AGRICHEMICAL TRANSPORT IN CORN ON FRAGIPAN SOILS IN NORTHERN MISSISSIPPI

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INTRODUCTION

Pesticides move from agricultural fields to surface waters mainly in runoff (both in solution and sorbed to eroded sediment). The most commonly detected pesticides in surface waters are herbicides, including atrazine, alachlor, cyanazine, metolachlor, metribuzin, and simazine (Chrisensen et al. 1993). Several studies have shown that these herbicides are lost from fields primarily in the water phase of runoff (Felsot et al. 1990; Hall et al. 1983; Smith and Cullum 1992; Smith 1993). Ninety percent of the samples collected from Midwestern rivers and streams after the first spring runoff in 1989 contained detectable levels of herbicides (Thurman et al. 1991). Wauchope (1978) reported that edge-of-field runoff losses for most commercial pesticides are 0.5% or less of that applied, except when severe rainfall occurs within 1-2 weeks after application. Other exceptions are the persistent organochlorines, which lose about 1% of the applied amount regardless of weather and surface-applied, easily-washed-off, wettable-powder herbicides, which may lose up to 5% of that applied (Wauchope 1978).

Efforts to control soil erosion and associated sedimentation problems in aquatic ecosystems surrounding agricultural lands has lead to increased adoption of no-till (NT) and other reduced-till (RT) practices in this region. However, NT and RT practices often require an increased use of herbicides to control weeds that are usually controlled by conventional tillage (CT). Also, increased infiltration generally associated with conservation tillage needs evaluation to determine the potential increase of contamination of our Nation's ground water with agrichemicals. The main objective of this study was to evaluate agrichemical transport and losses in runoff and shallow ground water from corn grown under different tillage practices in northern Mississippi to assist in development of better conservation tillage systems and agrichemical application practices.

METHODS

Agrichemical transport and losses were evaluated in corn systems on loessial fragipan soils in the uplands of northern Mississippi during a four year period (1990-1994). Pesticides and nutrients were measured in runoff and shallow (< 3 m) ground water from NT, CT, and RT corn plots in loessial deposits. Descriptions of the tillage practices were: (1) NT of plant (seed was slot planted using bubble coulters and double-disk openers), no row cultivation, harvest, and shred stalks, (2) RT of plant no-till, row cultivation twice during May, harvest, and shred stalks, and (3) CT of plant following chisel/disk preparation, row cultivation twice during May, harvest, and shred stalks. Nitrates, atrazine (aatrex or 2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine), alachlor (lasso or 2-chloro-2',6'-diethyl-*N*-methoxymethylace-tanilide), cyanazine (bladex or [2-(4-chloro-6-ethylamino-1,3,5-triazin-2-ylamino)-2-methylpropionitrile]), chlorpy- rifos (lorsban or *O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate), and tefluthrin (force or 2,3,5,6-tetrafluoro-4-methylbenzyl(1*R*,3*R*:1*S*,3*S*)-3-[(*Z*)-2-chloro-3,3,3-trifluoroprop-1-enyl]-2,2-dimethylcyclopropane-carboxylate) were the primary chemicals studied. Amounts and quality of surface runoff and subsurface drainage at top surface of fragipan layer also were determined.

Main components for shallow ground water evaluations at the Mississippi Agricultural and Forestry Experiment Station at Holly Springs included six hydrologically-isolated continuous corn plots (8.1-m wide by 38.1-m long) with subsurface drains (installed by horizontal drilling) placed on the fragipan surface; drain outlets into sumps equipped with tipping buckets mounted in 18.9-L containers; composite water samplers; dataloggers for data collection and control; and a series of observation wells ranging from 30-cm to 3-m depths positioned in one row of each main corn plot. Further description of and methodology can be found in Cullum et al. (1992). The dataloggers recorded ground water discharge by counting the tipping buckets during storm events and activated the water samplers when the cumulative discharge equaled 250 mm. Ground water incremental discharge and total discharge were recorded and the composite of the weighted-discharge samples were analyzed for specific chemicals introduced as fertilizer or pesticides. Also, water samples were collected for chemical analysis from the observation wells after depth measurements were made following major storm events.

