Cover Crops Alternatives for Sustainable Agriculture Systems in Uruguay

Walter Ayala
INIA, Uruguay

José A. Terra
INIA, Uruguay

Ethel Barrios
INIA, Uruguay

Ignacio Macedo
INIA, Uruguay

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Cover crops alternatives for sustainable agriculture systems in Uruguay

Walter Ayala*, Terra, José, Barrios, Ethel, Macedo, Ignacio
Instituto Nacional de Investigación Agropecuaria, Treinta y Tres, Uruguay
*Corresponding author e-mail : wayala@tyt.inia.org.uy

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Introduction

In Uruguay, the increase of cropland area during the last decade was based on rotation systems intensification and soybean expansion, achieving 1.321.000 ha (Souto, 2014). Diaz (2007) demonstrated the value of the ley-farming systems where the integration of livestock and crop production achieved benefits on sustainability. Despite the advantages of crop-pasture rotation systems (García Prechac *et al*., 2004), grain market prices and food demand resulted in pasture phase losses in rotation with crops. Recently, Livestock Agriculture and Fisheries Ministry implemented a national soil conservation plan, that regulates cropping rotation systems based on soil erosion estimations and other key soil quality indicators. Although, no-till was full adopted, climatic and soil conditions determine that soil must be cover by residues or vegetation all year to reduce erosion and degradation (Thorup-Kristensen *et al*., 2003). Cover crops contribute to protect soils during fallow periods. The 17% of total soybean area cultivated is in Eastern Uruguay, being soils with erosion risk , fertility, structure and drainage limitations. This paper evaluates cover crops adaptation, subsequent effects on soybean productivity, and estimations of nitrogen supply and extraction from cover crops and soybean, respectively.

Materials and Methods

The experiment was located at INIA Treinta y Tres, Uruguay, South America (33°15´59,5´´S; 54°29´50,94´´W), 59 m of altitude, on a fine, mixed vertic Argiudoll (ARS-USDA classification) with a pH (water): 5.33, organic carbon: 3.35 g/kg, phosphorus using acid citric extractant: 8 µg P/g and potassium: 0.30 meq K/100 g and magnesium: 1.9 meq Mg/100 g in the first 5 cm depth. An old oversown pasture was used, with a high proportion of natural grasslands and low proportion of introduced legumes (*Trifolium repens*, *Lotus uliginosus*). A split-plot design with four replicates was used, being the main plots two cover crops sowing methods (oversown previous soybean harvest vs no-till after soybean harvest), being the subplots the cover crops options (96 m^2). In spring, cover crops were sprayed with glyphosate and soybean crop established, repeating treatments at the same sequence to see cumulative effects.

Table 1. Species, cultivars, origin and sowing density (kg/ha) of cover crops.

Species	Cultivars	Origin	Sowing density
Trifolium vesiculosum	Sagit	INIA-Uruguay	10
Trifolium alexandrinum	INIA Calipso	INIA-Uruguay	18
Trifolium subterraneum	Goulburn (2012)	PGG-Wrighston	10
"	Bindoon (2013)	PGG-Wrighston	10
Trifolium resupinatum	LE 90-33	INIA-Uruguay	8
Vicia sativa	Barril	Fertiprado-Portugal	45
Raphanus sativus	Brutus	Agritec-Euro Grass	14
Raphanus sativus	Reset	Agritec-Euro Grass	14
Raphanus sativus	CCS-779	USA	14
Lolium multiflorum	INIA Cetus	INIA-Uruguay	15
Avena strigosa	Calprose Azabache	Calprose-Uruguay	100
Lupinus luteus	Cardiga	Fertiprado-Portugal	100

The experiment started in spring 2011, with a soybean crop, following a cover crop-crop sequence over two years (Table 1). In 2012-2013, cover crops treatments (Table 1) were established on April 19 for oversown method except *Vicia* and *Raphanus sativus* CCS-779 that were established on April 26 and 30 respectively; no-till was made on May 9. In 2013-2014, the oversown treatments were established on April 10 and no-till treatments on June 13.

Soybean cultivars used where Don Mario 6.2 (2011-2012 and 2012-2013), and Don Mario IPRO5958 (2013-2014). In 2012-2013, soybean was sowed on December 28 and harvested on May 30; in 2013-2014 on December 1 and April 22, respectively.

Determinations included herbage accumulation, botanical composition, nitrogen content in forage and soybean grain production. The statistical analysis was made using the PROC-GLM procedures (SAS 9.2), being means separation performed by LSD method (p=0.05).

Results and Discussion

Cover crops production: In 2012-2013, herbage accumulation to September 25 did not showed differences between sowing methods, however there were significant differences between species (Table 2). Sowing method x species interaction was not significant. *Raphanus sativus* Brutus and *Oat* were the more productive, achieving more than 8 Mg DM/ha in 5,3 months.

