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Effect of controlled release formulations of diuron and alachlor herbicides on the biochemical activity of agricultural soils

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HIGHLIGHTS

- The phosphatidylcholine (PC)-clay complex is innocuous to soil microorganisms.
- The PC-clay complex is optimal for use in formulating herbicidal slow release.
- The herbicide-PC-clay complex increases the half-life time of the herbicide in soil.
- Except for the urease activity, alachlor increased soil enzymatic activities.
- The diuron adversely affected soil dehydrogenase and β-glucosidase activities.

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ABSTRACT

The use of pesticides in agriculture is essential because it reduces the economic losses caused by pests, improving crop yields. In spite of the growing number of studies concerning the development and application of controlled release formulations (CRFs) of pesticides in agricultural soils, there are no studies about the effects of such formulations on the biochemical properties. In this paper the dissipation of diuron and alachlor in three agricultural soils for 127 days, applied either as commercial or CRFs, was determined as well as their concomitant effects on soil biochemical properties. Dehydrogenase, urease, β-glucosidase and phosphatase activities were measured thought the experimental period. The application of alachlor as CRF increases its half-life time in soils, whereas no differences were noticed between diuron formulations due to its slower degradation, which takes longer than its release from the CRF. At the end of the incubation period, the enzymatic activities were the same after the use of diuron either as commercial or CRF, recovering the soil previous status. For alachlor formulations, no differences in enzymatic activities were again observed between both formulations, but their levels in soils were enhanced. Therefore, the use of these CRFs does not adversely affect the soil biochemical properties.

1. Introduction

The application of pesticides is a common agricultural practice that aims at minimizing the economic losses caused by weeds, insects, and pathogens, improving crop yields [1–3]. However, only a certain fraction of the applied pesticide reaches its target, whereas the rest is inactive due to bound to soil colloids, lost by water lixiviation with the subsequent groundwater contamination or is in the soil solution, being degraded by chemical and/or biological processes [4–9]. In recent years various controlled release formulations (CRFs) of herbicides have been developed to provide small amounts of the herbicide to the soil along the time, improving its efficiency and decreasing the risk of groundwater pollution [3,10–15].

The use of clay and surfactant for preparing formulations of herbicides is a very common practice. In the field of CRFs, these formulates have focused mostly on the use of the clay mineral montmorillonite and quaternary ammonium surfactants [16,17]. In recent years new formulations have been developed by encapsulation of the herbicides in the structures formed by surfactants in solution (micelles or vesicles) and the subsequent, adsorption of micelles and vesicles containing the herbicide on montmorillonite. With the development of these new formulations, active substance content can reach high values, and in some cases, very close to those of the commercial products [11,16]. In a variant of these for-