Main components for surface runoff from subplots (4-m wide by 22-m long) within the above corn plots included properly-sized collectors, approaches, and H-flumes equipped with portable liquid-level recorders and potentiometers, runoff splitters, dataloggers, and composite water samplers (described by Cullum et al. 1992). The dataloggers recorded rainfall and runoff every minute during storm events. Water samplers were activated by the dataloggers when cumulative discharge equalled or exceeded one millimeter. Derived variables from surface runoff were incremental discharge rate, cumulative discharge, sediment loads, and water quality.

Soil water contents were evaluated for each tillage system by using time domain reflectometry (TDR). Four sets of buriable wave guides were inserted into the soil spaced 90 cm apart in one corn row of each of the six plots at depths of 0 to 10 cm, 0 to 20 cm, 20 to 40 cm and 40 to 60 cm. The 24 implanted soil probes (buriable wave guides) were connected into the multiplex port of the TDR unit. This port provided a switch to control the sequencing through the attached wave guides. Software within the TDR unit was used to program the start of sequencing through each wave guide for soil water determinations, the time interval between readings, and the total number of readings taken. The TDR unit was programmed to obtain dielectric constants and soil water contents from each probe on a 12-hr interval each day during the 1993 water year (Oct 1, 1992 to Sept 30, 1993). Periodic transfer of data occurred by linking the serial ports of the TDR unit and laptop computer for further interrogation.

RESULTS

Total runoff as percentage of total rainfall for the NT, RT, and CT systems was 56, 27, and 62 for 1991; 14, 29, and 38 for 1992; 14, 19, and 38 for 1993; and 12, 16, and 56 for 1994. The 92 water year produced approximately 30% greater sediment losses in the CT treatment than the NT treatment. Most differences occurred with first rains after planting when CT treatment was most exposed because of least amounts of residues. These trends were exhibited again in 1993 and 1994.

Water movement was insignificant above the fragipan's surface during each cropping season for all tillage systems. Free water was often perched above the fragipan intermittently from November through April during periods of soil profile saturation and is suspected to move down-slope across the fragipan's surface. Upon inspection of the mean soil water contents from the time domain reflectometry measurements, the deeper wave guides were showing wetter soils for each date probably due to the influence of the fragipan layer that underlies this area. NT soil water contents generally were higher than CT at the 0 to 10 cm and 0 to 20 cm profiles (Figure 1) because of the cooler soils and greater amounts of residue cover under the no-till. The relatively high readings of 35% to 40% for soil water content also showed that the soil profiles were near saturation. There were no significant differences among the tillage treatments on mean soil water content for this period of time.

Tillage practices had limited effect on concentration of nutrients in ground water. Shallow ground water (<3m) NO_3-N concentrations were essentially the same for either NT or CT and were usually less than the drinking water quality standard of 10 ppm as shown in Figures 2 and 3. Leaching of crop residues and the lack of sediment resulted in higher soluble nutrient concentrations in surface runoff under NT conditions throughout the study period. Surface and shallow ground water NO_3-N concentrations increased following spring broadcast of ammonium nitrate but decreased in subsequent storms to pre-fertilization concentrations. This was more noticeable under CT.

Results from the 1993 crop year (planting through harvest) showed that all five pesticides applied to the corn plots appeared in both the water and sediment phases of runoff. Total crop year runoff from NT and RT corn was 64 ± 9 and 75 ± 7 mm, respectively, whereas that from CT corn was about 3 times greater at 206 ± 13 mm. This likely resulted from higher crop residue levels on the surface in the NT and RT plots compared to the CT plots. The higher surface residue levels in NT and RT systems reduced runoff by reducing surface sealing and maintaining higher infiltration rates. Consequently, pesticide losses in the water phase of runoff from the three tillage treatments followed the order CT>RT>NT as displayed in Figure 4. As a pesticide class, herbicide losses in the water phase of runoff were higher than insecticide losses, primarily due to the herbicides' higher water solubilities. Of the herbicides, however, atrazine losses were greater than those of alachlor and cyanazine. Even though atrazine's water solubility is less than that of alachlor and cyanazine, its half-life is about 4 times longer. Atrazine concentrations in the ground water in the observation wells at the 3-m depth are shown in Figure 5. During the crop year, five ground water-producing rainfall events occurred after atrazine application (i.e., 2, 14, 21, 29, 167 days after application). During the first three weeks after application, atrazine concentrations for all three tillage treatments were about the same, averaging about 16, 18, and 20 $\mu g\ L^{-1}$ (ppb) for the NT, RT, and CT treatments, respectively. However, 29 days after application, atrazine concentrations reached their highest levels in the NT and RT treatments (94 and 54 ppb) and were about 6 and 3 times the concentration in the CT treatment (16 ppb), indicating increased infiltration in the NT and RT treatments. The last ground water-producing rainfall event during the crop year (167 days after application) resulted in ground water only in the NT treatment with atrazine at very low concentrations (5 ppb).

