CONTROLLED WATER-TABLE DEPTH TO IMPROVE WATER QUALITY

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INTRODUCTION

Pesticide and plant nutrient (especially nitrogen and phosphorus) contamination of surface and subsurface water resources has become a national concern that needs timely and rational solution. Despite considerable interest in efforts to reduce agrochemical utilization and to develop "sustainable" agriculture, some use of agrochemicals will probably continue into the foreseeable future. The anticipated continued need for agrochemical use requires that cultural practices and farming methods be developed that reduce the potential for agrochemical impairment of water resources.

An estimated 25% of the total U.S. cropland needs drainage (USDA 1987). Typically, much of this land is relatively flat, highly fertile, and has no serious erosion problems. These potentially productive wet soils are primarily located in the prairie and level uplands of the Midwest, the bottom lands of the Mississippi Valley, the bottom lands of the Piedmont and hill areas of the South, the coastal plains of the East and South, and irrigated areas of the West (Schwab et al. 1981). During most or part of the year, these soils have shallow water tables that are potential sinks for pesticides that may leach below the root zone.

Pesticides and fertilizers are used extensively in the lower Mississippi River Valley, the agriculturally important Mississippi River flood plain in Arkansas, Mississippi, and Louisiana commonly referred to as the "Delta" (Figure 1). Although large quantities of water flow down the Mississippi River, most fresh water supplies for domestic and agricultural use come from the Mississippi River alluvial aquifer, which underlies the Delta. The Mississippi River alluvium is generally less than 70 m thick and grades downward from silt and clay at the surface to coarse sand and gravel at the base (Whitfield 1975; Morgan 1961; Poole 1961). The thickness of the overlying silt and clay is generally less than 12 m. Rainfall, ranging from 1150 to 1500 mm annually, is the major source of recharge for the aquifer (Dial and Kilburn 1980; Whitfield 1975). The amount of recharge depends not only on the amount and rate of precipitation, but also on the permeability and thickness of the overlying silt and clay. These deposits are relatively permeable compared to typical clay because of their high content of organic material and because they have not been fully consolidated by heavy overburden (Whitfield 1975).

Water levels in the Delta generally are less than 9 m below the soil surface and are much closer to the surface during wet periods. These shallow water tables fluctuate considerably and respond mainly to rainfall. Because of the level terrain and high rainfall in the Delta, there is an abundance of streams, lakes, and wetlands. The existing conditions in the Delta (shallow water tables, nearby wetlands, high agrochemical use, and high rainfall) embody those that suggest a high potential for surface water and groundwater pollution. There have been several reported findings of agrochemicals in Delta surface and subsurface waters (Acrement et al. 1989; Calhoun 1988; Cavalier and Lavy 1987; Whitfield 1975; Cormier et al. 1990a; Cormier et al. 1990b; Demcheck and Leone 1983; Stuart and Demas 1990).

Management of water table depths may be a means for decreasing amounts of agrochemicals lost from alluvial soils via surface runoff and leaching. For example, if rain appeared imminent soon after pesticide or fertilizer application to the soil surface, the water table could be lowered to enhance infiltration and increase within-soil storage capacity, thereby decreasing runoff loss. Alternatively, if the pesticide and/or fertilizer were already incorporated into the soil surface, the water table could be maintained at some elevation above a subsurface drain line to retard agrochemical leaching below the root zone and thereby retain the chemical in the biologically active root zone longer for utilization or degradation.

This paper presents first-year results from a study of the effectiveness of a water management system that uses subdrainage and subirrigation to control water levels for the purpose of reducing agrochemical loss from agricultural land.

MATERIALS AND METHODS

The study is being conducted on sixteen 0.21-ha plots instrumented for automatic, microprocessor-controlled measurement and sampling of surface runoff and subsurface drain outflow, and water table management. The plots are on a Commerce silt loam soil (fine-silty, mixed, nonacid, thermic, Aeric Fluvaquents) located on the Louisiana Agricultural Experiment Station's Ben Hur Research Farm near Baton Rouge, Louisiana. A brief description of the experimental setup follows; for a more detailed description see the paper by Fouss et al. (this Proceedings).

