Reducing pesticide use while reaching economic and environmental sustainability in Arable Farming

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1 Introduction

The substantial reduction in pesticide use is one of the key-issue for improving agriculture sustainability. Integrated farming, based on Integrated Pest Management (IPM) principles that emphasize physical and biological regulation strategies to control pests while reducing the reliance on pesticides, is presented as an alternative path in between conventionnal and organic farming likely to better reconcile agricultural productivity with other components of sustainability (Holland *et al.*, 1994). Here, we used a network of 48 contrasted cropping systems (conventionnal, integrated or organic) to analyse the relationship between the level of pesticide use and eight aspects of agricultural sustainability (Lechenet *et al.*, 2015).

2 Materials and Methods

The cropping systems included in the study were from two regions in France (Burgundy and Poitou-Charentes), and were either tested in cropping system experiments or surveyed in commercial farms sampled so as to maximise the variability in the level of pesticide use. Eight systems complied with the specifications of organic farming, 30 systems followed some IPM principles (diversified crop rotations and/or non-chemical pest management options such as resistant cultivars, mechanical weeding and false seed bed techniques) and 10 systems were classified as conventional systems. At each site, a conventional system was identified as a local reference corresponding to the current standard crop rotation and crop management. Each system was described with a detailed sequence of operations for soil tillage and crop management.

For each system the level of pesticide use was estimated using the Treatment Frequency Index (TFI) quantifying the number of registered doses applied, and eight indicators of sustainability were computed from the management data, namely the productivity (harvested MJ ha^{-1} $year^{-1}$), the energy efficiency, the economic profitability expressed as the semi-net margin (Euros ha^{-1} $year^{-1}$), the fuel consumption (L ha^{-1} $year^{-1}$), the level of N fertilization (kg of N ha^{-1} $year^{-1}$), the indicator of environmental impact related with pesticides I-Pest in standardized environmental conditions (van der Werf & Zimmer, 1998), the sensitivity of the semi-net margin to price volatility, and the workload (h ha^{-1} $year^{-1}$). The Dia'terre® reference database was used for the computations of energy inputs and outputs. The sensitivity to price volatility was defined as the relative standard deviation of the semi-net margin calculated over ten contrasting real prices scenarios selected between 2000 and 2010. Each indicator was expressed as natural logarithm of the ratio between the cropping system and the local reference indicators, and this allowed separating the effects of the cropping system itself from the effects of the specific production context at each site. Pesticide use was expressed as relative TFI, i.e. as a ratio with the TFI of the local reference system.

3 Results - Discussion

Productivity of organic systems was about -50% on average below productivity of non-organic systems, which is a higher gap than highlighted in a recent review (Ponisio *et al.*, 2015). But we found no correlation between TFI and productivity for conventional and integrated systems (Fig. 1A). The energy efficiency was frequently higher in integrated systems as compared to organic and conventional ones (Fig. 1B), partly because the frequency of crops for which the whole above-ground biomass is harvested was higher in IPM-based systems. Excluding organic systems, the correlation between TFI and energy efficiency kept a negative tendency when cropping systems producing grain crops only were considered, because IPM-based systems reduced energy inputs thanks to lower levels of N fertilisation and higher frequency of legume crops. In spite of their low energy input, organic farming yielded significantly lower energy efficiency as compared to IPM-based systems.

The semi-net margin, when averaged over the ten price scenarios, was very similar for organic, conventional and IPM-based systems, and no correlation was detected between TFI and the average semi-net margin (Fig. 1C). The range of profitability was higher for IPM-based systems, as both the systems providing the highest and the lowest profitability were following IPM principles. The sensitivity to price volatility was significantly lower in organic cropping systems than in other ones, probably because (i) they were based on more diversified crop rotations, which spread risks and buffered semi-net margin at the farming system scale, and (ii) they are less dependent on exogenous inputs, and notably volatile inputs such as N fertilizers.

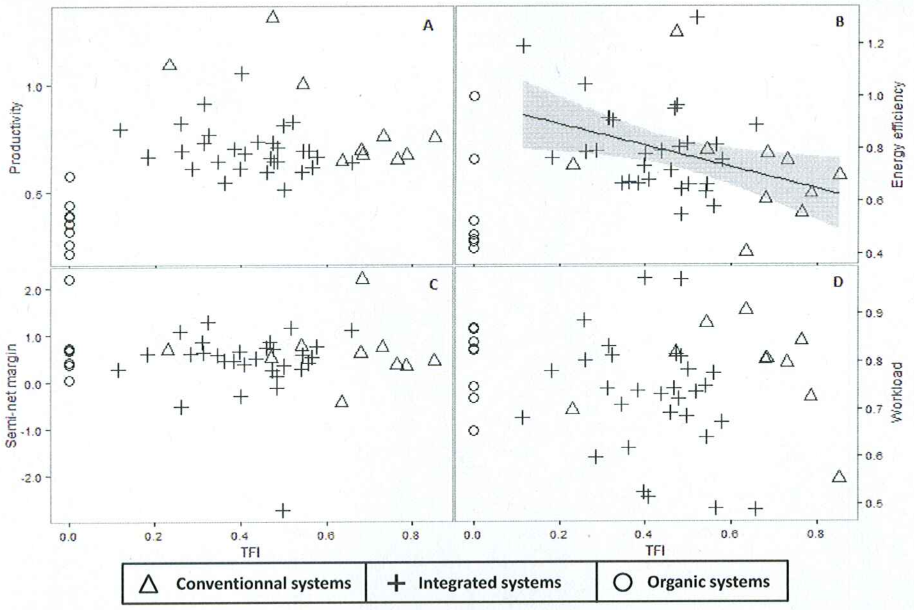

Fig. 1. Relationship between the level of pesticide use (relative TFI) and four sustainability indicators for 48 contrasted cropping systems: (A) productivity, (B) Energy efficiency (linear regression is represented with standard error, Pearson correlation test: rp = −0.38, P = 0.02), (C) Semi-net margin, and (D) workload. Each sustainability indicators is expressed as the natural logarithm of the ratio between the cropping system and the local reference indicators.

We found a large variability in the workload required to manage cropping systems (ranging from 2.5 to 6.2 h ha^{-1} $year^{-1}$), but surprisingly there was no correlation with TFI. High labour requirements were mainly correlated with the application of organic manure.

As expected we found a close relationship between TFI and the indicator related with the impact of pesticide residues in the environment I-Pest. Organic systems consumed significantly higher levels of fuel as compared to the rest of the sample, but we found no correlation between this non-renewable input and TFI for non-organic systems.

4 Conclusions

According to the results, IPM-based system appeared as the best compromise in sustainability trade-offs: they contribute to reduce substantially the use of pesticide and related environmental impacts while providing high productivities (higher than organic farming), good profitability, high energy efficiency, and this without necessarily increasing the workload and the consumption of non-renewable inputs. Both the crop diversification and the insertion of legume crops in grain crop rotations appear as major components of sustainable cropping systems (Lechenet *et al.*, 2015).

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