SUMMARY

The importance of rainfall timing relative to agrichemical application was emphasized. Amount and distribution of rainfall, rather than tillage system, were found to be the most common factor in influencing agrichemical movement from the corn systems for this study area. Annual mean nitrate concentrations in shallow ground water for all corn tillage systems were below the EPA maximum allowable drinking water quality standard of 10 ppm. Tillage differences in the study apparently do not affect the mean concentrations of plant nutrients in shallow ground water. Water movement was insignificant at fragipan's surface during cropping season for all tillage systems. NT had higher soil water content in root zone for longer periods during cropping season compared to CT. Atrazine, alachlor, cyanazine, chlorpyrifos, and tefluthrin used in corn were found in both water and sediment phases of the first runoff after application, and the three herbicides appeared in first shallow ground water of first major storm event after application. NT and RT reduced runoff losses of herbicides but increased their infiltration.

All programs and services of the U. S. Department of Agriculture are offered on a nondiscriminatory basis without regard to race, color, national origin, religion, sex, marital status, or handicap. Mention of a pesticide in this paper does not constitute a recommendation for use by the U. S. Department of Agriculture nor does it imply registration under FIFRA as amended. Names of commercial products are included for the benefit of the reader and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.

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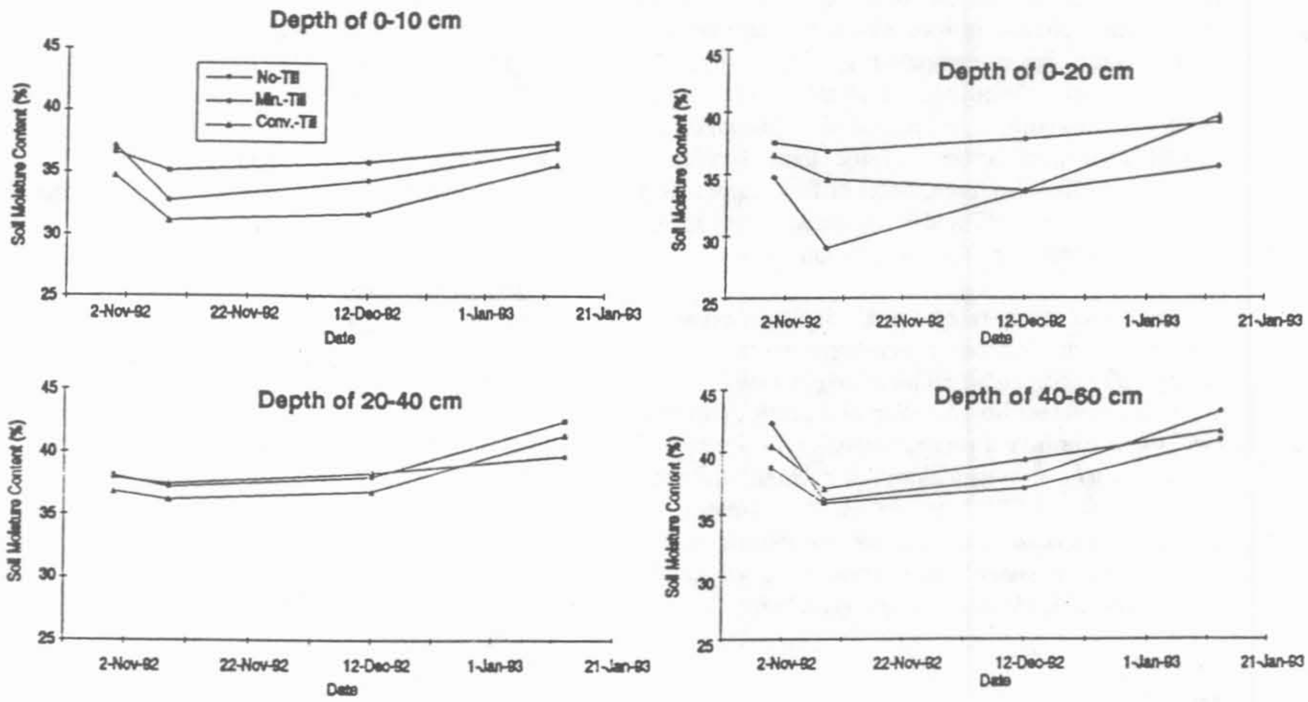