Four replications of four water-table management treatments were imposed on the plots. The treatments were:

1. Surface drainage only (SUR)

2. Conventional subsurface drainage at 1.2 m or more below the soil surface (DRN)

3. Controlled water table depth at a 45-cm depth (CWT-45)

4. Controlled water table depth at a 75-cm depth (CWT-75)

Each plot was hydraulically isolated from the surrounding areas by means of 20- to 30-cm high levies and vertical plastic sheeting that extended downward from 30 cm below the soil surface to 2 m below the soil surface (Figure 2). The levies and plastic barriers were continuous around the perimeter of each plot. Each plot had three 10-cm-diameter subsurface drain lines at 1.2 m below the soil surface (the drain lines were plugged on the SUR plots). The drain lines were connected to sumps where drain effluent was automatically measured, sampled (refrigerated storage), and pumped into a large drainage conduit to a gravity outlet. The sumps also served as a distribution point for water to be pumped back into the drain lines (i.e., subirrigation) to maintain water table depths for CWT-45 and CWT-75. Each plot was also equipped with a 46-cm H-flume and automated runoff measuring and sampling (refrigerated storage) equipment.

The plots were planted to corn (*Zea mays* L.) on May 25, 1994, and atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine) and metolachlor [2-chloro-6′-ethyl-*N*-(2-methoxy-1-methylethyl)acet-*o*-toluidide] were applied immediately at respective rates of 1.50 and 1.94 kg/ha. The water table treatments were imposed and all subsequent runoff and drain line effluent were measured and sampled. Corn planting was late because extended wet weather throughout much of April and May resulted in fields too wet for tillage and planting operations.

RESULTS AND DISCUSSION

Rainfall amounts and respective associated atrazine and metolachlor losses in runoff and subsurface drain effluent during the first 18 days after herbicide application are given in Tables 1 and 2. No runoff occurred during the first 8 days, even though 39.9 mm of rain fell during that period. A light rain (following six consecutive days of showers) caused a minor runoff event 9 days after herbicide application. Runoff occurred only from the SUR plots. Apparently, the soil in the SUR plots was saturated, resulting in runoff from even a small amount of rain. Atrazine concentrations in the runoff were in the 140 to 170 $\mu g\ L^{-1}$ range, while metolachlor concentrations were in the 80 to 90 $\mu g\ L^{-1}$ range (data not shown). Runoff volumes were very low, so only trace amounts of either herbicide were lost in runoff. The lack of runoff from the DRN, CWT-45, or CWT-75 plots suggests greater infiltration and internal storage capacity in the soil because of the imposed subsurface drainage treatments.

On day 11, atrazine and metolachlor losses in surface runoff from the DRN and CWT-45 plots were about same as for the SUR plots, while losses from the CWT-75 plot tended to be lower. Atrazine runoff losses from the DRN and CWT-45 plots were lower than for the SUR plots on days 12 and 15 and were about the same on day 18. Atrazine runoff losses from the CWT-75 plots on days 12, 15, and 18 were equal to or greater than from the SUR plots. Atrazine runoff losses from the SUR plots were 2.45% of the amount applied.

Metolachlor runoff losses from the DRN plots were lower than those from the SUR plots on days 12, 15, and 18. Losses from the CWT-45 plots tended to be equal to or less than those from the SUR plots for the same three runoff events. Metolachlor losses from the CWT-75 plots were equal to or greater than those from the SUR plots during the runoff events on days 12, 15, and 18. Metolachlor runoff losses from the SUR plots were 1.06% of the amount applied.

Subsurface drain line outflow occurred from the DRN plots during the first 8 days after herbicide application, even though no surface runoff occurred. Both atrazine and metolachlor were present in the drain effluent. The appearance of both herbicides in drain effluent so soon after application to the soil surface suggests the occurrence of preferential or bypass flow. Earlier studies with herbicides on nearby plots with similar soils also suggested the occurrence of bypass flow (Bengtson et al. 1990; Southwick et al. 1990a and 1990b). Subsurface drainage losses of atrazine and metolachlor from the DRN plots during the 18-day period were 1.41 and 0.70 g ha^{-1}, respectively. Herbicide subdrainage losses occurred from the CWT-75 plots during the 13- to 18-day period when controlled drainage was initiated to lower the water table to the predetermined 75-cm depth. Total atrazine and metolachlor subdrain losses from the CWT-75 plots were 1.98 and 1.17 g ha^{-1}, respectively.

Combined surface runoff and subdrainage losses of atrazine for the DRN, CWT-45, and CWT-75 plots were 34.10, 32.48, and 47.20 g ha^{-1}, respectively. Those amounts were 93, 88, and 128% of the SUR plots, respectively. Combined metolachlor losses from the DRN, CWT-45, and CWT-75 plots were 83, 94, and 125% of the SUR plots, respectively. Less metolachlor was lost from the plots even though it was applied at a slightly higher rate and is more water soluble than atrazine (530 vs. 33 mg L^{-1}; Wauchope et al. 1992). Apparently, metolachlor's greater tendency to sorb to soil (K_{OC} = 200 vs. 100 for atrazine; Wauchope et al. 1992) restricted its runoff and leaching losses.

