Diversification of cropping systems in a context of shallow soils: implementation and performances of both on-station and on-farm systems

Stéphane Cadoux*±1, Gilles Sauzet[2], Thibaut Pruvot[2], Francis Flénet[1]

[1] Terres Inovia, Avenue Lucien Brétignières, 78 850 Thiverval-Grignon, France
[2] Terres Inovia, Domaine du Grand Chaumoy, 18570 Le Subdray, France

⁎ Speaker
± Corresponding author: s.cadoux@terresinovia.fr

1 Introduction

A shift towards new production systems, based on ecological intensification, adapted to local conditions, and manageable by farmers is expected (Duru *et al.* 2015). Diversification of cropping systems in space and time is often claimed as a main driver for providing the necessary ecosystem services (Gaba *et al.* 2015). In France, an important area of arable crop production called ‘intermediate zone’, crossing the country from west to east at the south of Paris, is characterized by shallow and stony soils with low potential. In these situations rotations are generally short and based on winter crops (rapeseed/wheat/barley) and tillage is often reduced. These systems typically encounter agronomic problems: yield stagnation, increasing difficulties in controlling weeds and pests despite a high pesticide use. In that context, the diversification of cropping systems is particularly relevant, but its implementation on farms is hindered by the high risk of crop water stress.

To adress this issue, we developped, wthin the frame of the French project 'Syppre[1]' and of the European project DiverIMPACTS, an approach combining (i) the support to farmers in transition in their farm and (ii) on-station experiment of an innovative cropping system co-designed with local advisors and farmers. The aim of this paper was to describe the approach used, the cropping systems implemented, their performances and discuss the strengths, weaknesses and obstacles to cropping system diversification in this context.

2 Materials and Methods

The work was carried out in the center of France, in a semi-oceanic climate. The soils were stony clay-limestone of shallow to medium depth with low water holding capacity.

The group of farmers was set up about ten years ago. Originally, they requested the support of Terres Inovia to understand the origin of problems of yield stagnation and pest control in rapeseed and to find solutions. The group's thinking has gradually broadened to the scale of the cropping system and now aims to obtain "a fertile soil for robust crops". It now includes 12 farmers. Its approach consisted of (i) field visits at several times of the year to share information on the practices implemented and their results, and (ii) indoor meetings to share the assessment of the agricultural campaign and ideas for improvements. Advisors from local development structures (cooperatives, agribusiness, chambers of agriculture, etc.) were systematically involved in these meetings so that they can bring their expertise in and benefit from group’s ideas and approach.

In parallel, in 2014, the farmers of the group and the local advisors were involved in the co-design of prototypes of innovative cropping systems aimed at reconciling local (defined by the group) and global challenges (productivity, profitability and low environmental impacts), led by Terres Inovia as part of the inter-institute project Syppre[1]. The *a priori* most performing prototype was selected and has been tested on-station since 2016. Visits and discussions on the results were shared with those of the farmer network to stimulate innovation in both schemes.

The performances of farmers’ cropping systems and of the Syppre experiment were evaluated using the French tool Systerre® (Weber *et al.* 2018). For farmers' systems, to reduce the workload of evaluating twelve farms over several years, we have described with the farmers a typical ‘current’ and ‘before support’

[1] The Syppre project "Building tomorrow's systems together", co-led by Arvalis - Institut du végétal, Institut Technique de la Betterave (ITB) and Terres Inovia, was launched in 2013 for the long term.

system for the two main soil types of the group's farms. In this paper we only present the results for the shallow clay-limestone soils.

3 Results

The rotation of the typical 'before support' cropping system of the farmers was rapeseed-wheat-barley. Identifying problems of soil fertility, the farmers decided to diversify their cropping systems with the introduction of legume crops. They first introduced multi-species cover crops and came up with the idea of intercropping rapeseed with frost sensitive legume crops. They developed this innovation that is now used on 12% of rapeseed surfaces in France (Wagner and Lecomte 2019). Then they gradually lengthened their rotations, often with the insertion of lentil, in order to disrupt weeds and bring symbiotic nitrogen. This spring crop is adapted to shallow soils and benefit from a growing market. The rotation of the typical 'current' system defined with the farmers was intercropped rapeseed-wheat-lentil-wheat-barley. The gross margin improved by 7% while the treatment frequency index of pesticides (TFI), the amount of mineral fertilizer-N, and the greenhouse gas (GHG) emissions were reduced by approximatively 25% (Table 1).

Table 1: performances of the typical on-farm and on-station cropping systems.

	On-farm systems		On-station systems			
			2016-2017		2017-2018	
	Typical 'before support'	Typical 'current'	Control	Innovative	Control	Innovative
Gross product (€/ha)	1110	1126 (+1%)	942	955 (+1%)	1094	935 (-14%)
Gross margin (€/ha)	585	624 (+7%)	437	545 (+25%)	613	549 (-10%)
TFI	7.56	5.85 (-23%)	6.8	3.6 (-47%)	5.3	3.7 (-29%)
Fertilizer-N (kgN/ha)	177	137 (-23%)	174	113 (-35%)	158	104 (-34%)
GES emissions (kg CO2-eq)	2645	2018 (-24%)	2149	1577 (-27%)	2276	1587 (-30%)

The farmers of the group were strongly involved during the co-design of the innovative cropping system to be tested on-station. The selected innovative cropping system was based on a nine-year rotation. It included a succession of lentil, durum wheat and intercropped rapeseed proposed by a farmer who successfully practices it. To disrupt weeds a succession of two spring crops: maize, sunflower, followed by a wheat, was selected. These two crops were rarely grown in this low potential context, but farmers were interested in seeing if the agronomic benefits could make their introduction profitable. The crop rotation ended with winter pea intercropped with wheat-wheat-winter barley. A control system with an intercropped rapeseed-wheat-barley rotation was experimented alongside the innovative one.

The environmental performances of the innovative cropping system over the first two years were satisfying. The treatment frequency index was reduced by 30 to 50%, the amount of mineral fertilizer-N and the greenhouse gas emissions were reduced by approximatively 30% compared to the control system. The productivity and the profitability were improved in the first year but were worse in the second year of experiment.

4 Discussion and Conclusions

Thanks to an interactive and participative support approach, farmers have diversified their systems over 10 years with the benefit of an overall improvement in performances. But weed control difficulties persisted for most of them. The on station cropping system was further diversified. The performances were very positive in the first year notably due to a summer rainfall pattern favourable to spring crops. At the opposite a summer drought in 2018 led to very low yields of summer crops, penalizing the system's profitability. Nevertheless, farmers remained interested in knowing long-term performances as well as the practical feasibility of such a diversified system. The involvement of farmers in the co-design and steering committee of the on-station experiment seemed to be an effective way to help them explore innovative pathways for the step by step re-designing of their on-farm cropping system.

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