Figure 1. Mean soil water content for the three tillage operations at four depths in the corn experiment during the winter of 1992. (Min.-Till is the same as Reduced Till).

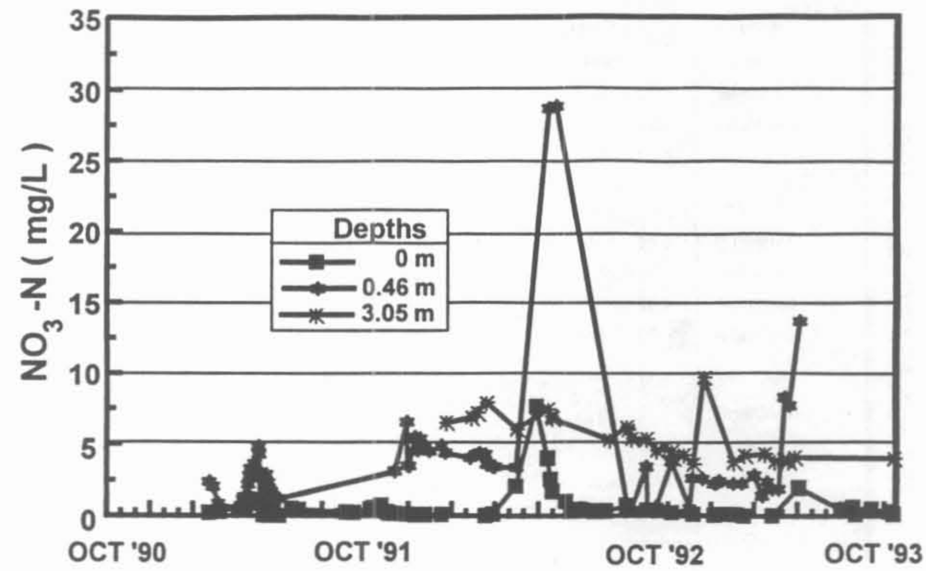

Figure 2. Seasonal variations in ground water nitrates under no-till corn for 1991 to 1993 water years.

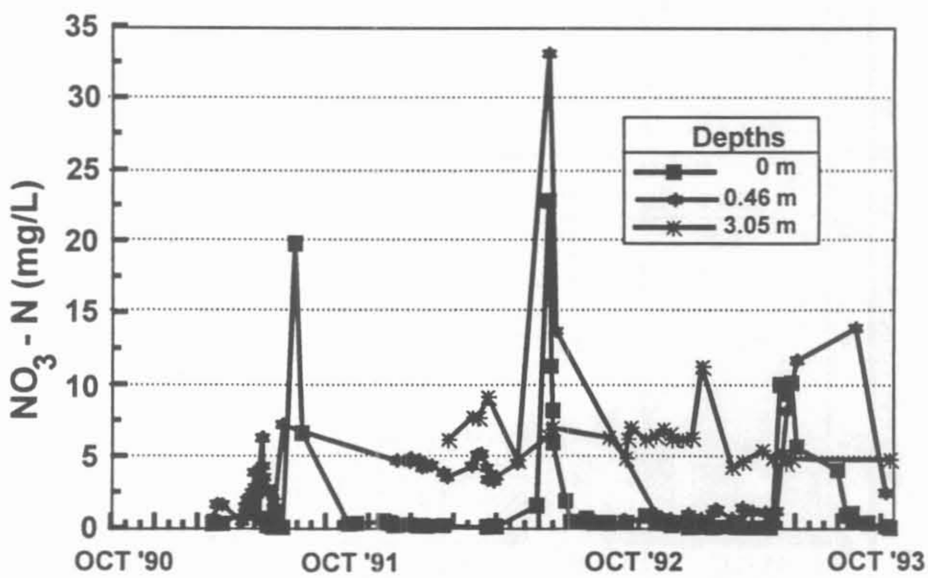

Figure 3. Seasonal variations in ground water nitrates under conventional-till corn for the 1991 to 1993 water years.

