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Effect of Subsurface Drainage on Runoff Losses of Atrazine and Metolachlor in Southern Louisiana[1]

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Subsurface drains increase soil infiltration of rainfall and thereby reduce the quantity of runoff water. This reduction in the volume of runoff leads to a reduction in surface loss of agricultural chemicals (nutrients and pesticides). Because subsurface drains by diminishing soil moisture increase the amount of soil leaching by rainwater, concentrations of leachable chemicals in the runoff active zone of the soil diminishes more quickly than in the absence of subsurface drains. Therefore, subsurface drains not only reduce the quantity of surface runoff but also increase its quality.

The above influences of subsurface drainage on surface runoff have been pointed out by Baker and Johnson (1976). Limited data are available in support of this analysis with respect to pesticides. Baldwin et al. (1975a, 1975b) reported that both fluometuron and prometryn in runoff were affected by antecedent soil moisture. Dry soil conditions before rainfall (simulated) gave rise to runoff losses of only about 10% of those resulting from runoff from wet soil. Concentrations of these herbicides in the first 45 L (10mm from 1.5 x 4.6m plots) of runoff were also about 10% of the concentrations in runoff from wet soil.

Bengtson et al. (1988) conducted a study of the effect of subsurface drainage on water, sediment, and nutrient losses in runoff from plots with 0.1% slope in southern Louisiana from 1981 to 1986. Subsurface drainage reduced total runoff by 34%, soil loss by 30%, and nitrogen and phosphorus losses by 20% and 36%, respectively. Using the field system of Bengtson et al. (1988), we investigated the effect of subsurface drainage on runoff losses of atrazine and metolachlor. We report here the results of that study.

MATERIALS AND METHODS

Field work was carried out on 9 plots at the Louisiana Agricultural Experiment Station's Ben Hur Farms about 6 km south of Baton Rouge. Plots ranging in size from 2.0 to 4.0 ha were laid out on Commerce clay loam graded to 0.1% slope. Five plots contained drains (10-cm

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diameter corrugated and perforated polyethylene tubes) 1 m deep; these plots varied in their drain spacing (10-, 20-, or 30-m separations). Runoff from each plot was directed through a 61-cm H-flume instrumented with an FW1 water stage recorder and an automatic sampler.

Samples were stored at 5 C until extraction. The samples (250 mL) were separated into sediment and water phases by passing through 0.45 u membrane filters. The sediment portion was extracted for atrazine and metolachlor by Soxhlet (3 hr) with a 41:59 azeotropic mixture of n-hexane-acetone. Acetone was removed from the extract by water washing and the hexane phase was dried with sodium sulfate. sodium chloride (2 g) was added to the water phase (for salting out) and the resulting solution was stirred (magnetic) with 100 mL of n-hexane for 1 hr. After drying with sodium sulfate, the hexane extracts were analyzed for atrazine and metolachlor by gas chromatography using both electron capture and Hall Electrolytic conductivity detection.

The above extraction procedure afforded the following recoveries: atrazine: sediment, 14.7 $\pm$ 5.1%, water 85.0 $\pm$ 10.4%; metolachlor: sediment, 64.3 $\pm$ 7.6%; water, 93.0 $\pm$ 4.6%. An error in recovery calculation for atrazine from sediment let us to adopt the employed technique for this herbicide. All herbicide quantities generated in the study were corrected for recovery.

The plots were planted to corn on April 15-16, 1987. On April 22-24, Bicep (Ciba-Geigy) was applied at 1.63 kg/ha atrazine and 2.16 kg/ha metolachlor. Corn harvest occurred in late July-early August.

RESULTS AND DISCUSSION

Herbicide concentrations in runoff from subsurface-drain plots showed no trend with respect to drain spacing. Consequently, in data analysis the 5 plots with drains were treated as replicates, as were those plots without drains.

