THE INFLUENCE OF REDUCED RAINFALL SEASONS ON THE RUNOFF AND LEACHING LOSSES OF MOBILE AGRICULTURAL PESTICIDES AND ON THEIR RUNOFF/LEACHING RATIOS

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INTRODUCTION

From 1985 to 1992 we studied runoff and leaching losses of soil-applied pesticides (mostly herbicides) from large plots (2 ha) on Commerce clay loam Mississippi River alluvial soil in southern Louisiana (Southwick et al., 1990a, 1990b, 1997). This is an area with typically 1500 mm of annual rainfall and with a runoff event from agricultural land about every week. Under these conditions we observed that 1-3% of applied atrazine and metolachlor [mobile pesticides: water solubility > 30 mg/L; Koc 200 mL/g (Hornsby et al., 1996)] left the field in runoff and more than an order of magnitude less left the field by leaching through the soil (Tables 1, 2). From these plots we measured 1.5-5.1 times as much water volume in runoff as in leachate, and 7.7-91 times as much herbicide in runoff as in leachate.

Since 1994 we have been studying runoff and leaching losses of the mobile chemicals atrazine, simazine, and metolachlor from 0.21 ha plots on Commerce clay loam. Here we compare our results for 1995-97, with typical rainfall patterns like our earlier studies, with our earlier large-plot work (1987-92), and contrast our 1995-97 results with those from the exceptionally dry years 1998-2000. The large change in rainfall pattern for the latter period led to great differences in runoff and to small differences in leaching behavior of the studied herbicides.

MATERIALS AND METHODS

The field installation has been described in detail by Willis et al. (1991). Briefly, runoff samples were passed through H-flumes and 50-mL subsamples of every 1000 L of flow were collected and stored automatically in refrigerated containers in the field. Leachate flow through subsurface drains at a depth of 1.2 m was directed into sumps. Again, subsamples (0.2 % of the flow) were collected and stored automatically in refrigerated containers in the field. Samples were brought to the laboratory, extracted for their pesticide content, and analyzed by gas chromatography.

RESULTS AND DISCUSSION

The first three years (1995-97) of our studies on the smaller plots produced runoff and leaching data for atrazine and metolachlor similar to our results for these compounds on the larger plots (Tables 3 and 4, compared to Tables 1 and 2). We have shown (Southwick et al., 2000) that generally we did not observe a plot size effect in these studies. Rainfall that was similar over a two-month period (a few hundred mm) in our small-plot work (1995-97) produced runoff and leaching volumes in the general range observed in our large-plot work (1987-92). That is, in both sets of studies, a few hundred mm of rainfall produced 28-76% of the rainfall volume in runoff and 11-20% of the rainfall volume in leachate. The ratio of runoff to leaching volume was in the range 1.5-5.1 for the five (1987-1997) investigations.

The first runoff events of the season occurred on or before day 11 in the latter studies (1995-1997) and on or before day 15 in the earlier (1987-1992) work (Tables 2 and 4). First-event concentrations in runoff were in the range 42-349 µg/L. Leachate concentrations in the first samples of the season occurred on or before day 12 and fell in the range 0.6-35 µg/L. Runoff/leaching ratios of herbicide losses for the 1987, 1992, 1995-97 seasons (Tables 2, 4) were in the range 20-91, except for a low of 7.7 for metolachlor in 1987 and a high of 239 for atrazine in 1997.

For the dry years 1998-2000, rainfall for the first two months after application was 50% or less of that for the 1995-97 seasons, except for 1999, which was 30 mm higher than that for 1995

(Table 5). This high value for 1999 was caused by a 100-mm rain on days 60-61. For all three of the dry seasons, runoff volumes were considerably below the runoff of 1995-97. But the leaching volume for 1999 was greater than that for 1995-96. The dramatic results of the dry seasons were the runoff/leaching ratios, which were less than 0.6 for 1998-2000. (Until the large runoff event on days 60-61, the 1999 runoff/leaching ratio was 0.10.) Generally, first event runoff concentrations (2.6-145 µg/L) for 1998-2000 were in the same range as for 1995-97 or were below this range. Lower concentrations in runoff would stem from increased removal of the soil surface residue by enhanced leaching due to drier soil. First event leaching concentrations (46.2-70.6 µg/L) tended to be higher for the dry years than for the wet ones. On a percent of application basis, runoff losses were an order of magnitude less for the dry years, whereas leaching was slightly higher. Consequently, the runoff/leaching ratios for 1998-2000 were smaller than for 1995-97.