Table 2. Cover crops herbage production (DM, kg/ha) and subsequent soybean grain production (Grain, kg/ha) evaluated.

	2012-2013		2013-2014		
Cover crops	**Cover crops**	**Soybean crop**	**Cover crops**		**Soybean crop**
	Herbage production	**Grain production**	**Herbage production**		**Grain production**
			Oversown	**No-till**	
Raphanus sativus Brutus	8557 a	2690	3942 bcde	2304 fghij	2792
Raphanus sativus Reset	6236 b	2537	4286 bc	2577 fghi	2967
Raphanus sativus CCS-779	6194 b	2537	4020 bcd	2825 efgh	3077
Lolium multiflorum INIA Cetus	5381 bc	2742	4667 b	2101 fghij	2975
Avena strigosa C. Azabache	8885 a	2750	4531 bc	2293 defg	2895
Trifolium vesiculosum Sagit	2782 de	2743	2222 fghij	1462 ij	3147
Vicia sativa Barril	2508 e	2672	3397 cdef	1825 hij	3014
Trifolim resupinatum LE 90-33	3282 de	2614	1881 fghij	1360 ij	2886
Lupinus luteus Cardiga	7581	2648	7281 a	2088 fghij	2813
Trifolium alex. INIA Calipso	4246 cd	2803	2896 defgh	2346 fghij	3020
Trifolium subterraneum	2320 e	2569	2261 fghij	1908 fghij	3235
Control (not seeded)	2709 de	2509	1848 fghij	1608 ij	2903
Oversown	4996	2655	3621		2892
Direct drilling	4659	2648		2058	3062
Sowing methods	0.3188	0.9084	<0.0001		0.1005
Species	<0.0001	0.3463	<0.0001		0.3673
Sowing methods x Species	0.6613	0.6398	<0.0001		0.9248

Note: *Lupinus luteus* was not included in 2012-2013 analysis. *Trifolium subterraneum* included cultivars Goulburn (2012-2013) and Bindoon (2013-2014). Different letters in columns shows differences between treatments (LSD 0.05).

In 2013-2014, herbage accumulation to October showed a significant interaction sowing method x species (p<0.0001) (Table 2). In average, differences between methods are associated with differences in sowing dates, as a consequence of climatic conditions that determined a delay in sowing date for no-till. *Lupinus luteus* showed high production in the oversown method compared with no-till, reinforcing the importance of an early sowing date. *Raphanus*, *Oat* and *Ryegrass* maintained a relevant performance. All species showed adequate establishment under oversown method. High autumn rainfall could affect no-till method, being more applied the oversown method based in a large sowing period and growing season, and lower cost.

Nitrogen balance: Nitrogen concentration (%) on the cover crops biomass was 1.63, 2.18, 1.92, 4.06, 3.24, 3.83, 3.24 3.54, 3.75 and 2.63 for *Rapahnus sativus, Lolium multiflorum, Avena strigosa, Trifolium vesiculosum, Vicia sativa, Trifolium resupinatum, Lupinus luteus,Trifolium alexandrinum,Trifolium subterraneum* and the control respectively. Subsequently, estimations of the nitrogen catched by cover crops biomass were 92, 96, 116, 105 and 55 kg/ha/yr of N for *Raphanus, Lolium, Oat, Legumes* and the control respectively . Nitrogen extraction by soybean grain was 211 kg/ha/yr of N. Considering, that N biological fixation in legumes cover crops and soybean represent 50-75% and 50% of absorbed N respectively, the N balance being neutral. On the other hand, N balance using other cover crops options is always negative. Independently of N balance, the non legumes options of cover crops catch N, reducing leaching losses and give an early soil cover. Cover crops effects are further related to sowing date, considering that winter affect growth rate.

Soybean grain production: Soybean yield was not affected by sowing method of cover crops, species or their interactions in any case. The average yield was 2652 and 2977 kg/ha for the year 2012-2013 and 2013-2014 respectively (Table 2). So, the different cover crops did not showed benefits in subsequent crop productivity, despite that it can be attributed advantages in terms of nitrogen balance (legumes), improved soil structure (grasses) or improved drainage conditions (*Raphanus*).

Conclusion

- *Cover crops performance*: Oat, ryegrass, *Lupinus* and *Raphanus* showed the highest herbage production.
- *Sowing method* : Differences in herbage production only occur in the second year by delaying sowing date, that affected the productivity under no-till method.
- *Nitrogen balance*: Some legumes options allowed an acceptable soil cover and a neutral or positive N balance. Other cover crop alternatives showed a negative N balance.
- *Soybean yield*: Grain production was not affected, mainly based on a reduced cropping history.
- *Opportunities*: There are different cover crop alternatives to provide soil protection, storage carbon, catch nitrogen and improve physical properties, that can be analyzed in mixtures combining effects. There are opportunities to integrate agriculture with livestock-production for fattening lambs, having concern of potential effects of treading and soil compactation.

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