Figures 1 (atrazine) and 2 (metolachlor) show the concentrations of herbicide in runoff (water plus sediment) during the 130-day period following application. Both herbicides underwent a rapid reduction in concentration for the first 34 days after application, followed by a variable but consistently low (<10 ug/L) concentration from day 54 to the end of the season.

Concentrations of the herbicides were significantly higher (65% and 60% greater for atrazine and metolachlor, respectively) from plots without subsurface drains for the first runoff event on day 12. From day 25 for metolachlor and day 31 for atrazine no difference trend was observable (t-test, P = 0.05).

Table 1 presents regression equations (PC-SAS, version 6.02) relating herbicide concentration in runoff to time after application. For each herbicide, the two equations were judged (PC-SAS) to be significantly different (P = 0.01). These hyperbolic equations lead

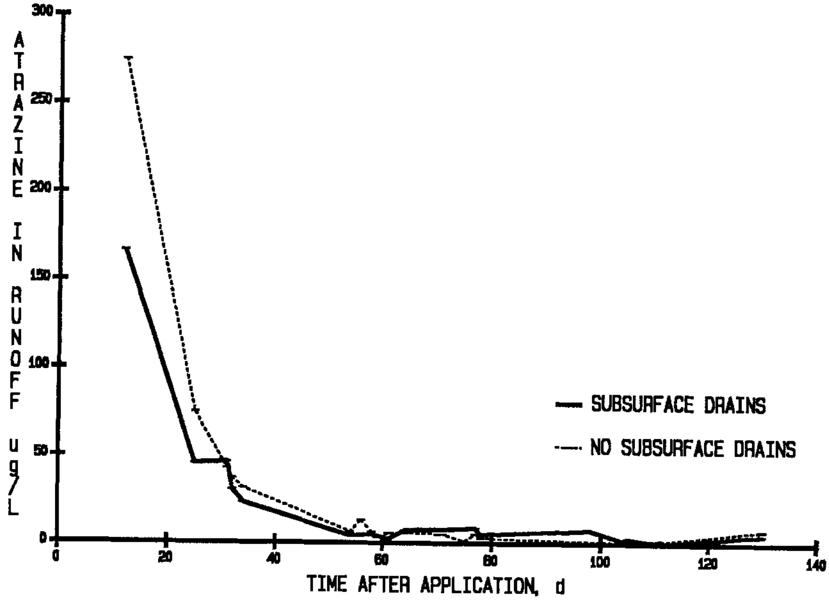

Figure 1. Atrazine in runoff.

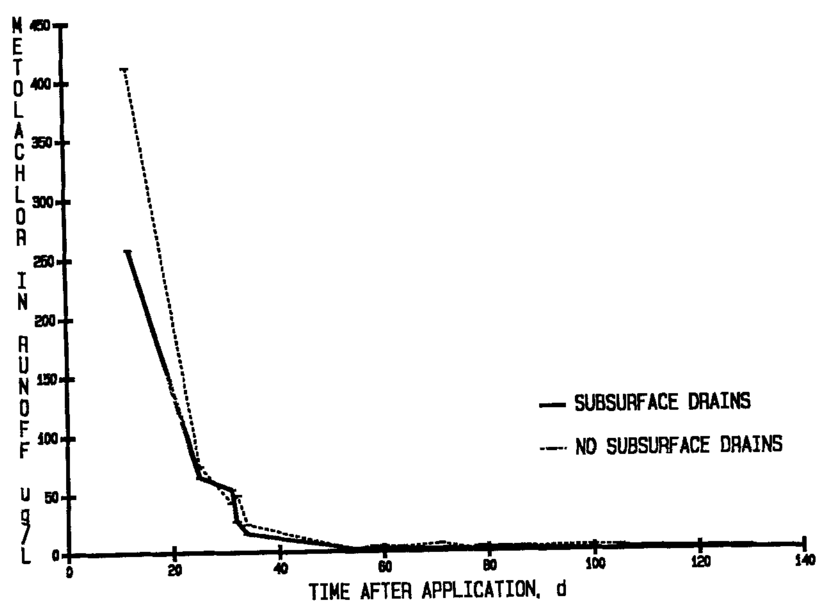

Figure 2. Metolachlor in runoff.

