Herbicide Mobility During Initial Infiltration Events

D. E. Radcliffe, S. C. Chiang, and J. A. Tindall[1]

Introduction

In an earlier field study comparing herbicide mobility in conventional tillage *(CT)* and no-tillage (NT), all of the downward movement of two herbicides occurred in the first infiltration event (Radcliffe et al., 1989). The herbicides in the previous study were metribuzin (4-amino-6-(l,l-dimethylethyl)-3-(methylthio)-l,2,4-triazin-5(4H)-one) and alachlor (2-chloro-N-(2,6-diethylpheny1)-N-methoxymethylacetamide). In the spring of 1987 and 1988, straw from the previous winter wheat crop was removed, tillage treatments were established (main plots), and herbicides applications were made. To one half of each main plot, straw was returned to the surface after herbicide application. Plots were further subdivided into a heavy (1.4 inch per week) and light (0.7 inch per week) irrigation treatment. No crops were planted and water was applied to the plots for 6 weeks. Soil cores for herbicide analysis were taken to a depth of 60 cm on four dates during this period. At the first sampling date (5 and 7 days after application in 1987 and 1988, respectively) alachlor moved to an average maximum depth of 2.7 inches and metribuzin to a depth of 5.0 inches. No further downward movement occurred after the first sampling date. The depth of initial movement was affected by treatments in that heavy irrigation, straw cover, and no-tillage favored slightly deeper movement. These are the treatments that should have had deeper movement of the initial infiltration event water due to greater water application (heavy irrigation), higher initial water content (straw cover), or more continuous large pores (no-tillage).

The results of the above experiment implied that herbicide mobility was relatively high during the initial infiltration event, but once water stopped flowing, irreversible adsorption took place. The purpose of this study was to test this concept under more controlled laboratory conditions.

Material and Methods

The herbicide used in this study was atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine), a compound that is similar to metribuzin and considered to be mobile in soils (Jury et al., 1987). Columns 14 inches in length were constructed by cementing together 9 plexiglass cylindrical sections 1.55 inches in height and 2.72 inches in diameter. The columns were packed with air-dry, sieved Worsham sandy loam soil (clayey, mixed thermic family of the Typic Ochraquults) to a depth of 11.4 inches. The soil contained 14.1% clay, 19.2% silt, 66.7% sand, and 0.8% organic carbon. Water content of the air-dry soil was 0.1% by weight.

Atrazine was added to the surface of the soil at a rate of 2 Ib ai per acre in a mixture with methanol and deionized water using a small mist applicator. Two treatments were imposed that differed in the amount of water added to the column immediately after herbicide application: in the small-event treatment, 0.1 pore volume of water was added and in the large-event treatment, 1.0 pore volume was added. The columns were allowed to sit overnight and the following day 1.4 and 0.5 pore volumes of water were added to the small-event and large-event columns so that the total amount of water added to the two treatments was the same. The experiment was repeated three times.

After each experiment, the columns were disassembled into 1.55 inch sections and the soil air-dried. A 0.7 oz sample of soil was taken from each depth increment and combined with 1.4 oz of 90% methanol and 10% water, shaken for 2 hours, and centrifuged. The supernatant was collected, filtered and analyzed on a high performance liquid chromatograph (HPLC).

The experimental design was a randomized complete block with strip subplots. Each repetition of the experiment over time was considered a block with the small-event and large-event columns as main plots. Soil column depth was considered a strip subplot, as opposed to a split subplot, in that depths could not be randomized. The overall error was used to test for an interaction between depth and treatment and since this was significant, an LSD was computed to test differences between treatment concentrations at each depth.

[1]**Department of Agronomy, The University of Georgia, Athens, GA 30603.**

Results

Although the total amount of water added to the columns in two days was the same in both treatments, mean atrazine distribution in the soil differed (Fig. 1). More atrazine moved to deeper depths when most of the water was applied in the initial event (large-event treatment), compared to when most of the water was applied on the second day (small-event treatment). In the small-event treatment, the greatest adsorption occurred in the top 2 inches of soil. In the large-event treatment, adsorption was nearly uniform to a depth of 9 inches.

These results imply that for a significant fraction of the atrazine, adsorption and desorption take time. Maximum adsorption took place near the surface in the small-event treatment because the atrazine "pulse" resided at a shallow depth in the 24 hour interval between the initial and subsequent events. Water added on the second day moved atrazine to the bottom of the column but did not remove the peak in the top 2 inches because there was not enough time for the atrazine to desorb after the pulse moved deeper.

This pattern of mobility can be attributed to either one of two types of adsorption kinetics that have been proposed: (1) adsorption takes time because an activation energy is required or, (2) adsorption takes time *because* water in the smaller soil pores is immobile and, to reach the adsorption sites in these pores, chemicals must move throught the immobile water by diffusion which is a slow process compared to mass flow in the larger pores (Pignatello, 1989). Desorption may not occur readily because of irreversible adsorption (Clay et al., 1988) or due to time that it takes for the chemical to diffuse out of immobile water regions.