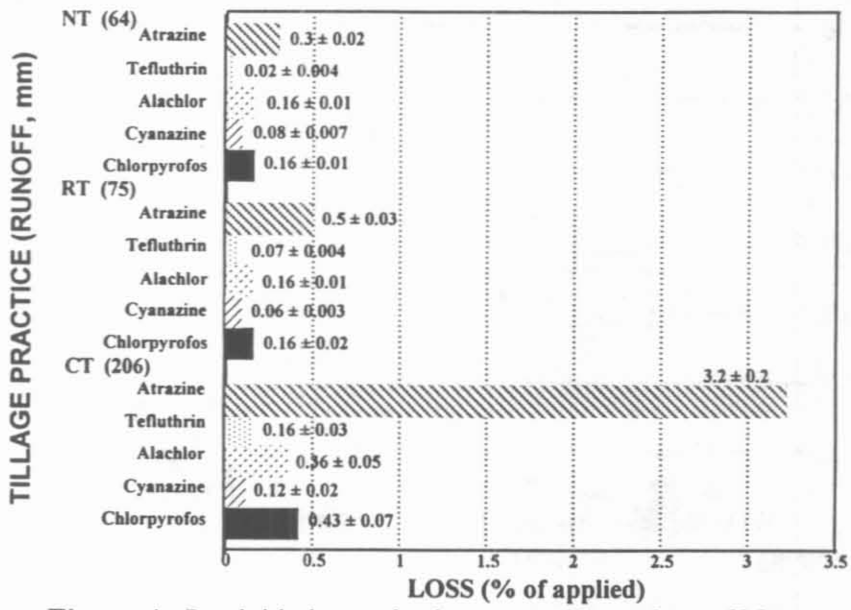

Figure 4. Pesticide losses in the water phase of runoff from the three tillage treatments (no-till=NT; reduced-till=RT; and conventional-till=CT).

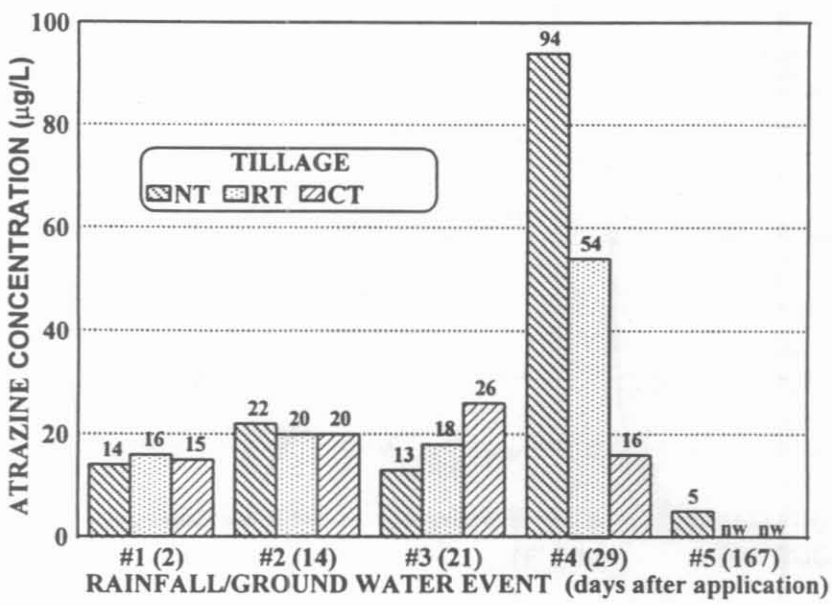

Figure 5. Atrazine concentrations in ground water in the observation wells at the 3-m depth.