to negative concentrations at t >= t'; for example, t' = 90.4 days for eq. (1). Table 1 lists the DT50 (50% disappearance time) for each equation, the time for the herbicide to disappear in runoff to a level 0.5 of its concentration at t = 12 days (the first sampling date). The DT50 for atrazine in runoff is about 25% of the t1/2 (35-36 days, reported by Southwick et al., 1990) for atrazine in the top 2.5 cm of soil; for metolachlor, the DT50 is less than 40% of the respective t1/2 (20-23 days).

Table 1. Regression equations-herbicides in runoff[a].

(1) Atr, subsurface drains:
 RunoffC = -23.0 + 2080/t, r2 = 0.94
 DT50[b] = 9 days
(2) Atr, no subsurface drains:
 RunoffC = -45.4 + 3450/t, r2 = 0.93
 DT50 = 9 days
(3) Met, subsurface drains:
 RunoffC = -46.5 + 3290/t, r2 = 0.92
 DT50 = 8 days
(4) Met, no subsurface drains:
 RunoffC = -77.4 + 5130/t, r2 = 0.89
 DT50 = 8 days

[a] C in ug/L, t in days

[b] DT50 (50% disappearance time): time for concentration at t = 12 days to decrease to 1/2 of its value

Tables 2 (atrazine) and 3 (metolachlor) give runoff losses of the herbicides for the season. Losses of each herbicide from plots with subsurface drains were less than half that from the plots without drains: 22.8 g/ha (1.40% of applied) vs 51.6 g/ha (3.17% of applied) for atrazine; 23.1 g/ha (1.07% of applied) vs 52.7 g/ha (2.44% of applied) for metolachlor. This difference was due both to the lower volume of water (Tables 2 and 3: 254 mm vs 412 mm) that flowed off the surface of the plots with subsurface drains and to the smaller concentration of herbicide in runoff from subsurface-drained plots in the first runoff event (Figures 1 and 2). The lowered runoff volume occurred in fewer runoff events from plots with drains (21 events for the season vs 27). Even after concentrations had approached each other (after day 25, Figures 1 and 2), twice as much herbicide was lost from plots without subsurface drains as came off plots with subsurface drains (Tables 2 and 3). The atrazine losses (% of applied) reported in Table 2 are comparable to results of an investigation of atrazine runoff from fields of 2-3% slope in Georgia; in those studies seasonal runoff amounted to less than 2% of the application (Wauchope 1978).

Table 2. Atrazine in runoff.

Days After Application	Cum. Runoff mm(% of Total)		Cum. Atrazine g/ha (% of Total)		Atrazine in Water Phase %	(SD)
			DRAINS			
12-31	8	(3.1)	9.32	(40.9)	98.7	(0.7)
32-61	137	(53.9)	19.02	(83.5)	90.7	(8.4)
63-98	162	(63.8)	20.76	(91.2)	54.9	(16.7)
104-130	254	(100)	22.77[a]	(100)	75.7	(22.8)
			NO DRAINS			
12-31	18	(4.4)	25.79	(50.0)	99.2	(1.1)
32-61	191	(46.4)	44.38	(85.0)	97.8	(4.6)
63-98	243	(59.0)	46.33	(89.7)	71.1	(16.3)
104-130	412	(100)	51.63[b]	(100)	78.0	(25.5)

[a]22.8 $\pm$ 5.1 g/ha; 1.40% of amount applied

[b]51.6 $\pm$ 14.8 g/ha; 3.17% of amount applied

Table 3. Metolachlor in runoff.