Although firm conclusions from such preliminary data cannot be made, the early data suggest that the DRN and CWT-45 water management treatments show promise for reducing pesticide loss from agricultural fields. It is probable that a predetermined, static water table depth will not be the best management practice. More likely, the best management practice will involve controlling the water table at various depths throughout the year as dictated by weather variables, plant growth requirements, and agrochemical management needs and will require skilled management.

SUMMARY AND CONCLUSIONS

Four water table management treatments were imposed on 0.21-ha corn plots located on silt loam, alluvial soil in the lower Mississippi River valley. The treatments included (1) surface drainage only (no subsurface drainage), (2) conventional subsurface drainage at 1.2 m or more below the soil surface, (3) controlled water table at 45 cm below the soil surface, and (4) controlled water table 75 cm below the soil surface. Atrazine and metolachlor were applied to the plots at rates of 1.50 and 1.94 kg ha^{-1}, respectively. Surface runoff and subsurface drain effluent were measured and sampled for the herbicides during the first 18 days following application. Atrazine and metolachlor losses in runoff from the surface-drained only plots (treatment 1) were 2.45 and 1.06% of the respective amounts applied. Drainage treatments 2 and 3 appeared to reduce combined runoff and subdrainage herbicide losses. Combined runoff and drainage losses for treatment 4 were higher than for treatment 1. These preliminary data suggest that water table management may offer a useful technique for reducing the amounts of atrazine and metolachlor, and presumably other agrochemicals, lost from agricultural fields in runoff and leaching.

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Table 1. Atrazine Losses in Surface Runoff and Drain Line Effluent

Days after application	Rain, mm	Treatment[a]	Herbicide loss, g ha^{-1} runoff	Herbicide loss, g ha^{-1} drain effluent
0- 8	39.9[b]	SUR	0	-
		DRN	0	0.20
		CWT-45	0	0
		CWT-75	0	0
9	0.2	SUR	trace	-
		DRN	0	0.12
		CWT-45	0	0
		CWT-75	0	0
10-11	8.1	SUR	2.52	-
		DRN	2.52	0.08
		CWT-45	2.45	0
		CWT-75	1.40	0
12	15.0	SUR	8.96	-
		DRN	5.04	0.33
		CWT-45	6.93	0
		CWT-75	12.39	0
13-15	20.6	SUR	4.41	-
		DRN	3.57	0.21
		CWT-45	2.87	0
		CWT-75	4.48	0.48
16-18	43.9	SUR	20.93	-
		DRN	21.56	0.47
		CWT-45	20.23	0
		CWT-75	26.95	1.50
TOTALS	127.7	SUR	36.82	-
		DRN	32.69	1.41
		CWT-45	32.48	0
		CWT-75	45.22	1.98

[a]SUR = surface drainage only, DRN = conventional subsurface drainage at 1.2 m or below, CWT-45 = controlled water table at 45 cm below the soil surface, CWT-75 = controlled water table at 75 cm below the soil surface.

[b]Total rain during the listed days after application.

Table 2. Metolachlor Losses in Runoff and Drain Line Effluent

Days after application	Rain, mm	Treatment[a]	Herbicide loss, g ha^{-1} runoff	drain effluent
0- 8	39.9	SUR	0	-
		DRN	0	0.05
		CWT-45	0	0
		CWT-75	0	0
9	0.9	SUR	trace	-
		DRN	0	0.07
		CWT-45	0	0
		CWT-75	0	0
10-11	8.1	SUR	1.47	-
		DRN	1.40	0.03
		CWT-45	1.40	0
		CWT-75	1.12	0
12	15.0	SUR	4.97	-
		DRN	2.59	0.19
		CWT-45	4.06	0
		CWT-75	6.51	0
13-15	20.6	SUR	1.96	-
		DRN	1.82	0.13
		CWT-45	1.61	0
		CWT-75	1.82	0.14
16-18	43.9	SUR	12.25	-
		DRN	10.64	0.23
		CWT-45	12.25	0
		CWT-75	15.12	1.03
TOTALS	127.7	SUR	20.65	-
		DRN	16.45	0.70
		CWT-45	19.32	0
		CWT-75	24.57	1.17

[a]SUR = surface drainage only, DRN = conventional subsurface drainage at 1.2 m or below, CWT-45 = controlled water table at 45 cm below the soil surface, CWT-75 = controlled water table at 75 cm below the soil surface.

[b]Total rain during the listed days after application.

