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Levels of glyphosate in surface waters, sediments and soils associated with direct sowing soybean cultivation in north pampasic region of Argentina

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Glyphosate concentrations in the environment from a region where little information exists about this and intensive cultivation activities predominate in large areas.

Abstract

Levels of glyphosate were determined in water, soil and sediment samples from a transgenic soybean cultivation area located near to tributaries streams of the Pergamino–Arrecifes system in the north of the Province of Buenos Aires, Argentina. Field work took into account both the pesticide application and the rains occurring after applications. The pesticide was analysed by HPLC-UV detection, previous derivatization with 9-fluorenylmethylchloroformate (FMOC-Cl). In addition, SoilFug multimedia model was used to analyse the environmental distribution of the pesticides. In the field, levels of glyphosate in waters ranged from 0.10 to 0.70 mg/L, while in sediments and soils values were between 0.5 and 5.0 mg/Kg. Temporal variation of glyphosate levels depended directly on the time of application and the rain events. The results obtained from the application of the model are in accordance with the values found in the field.

Keywords: Transgenic crops; Glyphosate; Herbicides; Multimedia model; Distribution of contaminants

1. Introduction

Soybean production in Argentina has increased over the last decade, currently with 10 000 000 hectares of sowed area. A total of 95% of this area corresponds to a transgenic variety of glyphosate tolerant soybean, which is cultivated by direct sowing (Pengue, 2005).

Glyphosate (*N*-(phosphonomethyl)glycine) is a broad-spectrum herbicide used to control a wide range of pests and is the active principle in Roundup®, a product widely applied in the regional agriculture practice. Glyphosate itself is an acid, but it is commonly used in salt form, most commonly the isopropylamine salt. It is a polar, highly water soluble substance that makes complexes easily. It binds tightly to the soil particles, reaching a persistence of up to 170 days and an usual half life of 45–60 days (EXTOXNET, 1996; Vereecken, 2005). Its wide use has led to controversy regarding its possible effect on the environment. However, no monitoring studies assessing the possible effects of the pesticide on the ecosystem have been recorded in the region. For this reason, is very

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important to count with methods to determine glyphosate concentration, to carry out the monitoring of this herbicide in the exposed areas. Owing to its physicochemical properties, it is not easy to establish simple methodologies to extract and determine residues of the herbicide. GC or HPLC techniques require the analyte derivatization, either to favour its volatilisation or to improve the UV or fluorecense detection (Sancho et al., 1996; Stalikas and Konidari, 2001; Veiga et al., 2001).

Within the frame of a general study of the pesticide impact assessment associated with the direct sowing, were started studies to develop suitable analysis techniques for the determination of glyphosate residues in environmental samples, and to optimize the application of contaminants distribution models to predict the levels of this herbicide in the same samples for an specific described situation (Camilión et al., 2003; Martin et al., 2003; Marino and Ronco, 2005; Peruzzo et al., 2003).

This paper present a study located in an area belonging to Pergamino–Arrecifes system, Province of Buenos Aires, where the aquatic and terrestrial systems are submitted to a direct influence by the crop. The procedure includes optimization of the methodology for the analysis of glyphosate by HPLC-UV, previous derivatization with FMOC-Cl. Glyphosate contents were determined in water, sediment and soil samples. In addition, with specific information of the studied area, the physicochemical properties of glyphosate, the concentration of the applied pesticide and the rain events, expected concentrations in the environment were estimated with the multimedia model "SoilFug".

2. Materials and methods

2.1. Area of study

Located in the north of the Province of Buenos Aires, this area presents the highest agricultural production in Argentina. The region is known as the "Pampa Ondulada Bonaerense" and is characterized by undulations cut by creeks, gullies, and rivers that originate well drained soils, rich in organic matter (Fidalgo et al., 1975; Camilión et al., 2003). Recent studies indicate a 3% organic matter in surface with a pH 5.5 value. This soil is highly susceptible to hydric erosion and would provide input material to the watercourse. The material accumulates in drag bottoms or is carried directly to the streams. Sediment has higher content of clay than surface soil. Dowstream the water-column lost a significant portion of the colloids. In fact, suspended matter is around 29.4 mg/L and dowstreams it decreases to 20.2 mg/L, and the content of organic carbon in this fractions were between 1.6 mgC/L and 0.6 mgC/L, respectively. A change in the tenor of clay is also observed. These clay particles, which are transported in suspension towards the wetland zone, have greater ability to retain toxic (Camilión et al., 2003; Carriquiriborde et al., 2007).

