European Weed Research Society
19th European Weed Research Society Symposium
20 – 23 June 2022 Athens Greece

The legume choice in a relay intercropping system with durum wheat determines the economic viability of this IWM strategy in a Mediterranean low-input cropping system

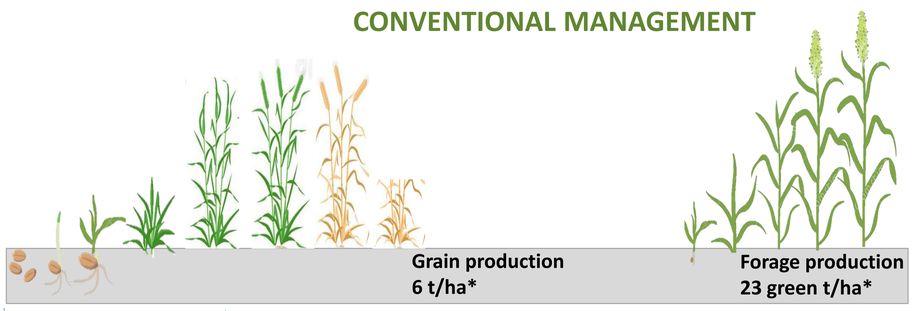
Federico Leoni[1] ; Pauline Triboulet[2] ; Anna-Camilla Moonen[1]
[1] Sant'Anna School of Advanced Studies, Center of Plant Sciences, Group of Agroecology, Pisa, Italy
[2] Unilasalle, Mont Saint Aignan, France

1. Introduction

The economic and environmental sustainability of input intensive farming systems is increasingly questioned. Agricultural policies in the EU are progressively stimulating a reduction in the dependence on agrochemicals and increasing restrictions to the use of herbicides such as glyphosate (MacLaren et al., 2020). Moreover, since agricultural production is sensitive to variations in energy prices, either through direct energy consumption or through energy-related inputs such as fertiliser or herbicides, the costs per unit of agricultural product are increasing rapidly while prices for agricultural commodities do not increase at the same rate (Sands & Westcott, 2011).

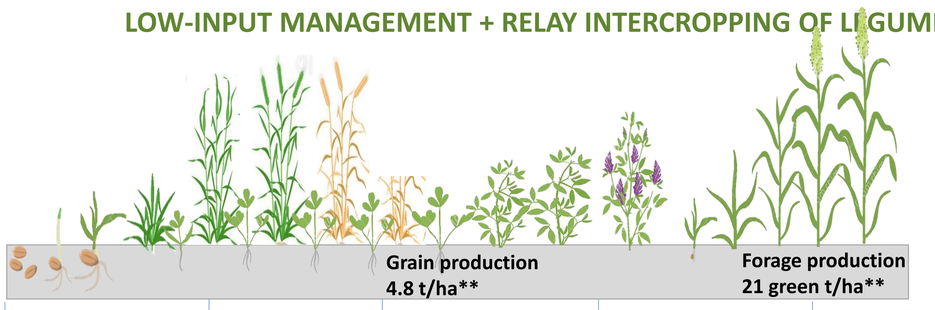
Therefore, conventional and simplified agricultural systems based on the massive use of external inputs are leading to an erosion of the gross margin for farmers. This, along with the climate change emergency and the consumers' call for sustainability, pushes farmers to take actions to decrease the negative impact of farming on the biosphere. Among the choices farmers have at hand today, crop diversification offers a wide range of opportunities to reduce the reliance on external inputs (Costanzo & Bàrberi, 2014). In particular, relay intercropping of wheat with subsidiary legumes has been proposed as valid method to reduce the use of external inputs in the long term in cereal-based cropping systems (Bedoussac & Justes, 2010).

