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SIMULATION OF PICLORAM LEACHING IN A BRAZILIAN LATOSSOL USING DRAINAGE LYSIMETER UNDER *Brachiaria decumbens* VEGETATION

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ABSTRACT: This work had the aim to study the leaching of the herbicide picloram in field conditions using a drainage lysimeter under *Brachiaria decumbens* vegetation and also to test the MACRO model to simulate the leaching of this herbicide. The experiment was carried out in the experimental area of the Agricultural Engineering Faculty in the State University of Campinas, in Campinas, São Paulo State, Brazil. The modified drainage lysimeter had 2 m diameter and 3m depth. Soil solution samples were collected in 10 points of 30-cm depth intervals using PVC tubes and were always collected one day after rainfall between October 2006 and March 2007. Quantification of picloram was done using gas chromatography linked to mass spectrometry. Sorption coefficient and degradation rate coefficient at 20°C were also obtained in laboratory. Results have shown that about 455 µg L^{-1} of picloram leached to 30 cm depth after 11 days of application. Picloram did not leach to below 30 cm depth. MACRO model did simulate the concentration peak of picloram after 11 days of application but overall simulated concentrations were underestimated.
KEYWORDS: MACRO, pesticide fate, environmental modeling.

INTRODUCTION: The traditional agriculture has the aim to increase yield levels and thus needs a considerable amount of pesticides (SPADOTTO et al., 2004). Herbicides are the main pesticides used worldwide for all crops. Field evaluations of herbicide behavior are time- and money consuming and the results or conclusions are specifics for the areas where were done. Another important point is that nowadays there is a considerable amount of active ingredients being used in agriculture and that need to be evaluated for environmental risks. However, this evaluation needs a great amount of field experiments to consider many combinations of soil type, climate conditions and active ingredients. To overcome this situation, many pesticide leaching models have been developed during the last two decades and can be classified as deterministic, stochastic, mechanistic, and empiric (WAGENET & HUTSON, 1990). One of the pesticide leaching models that has been used is the MACRO model (LARSBO & JARVIS, 2003). MACRO has been mainly used for situations where macropore flow and preferential transport are dominant processes to be considered. This work had the aim to study the picloram leaching in a drainage lysimeter under *Brachiaria decumbens* vegetation in Campinas, SP, Brazil, and also to test the MACRO model.

METHODOLOGY: The experiment was carried out in the experimental area of the Agricultural Engineering Faculty in the State University of Campinas, in Campinas, São Paulo State, Brazil, in a typical dystrophic Red Latossol with clay texture (EMBRAPA, 1999) cultivated with *Brachiaria decumbens*. The modified drainage lysimeter was adapted from LENG et al. (2000). The lysimeter has one undisturbed soil core with 2 m diameter and 3 m depth. Soil solution samples were collected at 30-cm depth intervals using PVC tubes that conducted soil solution to sampling bottles (Figure 1).

After every rainfall soil solution samples were collected (if possible because of low volumes in some dates) between October 2006 and March 2007. Tordon® was applied at rate of 6 L ha^{-1} being 64 g L^{-1} of picloram and 240 g L^{-1} of 2,4-D (DOW AGROSCIENCES, 2005) in the experimental area on 5 October 2006. The cumulative precipitation during the whole experimental period was 444 mm. All soil solution samples were collected one day after rainfall and kept at -20 °C until analysis. Extraction and quantification of picloram on soil solution samples were carried out by the Environmental Chemistry Laboratory of DOW AGROSCIENCES in Mogi Mirim, SP. Picloram quantification was done by gas chromatography linked to mass spectrometry.

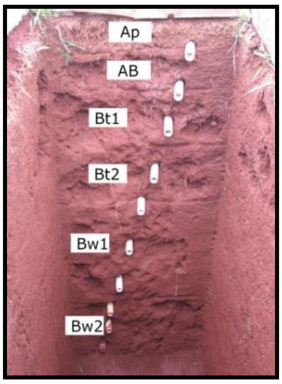

FIGURE 1. Overview of PVC tubes for soil solution sampling at 30-cm depth intervals in a trench outside the lysimeter. Campinas, SP, Brazil.

MACRO is a physically-based, one-dimensional, numerical model that is aimed to simulate the transient water flow and solute transport at the field scale. A full description of MACRO is given by LARSBO & JARVIS (2003). In MACRO, the total porosity in each soil layer is partitioned into micro and macropores. Each of these flow domains is characterized by a degree of saturation, conductivity, and flux. Richards equation is used to calculate the vertical movement of water in the micropores. Soil water retention and unsaturated hydraulic conductivity are described by the van Genuchten and Mualem´s model, respectively. A simplified approach is used to describe the water flow in the macropores assuming a non-capillary, gravity-driven flow. Pesticide transport in the micropores is calculated using the convection-dispersion equation. In the macropores, solute dispersion is neglected because pesticide transport is assumed to be dominated by convection. Pesticide sorption is described using the Freundlich isotherm and degradation by first-order kinetics. The main input parameters used in MACRO are shown in Table 1.

