320	427	**381**

**Bordeaux (harbour or plant delivery) (monthly data from July 2005 to June 2010)*
*** estimated from ONIDOL French survey (sunflower: +50 euros/t; soybean: +100 euros/t)*
****Chicago Board of Trade (monthly data from July 2005 to June 2010) +40 euros/t (non GMO and traceability)*

Table 3. Agricultural practices costs (euros/ha) used for gross margin calculation

xperiment	treatment	SUNFLOWER seeds	SUNFLOWER harvest	SOYBEAN seeds	SOYBEAN inoculum	SOYBEAN Harvest	PESTICIDES molluscicide	PESTICIDES herbicide	PESTICIDES insecticide	PESTICIDES fungicide	IRRIGATION	Total input costs
CETIOM experiment (high input)	2 Su/ 2 So	50	95	96	15	120	20	86	26	28	30	566
	2 Su/ 4 So	33	95	128	20	120	20	86	26	28	30	586
	sunflower	100	95	-	-	-	20	86	0	28	30	359
	soybean	-	-	192	30	120	20	86	26	0	0	474
INRA experiment (low input)	2 Su/ 2 So	50	95	96	15	120	20	14	0	0	0	410
	2 Su/ 4 So	33	95	128	20	120	20	14	0	0	0	430
	sunflower	100	95	-	-	-	20	14	0	0	0	229
	soybean	-	-	192	30	120	20	14	0	0	0	376

The Land Equivalent Ratio (LER; Willey and Osiru, 1972) is widely used to compare intercrop efficiency for grain yield (LERY) or gross margin (LERGM) with that of the sole crops. The LER was calculated as follows:

$LER = LER_{partial}(sunflower) + LER_{partial}(soybean)$

$LER = Y^{sunflower}_{intercrop} / Y^{sunflower}_{sole} + Y^{soybean}_{intercrop} / Y^{soybean}_{sole}$

where $Y^{i}_{intercrop}$ is the yield of the *i*th species in the intercrop and Y^{i}_{sole} that in the sole crop.

We proposed to calculate the Relative LER (RLER) to compare the intercrop grain yield (RLERY) or gross margin (RLERGM) to that of the sole crops if they were grown at the same land proportion as in the intercrop. RLER was calculated as follows:

$RLER = (X^{sunflower}_{intercrop} + X^{soybean}_{intercrop}) / (X^{sunflower}_{sole} * P^{sunflower}_{intercrop} + X^{soybean}_{sole} * P^{soybean}_{intercrop})$

where $X^{i}_{intercrop}$ is the yield or the gross margin of the *i*th species in the intercrop; X^{i}_{sole} that in the sole crop and $P^{i}_{intercrop}$ the land proportion of the *i*th species in the intercrop.

ANOVA with GLM procedure were performed on total intercrop grain yield, RLERY, and gross margin. Multivariate ANOVA with GLM procedure and MANOVA statement were performed on $LER_{partial}$ of both crops. Statistical analyses were done using SAS software 9.2.

RESULTS AND DISCUSSION

Agronomic results

In our experimentation, yield performances and economic results (table 4) showed lower results for sunflower-soybean intercrops than sole crops (unlike results presented by Shivaramu and Shivashankar in 1992, and Mondal *et al* in 1998, and Olowe's and Adebimpe for only yields' results in 2009) except for the 'low input' experiment with the combination '2 Su /4 So' (respectively 1.15 and 1.07 for RLERY and RLERGM).

The significant highest yield results in the CETIOM experiment for both intercrops and sole crops can be related to higher soil resources.

Intercrops were more profitable for sunflower intercrop according to its partial LER values (0.70 and 0.56 compared to its theoretical value of 0.5 for the combination of '2 Su / 2 So'; 0.46 and 0.44 compared to its theoretical value of 0.33 for the combination of '2 Su / 4 So'). These result seemed to confirm those given by Olowe and Adebimpe in 2009, but unconfirm those given by Shivaramu and Shivashankar in 1992. On the contrary intercropped soybean presented lower partial LER values in intercroppings than expected confirming results given by Shivaramu and Shivashankar (1992) and Mondal *et al* (1998). According to the statistical test (MANOVA) on partial LER, intercropped sunflower seemed to be a good crop opportunity whatever the experimental conditions ($p \geq 0,05$), but intercropped soybean only showed its best yield performances in the 'low inputs' experiment ($p=0,0006$).

Economic results

Sole crop sunflower gross margin was significantly higher than those of the others treatments. Our economic results based on the intercrops gross margin presented opposite performances to previous authors with significant lower results than sunflower sole crop (Shivaramu and Shivashankar (1992), Mondal *et al* (1998). Gross margin performances in the ‘low input’ experiment were significantly better than in the ‘high input’ experiment (p=0,0443) contrarily to total yield results (table 4). However, our experimentation could not present any statistical effect between treatment (intercrops’ combinations) related to experiment (high or low level of inputs; p≥0,05).