CONVENTIONAL MANAGEMENT



	-Tillage: **164€/ha** -Seed bed: **94€/ha** -Sowing (seeds + mechanical seed drills): **204€/ha** -Chemical weed control: **74€/ha** -Fertilisation: 128 **€/ha**	-Mechanical weed control: **59€/ha** -Fertilisation: **138€/ha** -Fungicides: **69€/ha**	-Harvest: **130€/ha**	-Tillage: **164€/ha** -Seed bed: **94€/ha** - Sowing (seeds + mechanical seed drills): **139 €/ha** -Chemical weed control: **74€/ha** -Fertilisation: **231€/ha**	-Harvest: **264 €/ha**	**TOT €/ha**	**Gross margin €/ha**
Costs	**664 €/ha**	**266 €/ha**	**130 €/ha**	**702 €/ha**	**264 €/ha**	**2026**	**428**
Incomes			**1350 €/ha**		**1104 €/ha**	**2454**	

LOW-INPUT MANAGEMENT + RELAY INTERCROPPING OF LEGUMES



	-Tillage: **164€/ha** -Seed bed : **94€/ha** -Sowing (seeds + mechanical seed drills): **204€/ha**	-Intersowing (seeds + Hoeing + -Mechanical seeder): **284€/ha**	-Harvest: **130€/ha**	-Legume termination: **68€/ha** -Tillage: **164 €/ha** -Seed bed :**94 €/ha** -Sowing (seeds + mechanical seed drills): **139 €/ha**	-Harvest: **264 €/ha**	**TOT €/ha**	**Gross margin €/ha**
Costs	**462 €/ha**	**284 €/ha**	**130 €/ha**	**465 €/ha**	**264 €/ha**	**1605**	**483**
Incomes			**1080 €/ha**		**1008 €/ha**	**2088**	

The quotations for agriculture operations and services were obtained from Regional Agricultural Mechanic Entrepreneurs' Association Price List referred to 2019-20 and include variable costs, downtime, insurance, depreciation, labour, machinery servicing and maintenance. The price quotation for productions (wheat and sorghum) refers to Bologna Stock Exchange for cereal grains and to the Chamber of Commerce of Brescia for forage sorghum.* data estimated according to the production level of nearby fields; ** data obtained from the experiment as average of production level of plots.

2. Objectives

Several studies support the environmental sustainability of relay intercropping of cereals with subsidiary legumes. However, **the question whether the relay intercropping is also sustainable from an economic point of view remains to be answered**. The objective of this study was to make an economical evaluation at cropping system level of eight different legumes species.

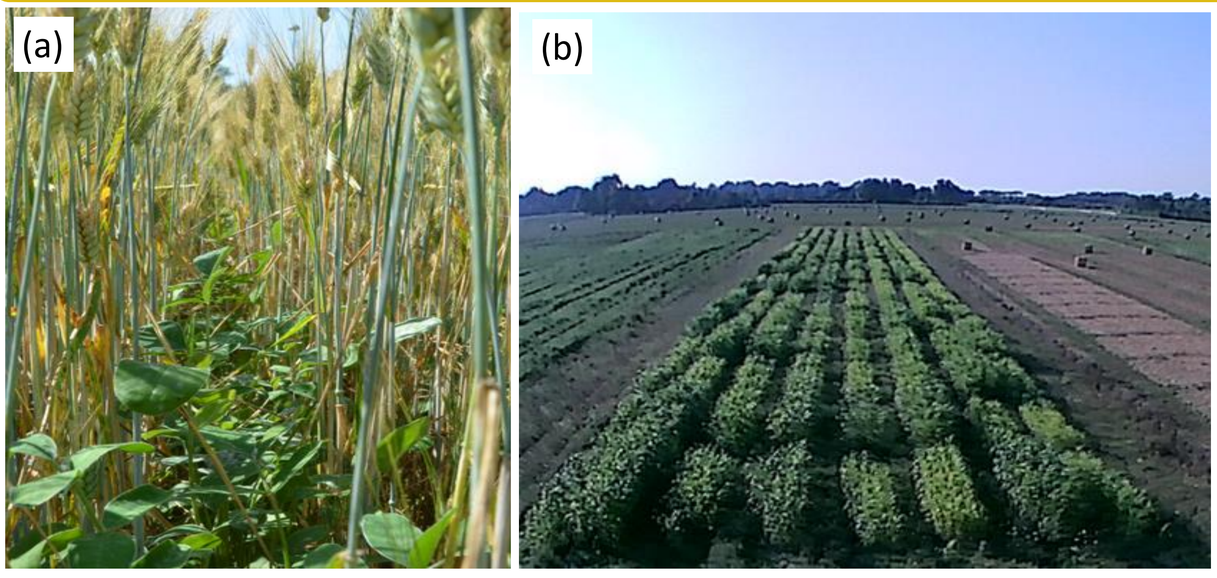
In this study these legumes were evaluated taking into account the impact of the legumes on the co-cultivated wheat and on the following summer crop, forage sorghum. We assumed that annual, annual self-seeding, and perennial legumes work differently and bring different margins, allowing to identify the most cost-effective ones. Our hypothesis was therefore that the cost due to the relay intercropping can be balanced by the ecosystem services it provides, if suitable legumes are chosen.