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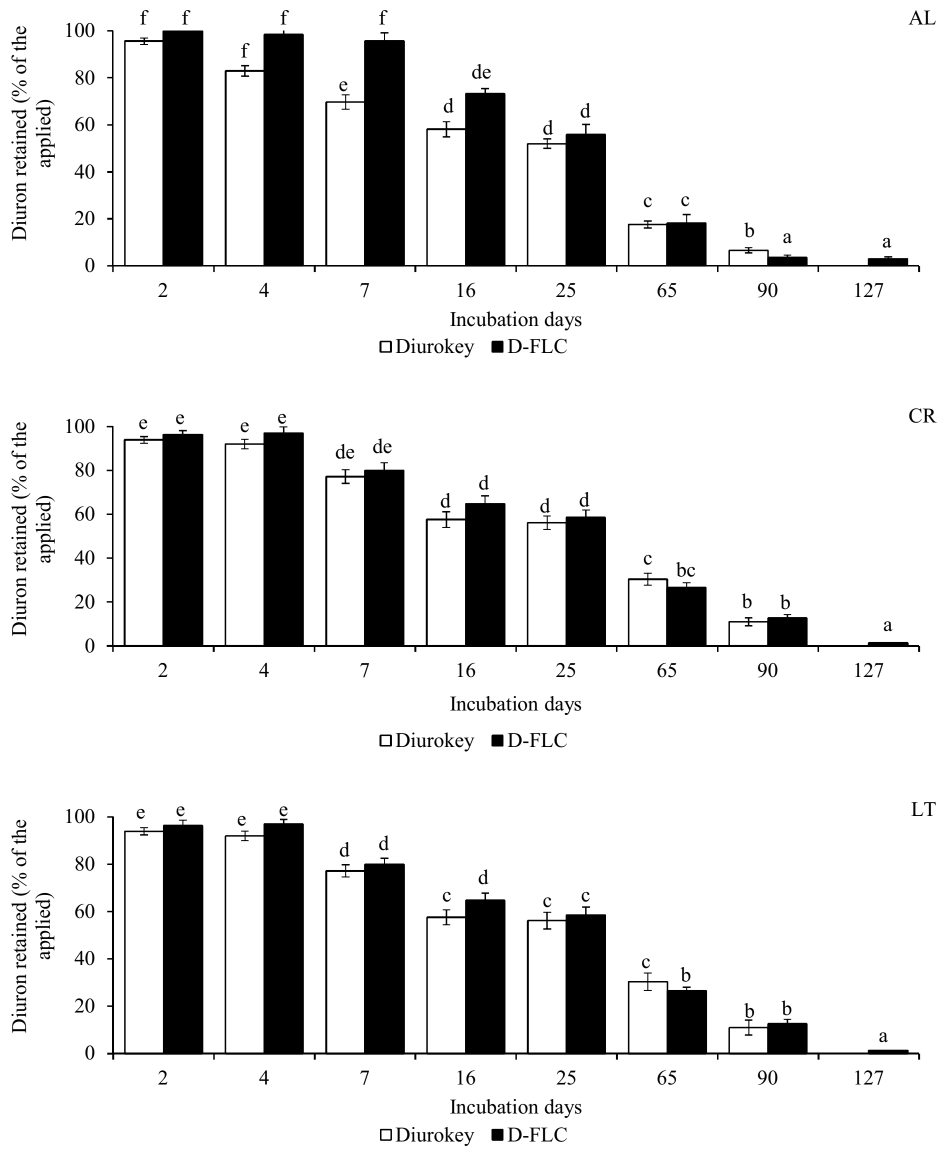

Fig. 1. Diuron dissipation in soils from commercial formulation (Diurokey) and controlled release formulation (D-CRF). Error bars represent the SE of means (n = 2). Column (mean ± SE) followed by the same letter(s) are not significantly different (p > 0.05). AL: dystric Cambisol; CR: calcaric Fluvisol; LT: calcaric Fluvisol.

mulations, quaternary ammonium surfactants that form vesicles and micelles involution have been replaced by the natural surfactant phosphatidylcholine (PC) [14,18–20]. The advantage of these formulations is that the adjuvants used (PC and clay) are nontoxic, indicated by the EPA as approved substances of minimal toxicological risk. These authors showed reduced leaching and enhanced herbicidal activity from these CRFs.

In spite of the growing number of studies in the last decades concerning CRFs, these studies have focused mainly on their preparation and their use for sustained release in the field. As far as we know, there are no studies about the potential toxic effects of CRFs on the soil biochemical properties. The current literature indicates that soil biological factors react faster than physical variables after any chemical change in the soil [21]. Soil enzymatic activities have been suggested as potential indicators of soil use and management because of their relationship to soil biology, and it is generally assumed that the biological properties of soil, such as enzymatic activities, are earlier indicators of soil degradation rather than chemical or physical parameters [22–24].

Dehydrogenase activity is an oxidoreductase enzyme which has been used as a measurement of overall microbial activity [25], since it is an intracellular enzyme related to oxidative phosphorylation processes [26]. Other hydrolytic enzymes involved in the cycling of principal nutrients such as β-glucosidase, urease and phosphate linked to C, N and P, are sensitive indicators of management induced changes in soil properties and provide rapid and accurate information on changes in soil quality [25].

There is abundant information indicating how herbicides influence on the soil biochemical properties. In this regard, several studies have shown that herbicides such as oxyfluorfen, MCPA, glyphosate or diflufenican cause negative effects on the biochemical properties of soils. Therefore, the study of enzyme activities is useful for understanding the potential toxicity of a particular herbicide on soil microorganisms [2,27–30].

Diuron and alachlor are herbicides widely used in order to minimize economic losses caused by weeds, and therefore to retain the current production and yield levels and maintain high quality [31]. Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea) is a substituted urea herbicide not only used to control a wide variety of broad leaf and grassy weeds in many crop cultures but also employed on non-crop areas such as roads, gardens, and railways [32]. Alachlor (2-chloro-*N*-(2,6-diethylphenyl)-*N*-