Sampling sites were selected according to two detail scales:

a) A first-order stream of the Pergamino–Arrecifes system. After flowing through the cultivation area, the water stream forms a wetland. Sampling sites are located as follows: Site 1 (S1), adjacent to the soybean cultivation area; Site 2 (S2), approximately to 150 m downstream from the limit of the cultivation area; and Site 5 (S5), 1.5 Km downstream, at wetland (Fig. 1B).
b) Four surface streams: "Arroyo del Medio" and "Arroyo Ramallo", "Río Arrecifes" and "Río Areco".

Fig. 1 shows the location of the sampling sites in a map of the studied area.

2.2. Sowing event, applications and precipitations

Fig. 2 shows the sowing event and the herbicide applications as well as the precipitations occurring during the studied period. Sowing of soybean (S) was done on 13/12/03; a dose of 1.5 kg/ha glyphosate were applied on 07/01/04 (A1) and a dose of 1.0 kg/ha glyphosate on 21/02/04 (A2). Soybean sowing and herbicide application dates were decided by the field manager, based on the weather conditions. It is important to note that the methodology of application involved sprinkling of the formulation using ground equipment. Precipitation data recorded during the period was provided by INTA (National Institute of Farming Technology)-Estación Experimental Agropecuaria Pergamino (Pergamino Experimental Farming Station).

2.3. Sampling

For the development of the sampling in the first-order stream, the glyphosate applications and the rain events were considered. The first sampling was realized before sowing in order to determine the base level of glyphosate in the field before the agriculture activities (samples SB). Additional sampling were realized after each herbicide application (samples SA) and after the first significant rain event (samples SR) after each glyphosate application. Creeks were periodically surveyed during the study period (samples C), without

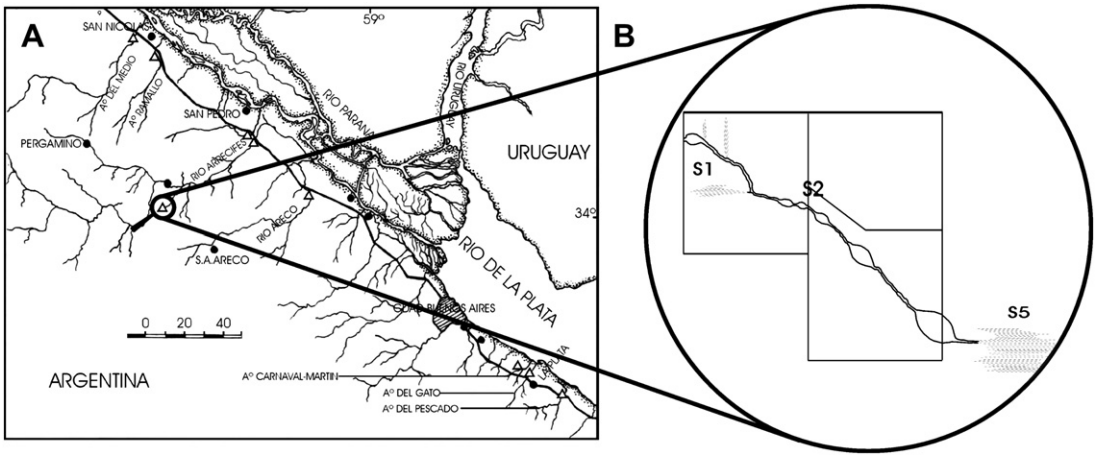

Fig. 1. A) Map of the region: studied area and sampling sites (△); and B) diagram of a first-order stream and sampling sites.