3. Material and methods

Location: Centre for Agri-Environmental Research Enrico Avanzi of the University of Pisa (CiRAA, San Piero a Grado, Pisa, Tuscany, Italy)
Duration: 2-year durum wheat-forage sorghum crop rotations (2018/19, 2019/20).
Experiment type: plot experiment (18 m^2 per plot).
Experimental design: Complete randomized block design with four replicates.
Management: The plot management was based on the principle of low-input farming, with no application of fertilisers, herbicides and fungicides. Relay intercropping of legumes done before wheat elongation phase. In the spring after wheat harvest, the legume biomass was chopped and incorporated as green manure into the soil by ploughing (30 cm dept). Later, forage sorghum was sown replacing the legume plots.
Crops:

- **Wheat:** cv Minosse, was sown in 30 cm wide-rows at the density of 350 viable seeds per m^2;
- **Relay intercropped legumes:**
  - 4 perennial legumes: ***Medicago sativa***, ***Trifolium repens***, ***Hedysarum coronarium***, ***Medicago lupulina***;
  - 2 annual legumes: ***Trifolium incarnatum***, and ***Trifolium resupinatum***;
  - 2 annual self-seeding legumes: ***Trifolium subterraneum***, and ***Medicago polymorpha;***
  - Control: wheat grown as the sole crop.
- **Forage sorghum:** cv. Sugar graze 2, was sown in 30 cm wide-rows.

Economic analysis:
Gross income (GI) was calculated for wheat (GIw) and sorghum (GIs) separately. Cumulative Gross Income (GIw+s) was then calculated to evaluate the effects of relay intercropped legumes at crop rotation level by summing gross income of wheat and sorghum. In this experiment wheat and sorghum yields were experimentally evaluated. We assumed pasta production and fresh forage as destination of wheat grain and sorghum respectively.



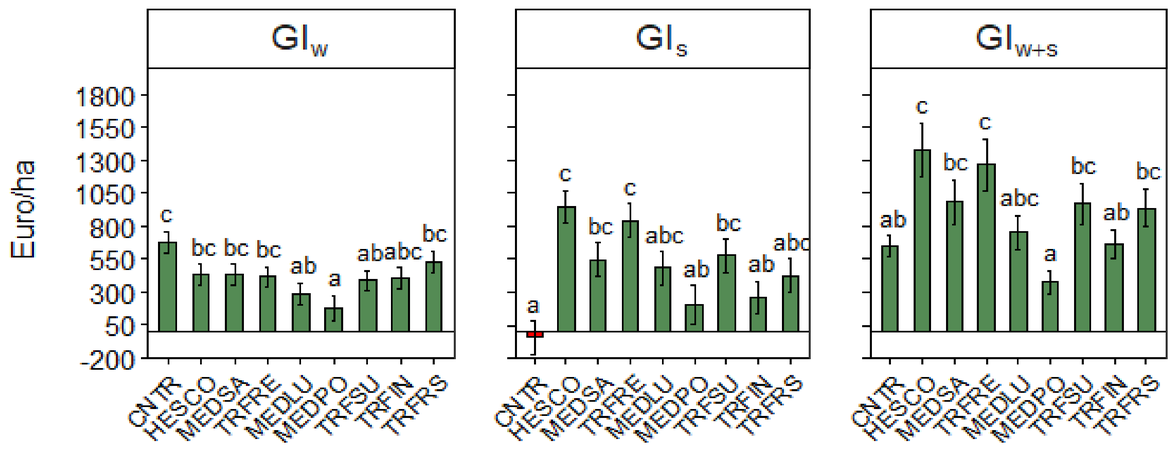
Relay intercropping of *Hedysarum coronarium* with wheat (a) and residual effect of legumes on the subsequent forage sorghum (b). Photographs by Federico Leoni.

