Herbicide leaching from maize fields as affected by weed control strategy

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The risk of groundwater contamination from herbicides is affected by several factors including chemical properties of the substance, the soil characteristics, and other climatic environmental aspects. Few studies have investigated the effect of herbicide application timing (pre-emergence vs post-emergence), and the interaction with mechanical intervention carried out after planting (eg. hoeing and ridging).

The study was aimed at assessing the leaching of terbuthylazine (TBA), its main metabolite desethyl-terbuthylazine (DTA) and S-metolachlor (MET), as affected by the different time of herbicide application (pre-emergence/post-emergence) associated or not with mechanical intervention (hoeing/ridging). The study was carried out in 2010 on twelve plots cultivated with maize located in Northern Italy. Each plot, of about 425 m^2 (5x85 m), was fitted with a subsurface drainage system operating from 2005. The drainage system is formed by three drainage lines, spaced 2 m apart and buried at 1.2 m, which end into a common manhole. The following treatment were compared according to a RCBD with three replications: A) pre-emergence application of terbuthylazine (750 $g_{a.s.}$/ha) + S-metolachlor (1250 $g_{a.s.}$/ha); B) pre-emergence application of terbuthylazine (750 $g_{a.s.}$/ha) + S-metolachlor (1250 $g_{a.s.}$/ha) followed by hoeing/ridging; C) early post-emergence application (crop at 2-leaf stage) of terbuthylazine (657 $g_{a.s.}$/ha) + S-metolachlor, (1094 $g_{a.s.}$/ha); D) control plots where weeds were controlled with other herbicides (flufenacet, at 1714 $g_{a.s.}$/ha, + isoxaflutole, at 206 ga.s./ha). Pre-emergence and post-emergence treatments were carried out on April 22 and May 11, respectively. All the plots had a common history of TBA and MET application from 2005 to 2009. After each drainage event (rains or irrigations), samples of water were collected from the manholes and TBA, DTA and MET content was determined by HPLC, adopting a methodology with a detection limit of 0.05 µg/L.

The presence of the chemicals studied was assessed also in the groundwater, by considering samples collected using a phreatimeter installed on the hedge of the field. Over the season, the underground water table ranged from 5 to 2 m.

From May 6 to May 8, continuous rains determined a series of leaching events. The first event of the series occurred 6 days after pre-emergence herbicide application and caused a strong movement of the substances trough the soil profile. Important concentrations of TBA (36.28 µg/L), DTA (4.27 µg/L) and MET (47.84 µg/L), were detected in leaching waters from treatments A and B. In the following events, concentrations detected in leached waters from pre-emergence treated plots initially decreased (at 7 days after treatment) and then peaked (8 days after treatment) to 75.60 µg/L (TBA), 7.44 (DTA) µg/L, and 96.79 µg/L (MET). TBA, DTA and MET were found also in leached waters from treatments C and D, probably as residues from previous growing seasons. In addition, the high rainfall intensity caused a partial flood of the experimental site, resulting in erratic runoff from treated plots to the adjoining untreated plots. A storm occurred 12 hours after post-emergence treatment determined a huge event of leaching. The highest amounts of TBA (145.77 µg/L), DTA (7.35 µg/L) and MET (142.08 µg/L) were detected in treatment C), while the values were roughly halved from treatments A) and B). On June 16, 48 days after pre-emergence treatment and 36 days after post-emergence applications, the highest concentrations of TBA and MET were found in treatments A) and B). DTA concentrations were 1.35 µg/L (treatment A), 1.47 µg/L (treatment B) and 1.24 µg/L (treatment C). As observed in the previous events, TBA, DTA and MET were detected also in control plots. At 107 days from pre-emergence application (last sampling), leachates were obtained only from A) and B) treatments. TBA and MET concentrations in treatment A) were 0.86 µg/L and 1.42 µg/L, respectively. In treatment C), TBA concentration was 0.05 µg/L, while MET was below the detection limit. In both A) and C), DTA never exceeded 0.5 µg/L. Unfortunately, no important events of leaching occurred early after ridging, thus it had not been possible to see clear differences among treatments A) and B). During the season, TBA, DTA and MET were frequently found in the water table over the season. The highest presence of the chemicals in the water was recorded (TBA, 1.38 µg/L; DTA, 1.71 µg/L; MET, 2.91 µg/L). On May 20, TBA, DTA and MET concentrations found in the water table were 1.18 µg/L, 2.11 µg/L and 3.52 µg/L, respectively. On June 3 TBA and DTA were detected at 2.66 µg/L and 1.49 µg/L, respectively, while MET was below the detection limit. On August 6, all chemicals were below the detection limits.

TBA, DTA and MET showed to easily move through the soil, and potentially reach ground waters. Risk of water contamination is particularly high when rainfalls or irrigations occur close to herbicide application. In this study, important rains occurred in the first days after pre-emergence application and 12 hours after post emergence application of herbicides. As a consequence, concentrations of chemicals detected in the leached waters were high, particularly in waters leached from post-emergence treated plots. The very short duration of interaction between chemicals and soil matrix, may have led to a reduced adsorption of TBA, DTA and MET, determining a more important movement of them trough the soil profile. In general, TBA resulted longer detectable in the leached waters than MET. This is probably related to the fast degradation of MET. DTA concentrations were particularly high at the first events of leaching. At the last samplings DTA concentrations in leached waters did not differ greatly between treatments.

TBA, DTA and MET, were present in water table before the herbicide treatments, indicating a previous contamination, likely due to other treatments carried out in the adjacent areas. MET resulted more present in the water than TBA, but for a shorter period of time. Maximum concentrations of MET were in effect found in April and May. Higher soil persistence of TBA, may have extended the release of this chemical in the water.
TBA, DTA and MET may reach ground water. Rainfall close to herbicide application may lead to a stronger transport of these herbicides trough the soil. The interaction with hoeing/ridging needs further studies. Water table showed to be vulnerable to leaching of the chemicals studied.

KEY WORDS: Leaching, terbuthylazine, desethyl-terbuthylazine, S-metolachlor, Pre-emergence, Post-emergence

Acknowledgements

This study was financially supported by the Agricultural Department of the Regione Piemonte.