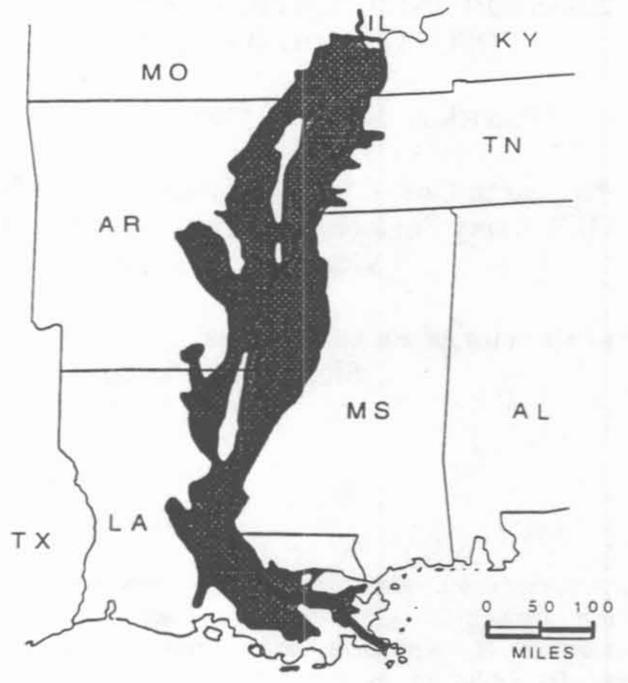

Figure 1. Map of the lower Mississippi River Valley

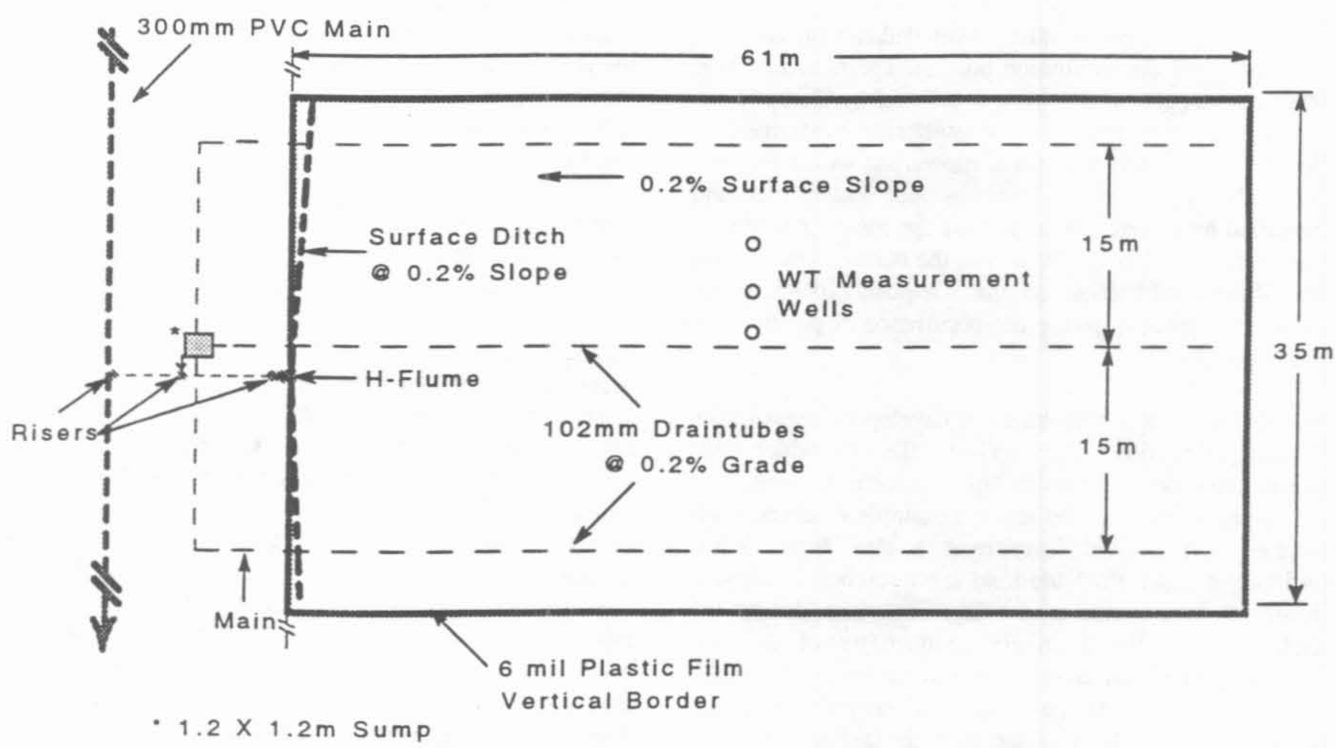

Figure 2. Schematic diagram (top view) of controlled-watertable research plot with surrounding plastic-film subsurface barrier