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Compost Effect on Diuron Retention and Transport in Structured Vineyard Soils

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ABSTRACT

Diuron is frequently detected in surface- and groundwater under the vineyards, where organic amendments are often used, in Burgundy of France. Undisturbed column experiments were conducted to study the influence of three composted organic amendments on diuron leaching through columns of two vineyard soils from Vosne-Romanée (VR, calcareous Cambisol) and Beaujolais (Bj, sandy Leptosol), France. Bromide (used as non-reactive tracer) and diuron breakthrough curves (BTCs) were analyzed using convective-dispersive equation (CDE), two-region (mobile-immobile, MIM) and two-site models. No influence of the composts was observed on the bromide recovery rates. The CDE model described well the bromide BTCs for all columns of the Bj soil and seven of the VR soil, suggesting a homogeneous water flow. However, for five VR soil columns, the MIM model fitted better, suggesting a partition of the water flow (15%–50% of matrix flow). The texture, the coarse material content and the tillage of the VR soil could explain this heterogeneity. However, for all columns, diuron leaching was greater through the Bj soil (46%–68%) than the VR soil (28%–39%). The compost addition resulted in a contrasting effect on diuron leaching: no difference or a decrease was observed for the VR soil, probably due to an increase of adsorption sites, whereas no difference or an increase was observed for the Bj soil possibly because of interactions and/or competition of diuron with the compost water-extractable organic matter which could facilitate its transport. All the diuron BTCs were best described using the two-site model, suggesting a large proportion of time-dependent sorption sites (30%–50%). The soil type and the nature of the amendments had contrasting influences on diuron transport. Composts with a high water-soluble fraction must be avoided in sandy soils to reduce the risk of groundwater contamination.

Key Words: groundwater contamination, leaching, organic amendment, soil type, sorption, water-extractable organic matter

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INTRODUCTION

Over the last few decades, diuron has been one of the most widely used herbicides for weed control in vineyards in France. It has frequently been detected in surface- and groundwater (DIREN *et al.*, 2008; DREAL, 2009), at concentrations regularly exceeding the European regulatory limit of quality standard for surface waters (0.2 μg L^{-1}) (EPCEU, 2013). Studies have shown that for vineyards, diuron leaching depends on soil nature and management (Landry *et al.*, 2004; Thevenot *et al.*, 2008).

Addition of organic amendments to soil could modify pesticide leaching (López-Piñeiro *et al.*, 2013; Fenoll *et al.*, 2014), increasing diuron desorption and leaching through soils (Cox *et al.*, 2007; Thevenot *et al.*, 2008). This increase in diuron mobility could be explained by the formation of mobile complexes between the herbicide and the water-extractable organic matter (WEOM), or by competition for adsorption sites in soil (Ahangar *et al.*, 2008; Thevenot *et al.*, 2009). However, decreases in diuron leaching through amended soils have also been reported (Cabrera *et al.*, 2010; López-Piñeiro *et al.*, 2010; Romero *et al.*, 2010). Therefore, the impact of organic amendments on diuron leaching is contradictory, and the mechanisms involved are not yet fully understood. The impact of the amendments on the hydrodynamic properties of the soils is in particular still little known despite recent studies on this purpose (Peña *et al.*, 2011; Marín-Benito *et al.*, 2013; Maraqa and Khashan, 2014). Moreover, the influences of the composition and maturity of the amendments are also not fully understood.

Thus, the objectives of this work were to assess the early and short-term effects of composted organic amendments on diuron mobility through two vineyard soils, and to bring new knowledge by studying these effects through their hydrodynamic parameters, still po-

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orly known. In this purpose, displacement experiments were performed: i) to evaluate the impact of compost characteristics on diuron mobility and ii) to evaluate this impact using solute transport models.

MATERIALS AND METHODS

Chemicals

Diuron (3-(3, 4-dichlorophenyl)-1, 1-dimethylurea) was purchased from Dr. Ehrenstorfer (Augsburg, Germany). The average half-life of diuron in soils is 75.5 d; its solubility in water is 35.6 mg L^{-1} at 20 °C; its average linear adsorption coefficient is 8.3 L kg^{-1} (PPDB, AERU, University of Hertfordshire, 2013). Bromide was used as a non-reactive tracer in column experiments.

Soil and column sampling

Two vineyard soils were sampled: a Cambisol and a Leptosol (IUSS Working Group WRB, 2007) from Vosne-Romanée (VR) of Burgundy, France and from Odenas of Beaujolais (Bj), France, respectively. The two soils were sampled at 0–20 cm depth, and then air-dried and sieved (2 mm). Their physical-chemical characteristics were determined at the INRA laboratory (Arras, France), using the methods reported by Jacobson *et al.* (2005) (Table I). The calcareous VR soil presented a more heterogeneous particle-size distribution, with more coarse material (> 2 mm, > 50%) and clay than the sandy Bj soil, suggesting a greater heterogeneity of the soil structure at the field scale. The VR soil also presented higher pH, cation exchange capacity (CEC) and organic carbon (OC) content values (Table I). Mean bulk densities were 1.76 ± 0.10 g cm^{-3} for the VR soil and 1.86 ± 0.11 g cm^{-3} for the Bj soil. Assuming a particle density of 2.65 g cm^{-3}, the total porosity was equal to 0.51 ± 0.09 cm^3 cm^{-3} for the VR soil and 0.43 ± 0.09 cm^3 cm^{-3} for the Bj soil.

For each soil, twelve undisturbed soil columns were sampled by carefully excavating soil monoliths (16 cm diameter, 20 cm long), as described in Landry *et al.* (2004). The soil columns were removed from the field, and a nylon mesh was placed at the bottom of each column to retain the soil.

Organic amendments

Two composted organic amendments (the composts A and B), frequently used in French vineyards for soil improvement, were sampled in their commercial formulation. The main difference is in the composition of the two composts (Table II), with the composting process being the same. The compost B was also sampled at an early stage, *i.e.*, less than 48 h after the preparation of the fresh mixture, as another compost, B_F. After sampling, all three amendments (the composts A, B and B_F) were dried at 30 °C for 3 to 5 d and then sieved (5 mm).

The composts used varied in their OC and water-extractable organic carbon (WEOC) contents, which were higher for the compost A (Table II). Both the OC

TABLE I

Main physical-chemical properties[a)] of two vineyard soils (0–20 cm), a Cambisol from Vosne-Romanée (VR) and a Leptosol from Beaujolais (Bj), France

Soil	Texture				OC	C/N	$CaCO_3$	pH (H_2O)	CEC
	Coarse material[b)]	Sand	Silt	Clay					
	g kg^{-1}						g kg^{-1}		cmol kg^{-1}
VR	510	300	354	345	14.3	10.9	332	8.1	19.1
Bj	174	667	239	93	5.0	10.2	< 10	5.6	5.5

[a)] OC = organic carbon; CEC = cation exchange capacity.

[b)] > 2 mm.

TABLE II

Composition and main physico-chemical properties[a)] of the composted organic amendments used (on a dry weight basis)

Compost	Composition	pH	EC	OC	OM	WEOC	C/N
			mS m^{-1}	g kg^{-1}			
A	Cocoa, grape and olive cakes (20/20/60)	6.2	607	454	848	69.7±0.3[b)]	17
B	Sheep manure, plant cakes and wool dust	5.7	650	438	770	32.8±0.3	18
B_F	(36/42/13), plus Mg	6.4	826	383	672	34.9±0.1	12

[a)] EC = electric conductivity; OC = organic carbon; OM = organic matter; WEOC = water-extractable organic carbon (soil/water ratio of 1:40).

[b)] Means±standard deviations.