The results are consistent with our field observations that all of the movement of alachlor and metribuzin seemed to occur in the first 5 to 7 days and that this initial movement was greater in NT than CT (Radcliffe et al. 1988). The pulse of herbicide probably moved deeper with the first irrigation in NT than in CT because of more continuous large pores and wetter soil in NT. In the one week interval before the next irrigation event, adsorption of the "slow" fraction occurred and subsequent infiltration events did not cause desorption. Since we did not observe any movement after the initial event in the field, it appears that more of the herbicide was in the "slow" fraction under field compared to laboratory conditions. This could be due to a greater proportion of immobile water in the undisturbed soil compared to the packed columns.

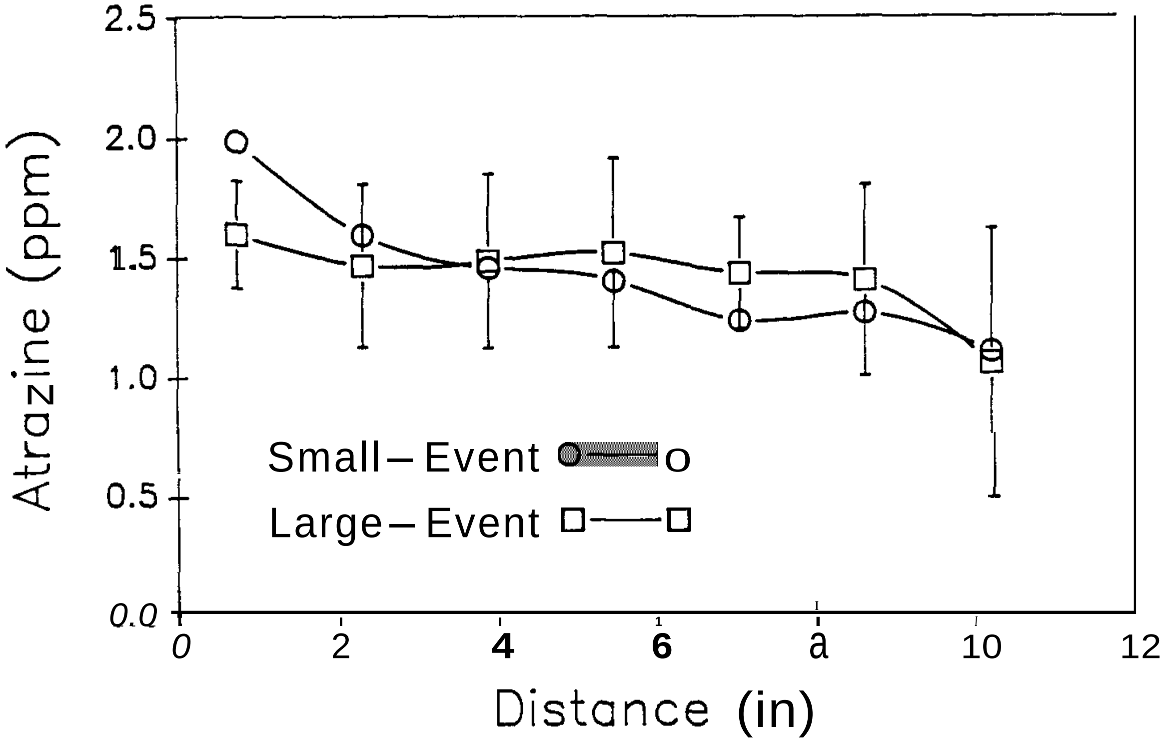

Figure 1. Mean atrazine concentration as a function of soil depth in the small-event and large event treatments. Error bars for signiIicant differences at the 0.05 level are shown.

Conclusions

Mobility of some herbicides appears to be greatest during the initial infiltration event. If a rain or irrigation occurs shortly after application or if a herbicide is added by chemigation, deeper movement can be expected. Adsorption of a significant faction of the herbicides appears to take time and does not occur when water is moving through the soil. This fraction will be likely to move deeper in NT compared to CT systems because water flow will be more rapid in the large continuous pores in NT. Once the water stops moving, however, adsorption takes place and may be irreversible.

References

Clay, S. A, R. R. Allmaras, W. C. Koskinen, and D. L. Wyse. 1988. Desorption of atrazine and cyanazine from soil. J. Environ. Qual. 17:719-723.

Jury, W. A, A. M. Winer, W. F. Spencer, and D. D. Focht. 1987. Transport and transformations of organic chemicals in the soil-air-water ecosystem. Rev. Environ. Contam. Toxicol. 99:120-164.

Pignatello, J. J. 1989. Sorption dynamics of organic compounds in soils and sediments. B.L. Sawhney and K. Brown (ed.) **in** Reactions and movement of organic chemicals in soils. American Society of Agronomy. Madison WI.

Radcliffe, D. E., R. E. Jones, and P. A. Banks. 1989. Herbicide movement in conventional and reduced tillage soils. Proceedings Georgia Water Resources Conference. May 16-17. Athens. University of Georgia. Athens, GA 30603.