We noticed that, for three treatments, the RLERGM was worse than the RLERY because the input costs of both crops were added to the already lowest yield performances. The best RLERGM had been reached by the combination ‘2 Su /4 So’ in the ‘low input’ experiment. In that case, the yield performance of this intercrop design was high enough to compensate the increase in input costs required by both crops. However statistical tests did not confirm differences between all treatments.

Table 4. Economic and technical performances of sunflower-soybean intercrops.

experiment	treatment		yield (t/ha) ± standard deviation	LERpartial ± sd** or **RLERY ± sd***	gross margin (euros/ha)****	RLER GM
CETIOM experiment (high input)	**sole crop**	sunflower	4.7 ± 0.2		1080	
		soybean	3.3 ± 0.2		454	
	2 su/2 so	sunflower	3.3 ± 0.1	0.70 ± 0.02		
		soybean	0.7 ± 0.0	0.20 ± 0.01		
		total	3.9 ± 0.2*	**0.98 ± 0.04**	624	0.81
	2 su/4 so	sunflower	2.2 ± 0.1	0.46 ± 0.01		
		soybean	1.5 ± 0.2	0.44 ± 0.05		
		total	3.6 ± 0.2*	**0.96 ± 0.06**	491	0.74
INRA experiment (low input)	**sole crop**	sunflower	3.7 ± 0.4		1108	
		soybean	2.4 ± 0.7		555	
	2 su/2 so	sunflower	2.1 ± 0.3	0.56 ± 0.09		
		soybean	0.9 ± 0.3	0.36 ± 0.10		
		total	3.0 ± 0.6*	**0.97 ± 0.18**	680	0.82
	2 su/4 so	sunflower	1.7 ± 0.1	0.44 ± 0.04		
		soybean	1.6 ± 0.2	0.67 ± 0.10		
		total	3.3 ± 0.2*	**1.15 ± 0.08**	791	1.07

** ANOVA and student test (‘experiment’=0,0060; ‘treatment’ p≥0,05; ‘experiment x treatment’ p≥0,05).*
***MANOVA and Wilks lambda test (‘experiment’ p=0,0004, ‘treatment’p≤000,1) : ANOVA LERp sunflower (‘experiment’ p≥0,05; ‘treatment’ p=0,0005); ANOVA LERp soybean (‘experiment’ p=0,0006; ‘treatment’ p≤0,0001)*
**** ANOVA and student test (experiment’ p≥0,05; ‘treatment’ p≥0,05; ‘experiment x treatment’ p≥0,05).*
***** ANOVA (‘farming systems’ p=0,0443; ‘treatment’ p≤0,001 (student test : 2su/2so (a), 2su/4so (a), sunflower (b), soybean (a)); ‘farming systems x treatment’ p≥0,05).*

Estimating yields from observed gross margins

Considering the gross margin obtained by the sole crops (table 4) we estimated sunflower and soybean minimum grain yield needed in intercrop to reach a RLERGM of 1 (i.e. to be at least as economically interesting as two adjacent fields of sole crops). Except for the ‘2 Su / 4 So’ combination in the low input system (INRA experiment), we estimated that a minimum of 12% to 16% yield increase was required (table 5) to reach the same gross margin as in sole crops (considering the same species land proportion). The required yield evolution to obtain an economical balance for both experimental systems and intercrops’ combinations seemed to be realistic. However, new trials would be necessary to test this hypothesis in order to promote intercrops in various contexts.

Table 5. Estimated yield and gross margin considering an expected RLERGM of 1.
Evolution were calculated considering data given in Table 4.

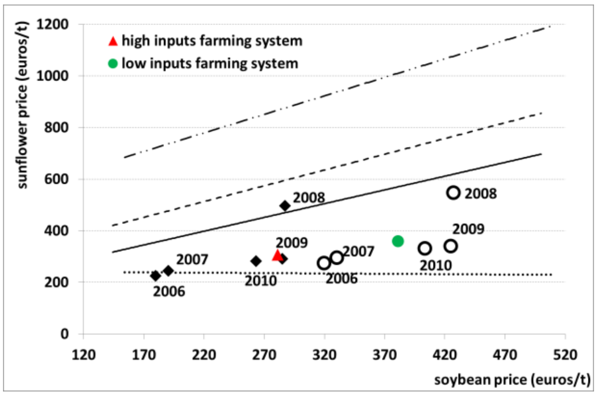
		estimated yield (t/ha)		**estimated gross margin**
experiment	**treatment**	**sunflower**	**Soybean**	(euros/ha)