Days After Application	Cum. Runoff mm(% of Total)		Cum. Metolachlor g/ha (% of Total)		Metolachlor in Water Phase %	(SD)
			DRAINS			
12-31	8	(3.1)	13.38	(58.0)	83.3	(3.3)
32-61	137	(53.9)	21.48	(93.1)	98.0	(3.6)
63-98	162	(63.8)	22.14	(95.9)	98.2	(3.5)
104-130	254	(100)	23.08[a]	(100)	99.2	(1.6)
			NO DRAINS			
12-31	18	(4.4)	33.14	(62.9)	85.9	(2.7)
32-61	191	(46.4)	47.79	(90.7)	94.6	(9.9)
63-98	243	(59.0)	49.13	(93.3)	83.2	(11.8)
104-130	412	(100)	52.68[b]	(100)	100	(0.0)

[a]23.1 $\pm$ 5.4 g/ha; 1.07% of amount applied

[b]52.7 $\pm$ 8.07 g/ha; 2.44% of amount applied

For the season, loss of atrazine from subsurface drained plots was 28.86 g/ha less than from plots without drains (Table 2). This reduction was composed of 4.84 g/ha (16.8% of the total reduction) stemming from the lower concentration of herbicide in the first runoff event from plots with drains and of 24.02 g/ha (83.2%) of the total reduction) arising from the smaller volume of runoff from subsurface drained plots throughout the season. Loss of metolachlor from plots with drains amounted to 29.60 g/ha less than from those plots without drains (Table 3). The reduction in this case was composed of 6.54 g/ha (22.1% of the total reduction) caused by the smaller herbicide concentration in the first event and of 23.06 g/ha (77.9% of the total) coming from the smaller runoff volume for the season.

Tables 2 and 3 show that the early runoff events exhibited the greatest influence on runoff losses of the herbicides. The runoff (3-4% of the total for the season) that occurred in the first 31 days contained 41-50% of the atrazine (Table 2) and 58-63% of the metolachlor (Table 3) that flowed off the plots during the 130-day season. Within 61 days greater than 83% of the atrazine losses and more than 90% of the metolachlor losses took place. During this 61-day period more than 90% of the atrazine [water solubility = 33 ug/mL (ppm) (Beste et al. 1983)] and more than 83% of the metolachlor [water solubility = 530 ug/mL (Beste et al. 1983)] occurred in the water phase of the runoff. Pesticides with water solubilities greater than 3 ug/mL usually occur mostly in the water phase of runoff (Wauchope 1978).

Leonard et al. (1979) reported on loss of several herbicides including atrazine in runoff from small Piedmont watersheds in Georgia. They developed the following relationship between herbicide concentration (mg/L) in runoff (almost entirely in the water phase) and in the top 1-cm soil layer (ug/g):

runoffC = 0.05(soilC)**1.2, r2 = 0.86

Our atrazine and metolachlor runoff and soil data (soil concentrations from Southwick et al., 1990) produced the following corresponding equations (subsurface- and nonsubsurface-drained plots were combined since the soil concentrations showed no difference with respect to drainage):

runoffC (atr) = 0.034 (soilC)**1.9, r2 = 0.69

runoffC (met) = 0.013 (soilC)**1.4, r2 = 0.73

Paraphrasing the analysis of Leonard et al. (1979), the coefficient reflects the distribution between runoff and the soil zone that provides pesticide to runoff (top 2.5-cm in our case). The exponent, significantly different from 1, may indicate decreasing partitioning with time; that is, partitioning into the runoff phase soon after application was highest when surface concentrations were also at their highest.

In summary, concentrations of atrazine and metolachlor in runoff were affected by subsurface drainage status for only the first 1-2 runoff events. After this time no significant trend in concentration (runoff quality) was observable with respect to the presence or absence of subsurface drains. On the other hand, runoff quantity consistently showed an influence due to subsurface drains: over twice as much runoff flowed from plots without subsurface drains. This reduction in runoff losses from subsurface-drained plots was not offset by an increase in leaching losses from these plots. Atrazine runoff was reduced by 28.8 g/ha but leaching losses were only 0.62 g/ha; metolachlor runoff decreased by 29.6 g/ha but leaching amounted to only 2.76 g/ha (Southwick et al. 1990).

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