TABLE 1. Main input parameters used in MACRO for simulation of picloram leaching in Campinas, SP, Brazil. The bold names and values mean calibrated parameters.

Parameters	**Depth (cm)**	
	0-18	**18-30**
Saturated water content (%)	73	60
Boundary water content (%)	64	55
Pressure head at the boundary (cm)	10	10
Saturated hydraulic conductivity (mm h^{-1})	469	48
Hydraulic conductivity at the boundary (mm h^{-1})	**0,05**	**0,10**
Aggregated half-width (mm)	**360**	**475**
Degradation rate coefficient (day^{-1})	0,0062	0,0050
van Genuchten parameter n (-)	1,636	1,542
van Genuchten parameter α (cm^{-1})	0,088	0,087
Mixture layer (mm)	1	1

RESULTS AND DISCUSSION: Measured and simulated picloram concentrations in soil solution at 30-cm depth are shown in Figure 1. There was not picloram leaching for depths below 30 cm. In most of the rainfall events the collected soil solution amount was not sufficient for picloram analysis. About 11 days after application, picloram concentration in soil solution at 30-cm depth was 455 µg L^{-1}. Based on piston flow theory (HILLEL, 1998) the expected depth of picloram leaching after 28 mm of rainfall (and considering an average soil moisture content of 0.55 m^{-3} m^{-3}) is 5 cm. So this 455 µg L^{-1} at 30 cm-depth was possible due to a result of preferential transport in the macropore. The average macroporosity in the 30-cm layer of this soil was about 7%. The presence of macropores in soils can enhance the leaching of surface applied pesticides by creating high-conductivity flow pathways, which bypass most of the chemically and biologically reactive topsoil (BOUMA, 1991). Moreover, preferential transport of pesticides can increase the risks of groundwater contamination by pesticides. It has been established that preferential transport of pesticides is an important mechanism for pesticide leaching at the field scale (FLURY, 1996). Picloram concentrations in soil solution at 18, 53, and 55 days after application were 235, 344, and 386 µg L^{-1}, respectively. In general, there was a tendency of picloram concentration peak just after application (11 days) and a decrease in the concentration thereafter. MACRO model did simulate well the concentration peak of picloram after 11 days of application. Considering that this concentration peak is mainly due to preferential transport, the preferential flow model MACRO can be considered adequate to simulate picloram concentration peaks under these conditions. However, MACRO model did not simulate well picloram concentrations after 18 days of application. For all these sampling dates after 18 days of application, MACRO underestimated picloram concentrations and in some dates did simulate the appearance of picloram when we could not collect any soil solution. It is important to mention that the parameters hydraulic conductivity at the boundary and aggregate half-width were calibrated using the SUFI tool, which is linked to MACRO. So this simulation was only possible after a careful calibration procedure. These two calibrated parameters do show the need of a highly non-equilibrium condition to simulate the picloram concentration peak after 11 days of application. We do believe that calibration could improve the simulation if more measured data were available.

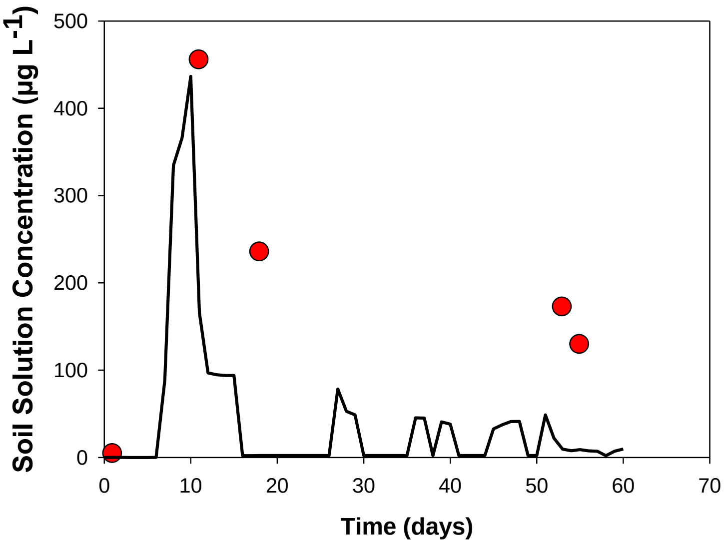

FIGURE 2. Measured (red points) and simulated (black solid line) soil solution concentrations of picloram in a drainage lysimeter at 30-cm depth in Campinas, SP, Brazil.

CONCLUSION: MACRO model was able to simulate picloram concentration peak just after application and after using a careful calibration procedure. Therefore, MACRO can be a promise tool to evaluate pesticide leaching risks in Brazilian areas where preferential transport of pesticides is an important process.

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