4. Results

Legume	*Durum wheat* Y_w t/ha	Q_w Euro/t	GPV_w Euro/ha	*Forage sorghum* Y_s t/ha	Q_s Euro/t	GPV_s Euro/ha
2018/2019						
CNTR	5.2	225	1167.7	10.6	48	512.6
HESCO	5.2	225	1174.5	31.1	48	1494.2
MEDSA	4.7	225	1066.5	22.9	48	1099.6
TRFRE	4.6	225	1044.0	20.5	48	988.3
MEDLU	4.9	225	1118.2	21.4	48	1027.6
MEDPO	4.4	225	996.7	14.4	48	694.6
TRFSU	5.2	225	1172.2	23.0	48	1104.9
TRFIN	4.9	225	1102.5	16.9	48	812.6
TRFRS	5.2	225	1172.2	20.3	48	977.7

Yield (Y), Price quotation (Q) and Gross Production Value (GPV) of durum wheat and forage sorghum for 2019/20 growing seasons. CNTR: Control plot (wheat sole stand crop); HESCO: *Hedysarum coronarium*; MEDSA: *Medicago sativa*; TRFRE: *Trifolium repens*; MEDLU: *Medicago lupulina*; MEDPO: *Medicago polymorpha*; TRFSU: *Trifolium subterraneum*; TRFIN: *Trifolium incarnatum*; TRFRS: *Trifolium resupinatum*.

- Relay intercropping reduces profitability of the co-cultivated durum wheat due to the cost for inter-seeding.
- Forage sorghum preceded by *H. coronarium*, *T. repens*, *T. subterraneum* and *M. sativa* had a significantly higher biomass production compared to the control and the gross margin was positive (945, 845, 576 and 548 Euro/ha respectively). Gross margins for sorghum preceded by *M. lupolina, M. polymorpha* and *T. incarnatum* was positive but it was not significantly different from the control. The gross margin for the control was just below 0 (-42 Euro/ha)
- The overall economic assessment of durum wheat and forage sorghum showed that higher production costs of wheat due to the intercropping operation is balanced with the benefits provided by legumes in the subsequent forage sorghum for all of the legumes used in this experiment. In particular, *H. coronarium* and *T. repens* had the highest comulative gross margin (1381 and 1267 Euro/ha respectively).



Gross margin of durum wheat (GIw), forage sorghum (GIs) and cumulative gross margin (GIw+s) for 2019/20 growing season. CNTR: Control plot (wheat sole stand crop); HESCO: *Hedysarum coronarium*; MEDSA: *Medicago sativa*; TRFRE: *Trifolium repens*; MEDLU: *Medicago lupulina*; MEDPO: *Medicago polymorpha*; TRFSU: *Trifolium subterraneum*; TRFIN: *Trifolium incarnatum*; TRFRS: *Trifolium resupinatum*. Different letters (a-e) indicate significant differences at the 0.05 level. Error bars represent standard error (SE). GI do not include the Common Agricultural Policy (CAP) payment.

References

MacLaren, C., Storkey, J., Menegat, A., Metcalfe, H., & Dehnen-Schmutz, K. (2020). An ecological future for weed science to sustain crop production and the environment. A review. Agronomy for Sustainable Development, 40(4), 24. https://doi.org/10.1007/s13593-020-00631-6

Sands, R., & Westcott, P. (2011). Impacts of Higher Energy Prices on Agriculture and Rural Economies. 56.

Costanzo, A., & Bàrberi, P. (2014). Functional agrobiodiversity and agroecosystem services in sustainable wheat production. A review. Agronomy for Sustainable Development, 34(2), 327–348. https://doi.org/10.1007/s13593-013-0178-1

Bedoussac, L., & Justes, E. (2010). Dynamic analysis of competition and complementarity for light and N use to understand the yield and the protein content of a durum wheat–winter pea intercrop. Plant and Soil, 330(1/2), 37–54

Acknowledgements The authors would like to thank Giacomo Nardi (Sant'Anna School of Advanced Studies) for technical assistance with the field experiments management.
Funding This research was funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 727321 (IWMPRAISE). F.L. has a study grant from PhD course in Agrobiodiversity at Sant'Anna School of Advanced Studies, Pisa, Italy

Sant'Anna Scuola Universitaria Superiore Pisa
@GoAgroecology
IWMPRAISE Funded by European Union Horizon 2020 Grant agreement nº 727321