Design and assessment of diversified low input cropping systems in southwestern France: an application of agroecological principles aiming at decreasing pesticides and N-fertilizers use

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1 Introduction

Spatial and temporal diversification of cropping systems (CS) is recognized as a relevant alternative to move towards sustainable agriculture (Duru et al. 2015). It could be achieved by several agronomic levers, and more particularly by lengthening and diversifying crop rotations notably by the introduction of legumes, crop mixtures and multi-services cover crops. In this study, we assumed that diversified CS could reduce the use of pesticides and N fertilizers in South-West France context, while maintaining the economic profit and improving the overall performances of CS in terms of ecosystem services. After designing CS varying by their degree of agro-ecologization, our objective was to illustrate their strengths and weaknesses and discuss the possible way to improve their performances for favoring their adoption by farmers in the future.

2 Materials and Methods

The experiment was located at INRA station in southwestern France (43°53'N, 1°51'W) and was carried out on two rotation cycles of three years each (2011-2013, 2014-2016), each crop of the rotation being present each year. The CS were designed as alternatives to the local two-years reference rotation of durum wheat and sunflower (REF) and were designed based on a lengthening of the rotation (3 years instead of 2), a pesticides reduction of 50%, and a variable reduction of N-fertilizer:

- LI: low-input CS aiming at reducing N-fertilizers by 25%, relying on a rotation of sunflower-durum wheat-sorghum,
- VLI_CM: very low-input CS aiming at reducing N-fertilizers by 50%, relying on a rotation of sunflower-fababean-durum wheat and including cultivar mixtures (CM),
- VLI_IC: VLI composed of three successive intercrops (IC): sunflower+soybean, then triticale+fababean (2011-2013) or durum wheat+winter pea (2014-2016), and then durum wheat+winter pea (2011-2013) or soft wheat+fababean (2014-2016).

Each CS was tested with and without cover crops (CC) during the fallow period. Thus, six CS were designed covering an agroecological gradient of reduced inputs use and increased diversification.

ANOVAs were run to compare the six CS and the reference at the rotation scale, considering 4 indicators calculated for each rotation at the year scale: i) the mean semi net margin (€.ha^{-1}, =[Grain yield x Crop price + Subsidies] - [Operational charges + Mechanical charges + Fuel]) as an integrative indicator, ii) the mean yield (t.ha^{-1}), iii) the gross proceeds (€.ha^{-1}, = Grain yield x Crop price, which is for intercrops the price of the mixture) and iv) the N-fertilizer amount (kg N.ha^{-1}).

3 Results

The CS (reflecting plant diversification and input effects) and the rotation cycle (reflecting mainly a climate effect) had a significant ($p < 0.05$) impact on semi net margin (Figure 1A). The effect of the rotation cycle was predominant, and involved a global decrease of semi net margin during the second rotation cycle, highlighting the importance to consider the environment through modelling in order to assess its impacts.

Semi net margin decreased following the diversification gradient, with a lower semi net margin for VLI_IC and intermediate values for VLI_CM, partly because no additional costs are linked to grading of grains. Moreover, for a given CS, the presence of CC had globally no significant impact on semi net margin.

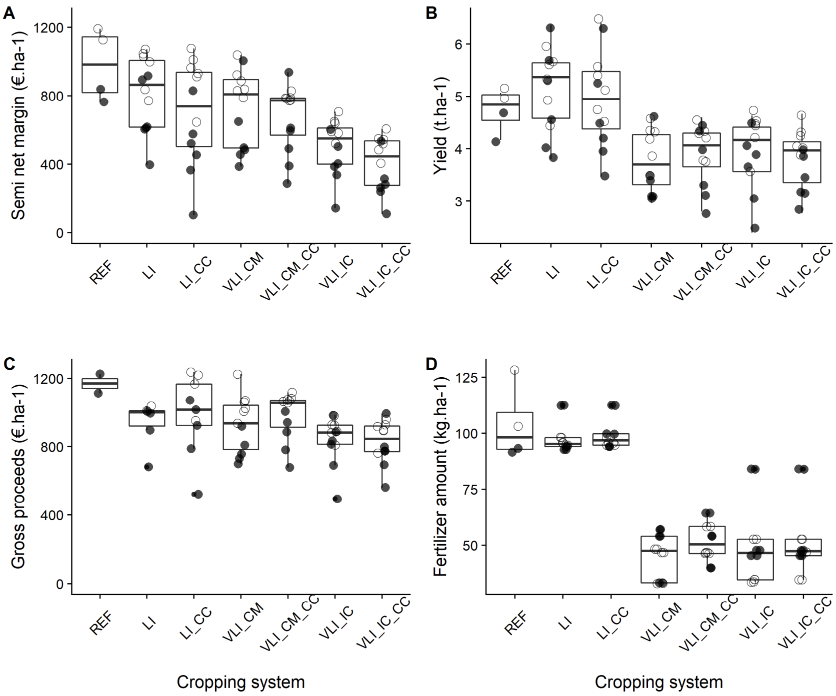

Figure 1. Semi net margin (A), yield (B), gross proceeds (C) and fertilizer amount (D) of seven cropping systems differing by their level of diversification: REF (standard local system), LI (low input system), LI_CC (LI with cover crops CC), VLI_CM (very low input system with cultivar mixtures), VLI_CM_CC (VLI_CM with CC), VLI_IC (VLI with intercrops) and VLI_IC_CC (VLI_IC with CC). White dots: rotation 2011-2013, Black dots: rotation 2014-2016.

4 Discussion and Conclusions

When focusing on agro-economic indicators, diversification and the related reduced inputs use were not profitable. Despite the input cost reduction in VLI systems, lower yields (Figure 1B) and gross proceeds (Fig.1C) penalized these diversified CS. In order to study such innovative CS and highlight their potential benefits, new indicators should be taken into account, considering an economic value of the ecosystem services provided by diversification. For example, the strong decrease of N-fertilizer amount in VLI systems (Fig.1D) suggests that they could have a reduced environmental impact compared to LI systems or the REF considering both greenhouse gases emissions and water pollution, as ever demonstrated (Plaza-Bonilla et al. 2018). For this reason, agroecological CS able to deliver on reduce N-fertilizer inputs would require reward. Additionally, soil fertility and biodiversity could also be valuable indicators to highlight the ecosystem services brought by these diversified CS and in particular, the benefits of multi-services CC. In addition, these results suggest that the choice of the crop species and cultivars is crucial. When the CS is less productive, partly because of the decrease in chemical inputs use, choosing species that are characterized by a high price could be relevant, *e.g.* lentil dedicated to human consumption vs fababean. Finally, intercrops grain products were sold as a mixture while the improvement of agricultural machinery, able to separate grains, could increase their selling price.

References

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