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Comparison of the environmental performance of four maize monocropping systems: a three-year monitoring of pesticide leaching.

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Introduction

The objectives fixed by the EU Water Framework Directive (Directive 2000/60/CE) to prevent and control groundwater pollution by pesticides involve a better assessment of environmental impacts of agricultural practices. In order to reach these objectives of water quality, the French Ecophyto plan, started in 2008, aims at cutting by half the use of pesticides for each production over ten years. Among the main crop production in France, maize monoculture is known to be a source of water pollution by nitrate and pesticides and consumes water for irrigation (Agence de l'eau Adour-Garonne, 2007). In order to reduce these environmental impacts, innovative maize cropping systems need to be designed and tested.

The objectives of this study were to i) design innovative maize cropping systems that aimed at reducing the use of inputs such as pesticides, nitrate, water and energy and ii) assess (with a multicriteria quantitative approach) the agronomic, economic, social and environmental performances of these cropping systems.

Materials and methods

Design of innovative maize cropping systems was started in 2010. A field experimentation was then started in 2011 for the spring crops on the experimental farm of Lamothe located in the alluvial corridor of the Garonne river (near Toulouse, South-West of France).

Compared to the conventional monocropping for irrigated maize (MM1) mainly based on the optimisation of economic performances, three alternatives cropping systems with different objectives were tested.

MM2 aimed at reducing irrigation, the use of herbicides and limiting nitrate leaching during the fallow period by undersowing a cover crop at the 6-leaf stage of the maize. Herbicide treatments were localized on the seed row and an early variety was chosen in order to reduce irrigation and to enhance the development of the cover crop by an earlier harvest than in MM1.

MM3 aimed at reducing energy and water consumption and limiting nitrate and pesticide leaching. An early variety of maize was sown after a strip tillage. A cover crop was sown after maize harvest and destroyed either by the frost or by a glyphosate treatment in early spring.

Finally MM4 aimed at reducing the use of fertilizers and pesticides and to maintain the gross margin of MM1. A late maize variety was sown after a strip tillage but a living cover crop of white clover was maintained on the field.

For each monocropping (replicated twice), water dynamic and temperature were monitored by tensiometers, volumetric water content and temperature probes installed at 20-, 50- and 100-cm depth. Tension plate lysimeters were installed at 100-cm depth in order to collect drainage and monitor pesticides (all applied molecules) and nitrate leaching.

Table 1. Pesticide losses (concentration and cumulated losses), drainage and quantification date of the pesticides in leachate for the four maize cropping systems in 2011 and 2012.

Year	Cropping system	Pesticide	Concentration $\mu\text{g L}^{-1}$	Cumulative drainage (mm)	Quantification of pesticide (in DAT)	Cumulated loss (% of applied dose)
2011	MM1	SMOC	0.04	18.8	136	< 0.001
	MM2	∅				
	MM3	Nicosulfuron	0.05	35.7	142	< 0.001
	MM4	Nicosulfuron	0.03 – 0.05	78.8	138	< 0.001
2012	MM1	Mesotrione	0.24 – 0.40	53.3	41 - 97	0.2
		SMOC	0.03 – 0.25			0.03
		Nicosulfuron	0.02 – 0.05			< 0.001
		Metaldehyde	0.02			< 0.001
	MM2	Nicosulfuron	1.15	75.3	36	0.3
		SMOC	0.01			0.04
		Metaldehyde	0.03			< 0.001
	MM3	AMPA	0.05 – 0.4	62.8 – 128	303 - 491	0.3
		Glyphosate	0.03 – 0.05			125
		SMOC	1.3 – 7.1			41
		Mesotrione	1.0 – 2.7			1.2
	MM4	AMPA	0.05 – 0.08	64 – 198	9 – 162	< 0.001
Glyphosate		< LOQ	68			
Nicosulfuron		2.2 – 3.6	0.01			
Bentazone		8.7 – 11.5	2.0			

Results and discussion

After three years of experimentation, most of the applied chemicals were found at least once in leachate. The greatest losses were bentazone (0.5-2.0 % of applied dose), S-metolachlor (0.5-1.7 % of applied dose) and mesotrione (0.2-1.2 % of applied dose) (Table 1). Glyphosate, nicosulfuron, metaldehyde, benoxacor were also quantified in several leachates but in lower quantities.

Whatever the cropping system, migration of pesticides in soils was rapid with the fastest migration observed for the strip-tilled MM4 system (AMPA was detected in leachate 9 days after treatment, Table 1).

A significant effect of the cropping system on pesticides losses was found with the lowest leaching measured under the MM2 system. Reducing herbicide application by location of the molecule on the seed row seemed to be a promising technique to reduce pesticides fluxes. On the other hand, strip tillage systems appeared to have the highest pesticides losses during the three years probably due to preferential transport (Bosch *et al.*, 2005; Alletto *et al.*, 2010).

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