		Estimated	Evolution	estimated	Evolution	Estimated	evolution
CETIOM experiment (high input)	**2 Su/ 2 So**	**3.6**	12%	**0.8**	12%	**767**	23%
	2 Su/ 4 So	**2.5**	16%	**1.7**	16%	**663**	35%
INRA experiment (low input)	**2 Su/ 2 So**	**2.4**	14%	**1.0**	14%	**831**	22%
	2 Su/ 4 So	**1.6**	-4%	**1.6**	-4%	**739**	-11%

Estimating prices from observed yields

We estimated needed prices to offset the lower yields in the sunflower-soybean intercrop in order to identify future convenient economic contexts (Figure 6). These predicted curves were a compromise to reach a balanced gross margin (RLERGM = 1) with performed yields in our experiments compared to sole crops. For the past five years, price context was mainly favourable for the 'low input' system and for the combination '2 Su /4 So' which confirmed why this treatment got the best results in our experiments (even if difference was not significant). The increasing interest in 'low input' farming system and organic farming in France seemed to be a suitable future for the sunflower-soybean intercrops and particularly for '2 Su /4 So' combinations.

Figure 6. Prices crops relationship from observed yields and considering an expected RLERGM of 1



Sunflower and soybean price relationship for intercrops:

in 'high input' system:

- ——— intercrop: 2 Su / 2 So
- - - - - intercrop: 2 Su / 4 So

in 'low input' system:

- —·—· intercrop: 2 Su / 2 So
- ……… intercrop: 2 Su / 4 So

◆ French price context (2006 to 2010)

○ French price context for organic crops (2006 to 2010)

Agricultural practices scenarii simulations

Due to the limited conclusions which could be drawn from experimental conditions, we decided to simulate intercropping results in other contexts considering data obtained from local surveys. We calculated the gross margin obtained by sole crops using input costs described in Table 3 for two scenarii: i) a high input system (pesticides) without irrigation which is the most current farming system for sole crop sunflower in France and ii) a low input system (only a spread of herbicide and molluscicide) with irrigation which is the most common farming system for sole crop soybean in France. For each scenarii, we estimated the grain yield needed in intercrop to reach the same gross margin as the best sole crop of each system (sunflower for the high input system and soybean for the low input system with inputs costs of 409 and 623 euros/ha respectively). The intercropped yield was estimated (Table 7) using the experimental data altogether with the proportion of each intercrop involved in the intercropped gross margin (respectively to their 'combination x production' system). According to their estimated partial LER values (table 7), the combination of '2 Su /4 So' seemed to be the most realistic intercropping for both farming systems. Actual French farming systems could adopt these sunflower-soybean intercroppings (particularly the combination 2 Su/4 So) in both faming systems even if new experiments should be carried out to confirm these simulations.

Table 7. Simulated performances in other farming systems scenarii considering current prices.

farming system	**treatment**	**yield (t/ha)**	**estimated input cost** (euros/ha)	**gross margin*** (euros/ha)	**RLER GM**	**estimated yield (t/ha)**	
						sunflower	**Soybean**

			observed in suveys	*(adapted from table 3)*	performed in surveys	objective (hypothesis)	Estmated	estimated	LERp	Estimated	LERp
Simulations	**High input system (pesticides. no irrigation)**	**2 Su/ 2 So**		536 = 566 – 30 (no irrigation)		409	1.34	2.6	1.08	0.5	0.22
		2 Su/ 4 So		556 = 566 – 30 (no irrigation)		409	1.51	1.9	**0.81**	1.3	**0.54**
		sunflower*	2.4	329 = 359 – 30 (no irrigation)	409						
		soybean**	2.4	474 (no irrigation)	201						
	Low input system (few pesticides. irrigation)	**2 Su/ 2 So**		440 = 410 + 30 (irrigation)		623	1.33	2.1	1.28	0.9	0.32
		2 Su/ 4 So		460 = 430 + 30 (irrigation)		623	1.20	1.5	**0.92**	1.5	**0.54**
		sunflower***	1.6	259 = 229 +30 (irrigation)	313						
		soybean**	2.7	406 = 376 + 30 (irrigation)	623						

*South-West farmers' surveys: *CETIOM 2009. **CETIOM 2007. ***Chambre Régionale d'Agriculture Midi-Pyrénées. 2009.*

CONCLUSIONS

The price contexts, experimentations and simulations data promoted the intercropping combination of 2 sunflowers with 4 soybeans rows as the most efficient. The 'low input' systems (irrigated or not) seemed to be suitable and resilient context to introduce this novel cropping system. However, due to the fact that our experiment was based on a single year and our simulations were established from French scenarii (with higher prices than the world market and with high yields for sole crops) we could not extrapolate easily our results to other contexts.

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