Compared to wet seasons, runoff volumes not only decreased absolutely but also deceased as a percentage of rainfall (Tables 3 and 5). On the other hand, leaching volumes were in the same absolute range during wet and dry years, although percent of rainfall in leaching showed a slight upward trend during dry compared to wet seasons. No trend was evident in first- event runoff concentrations (Tables 4 and 6), but first-event leaching concentrations increased from wet to dry years.

The increased infiltration resulting from decreased rainfall during a dry season is clearly revealed by comparing runoff/leaching ratios of the two kinds of season (Table 7). Water volume ratios decreased by an order of magnitude from the wet to the dry years. Herbicide runoff/leaching ratios decreased by two orders of magnitude. Chemical ratios show a greater decrease than the water volume ratios, indicating increased sorption of the herbicides in the soil profile during leaching events. That is, during dry seasons there is a greater sorption of the herbicides from leachate water as it passes through the soil profile. Comparing relative (percentage of application) leaching between wet and dry seasons (Table 8) shows that for both atrazine-simazine and metolachlor, there is roughly a 30-fold decrease in runoff losses in going from the wet seasons to the dry ones, and only a doubling in leaching losses. Leachate volume increase does not make up for the runoff volume decrease. A 15-fold increase in soil profile residues is indicated. We do not have soil core residue data to support this suggestion, but the half-life for atrazine in the top 2.5 cm soil layer for 1998-99 was 34% longer than for 1995-97, and that for metolachlor in 1998-99 was 23% longer than for 1995-97.

Even though the soil surface residues of atrazine-simazine and metolachlor had an extended persistence during dry years, these longer-lived residues did not exhibit extended availability for extraction into runoff and leachate. The 100-mm rain on days 60-61 in 1999 removed in runoff and leachate a total of about 0.02% of application of simazine and 0.06% of application of metolachlor.

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Table 1. Rainfall, and Runoff and Leaching Volumes in Ben Hur Studies of 1987, 1992.[a]

Study	Rainfall mm (Days)	Runoff Volume mm (Days) (% of Rain)	Leaching Volume mm (Days) (% of Rain)	Runoff / Leaching
1987	450 (64)	137 (61) (30.4)	92.7 (64) (20.4)	1.49
1992	392 (68)	296 (71) (75.5)	58.7 (76) (15.1)	5.09

[a] 1987, conventional tillage corn; 1992, conventional tillage soybean.

Table 2. Atrazine and Metolachlor in Runoff and Leaching Studies, Ben Hur, 1987, 1992.

Study		1st Runoff Conc. µg/L (Day)	1st Leaching Conc. µg/L (Day)	Loss, % of Appl. Runoff (Days)	Loss, % of Appl. Leaching (Days)	Runoff / Leaching
1987	Atrazine	167 (12)	3.53 (12)	1.17 (61)	0.035 (64)	33.4
	Metolachlor	258 (12)	29.3 (12)	1.00 (61)	0.13 (59)	7.69
1992						
	Metolachlor	42 (15)	0.60 (2)	2.46 (71)	0.027 91.1 (85)	

Table 3. Rainfall, runoff, and leaching volumes in Ben Hur studies, 1995-1997.[a]

Study	Rainfall mm (Days)	Runoff Volume mm (Days) (% of Rain)	Leaching Volume mm (Days) (% of Rain)	Runoff / Leaching
1995	253 (69)	70.6 (64) (27.9)	41.2 (66) (16.3)	1.71
1996	364 (66)	186 (66) (51.1)	54.0 (66) (14.8)	3.44
1997	715 (68)	378 (68) (52.9)	79.4 (70) (11.1)	4.76

[a] All studies, conventional tillage corn.

Table 4. Atrazine and Metolachlor in runoff and leaching studies, Ben Hur, 1995-1997.

Study		1st Runoff Conc. µg/L (Day)	1st Leaching Conc. µg/L (Day)	Loss, % of Appl. Runoff (Days)	Leaching (Days)	Runoff / Leaching
1995	Atrazine	60.9 (11)	15.4 (12)	5.37 (64)	0.18 (66)	29.8
	Metolachlor	52.7 (11)	22.4 (12)	3.58 (64)	0.18 (66)	19.9
1996	Atrazine	349 (1)	34.9 (3)	9.11 (41)	0.28 (42)	32.5
	Metolachlor	154 (1)	19.3 (3)	6.27 (41)	0.10 (42)	62.7
1997	Atrazine	204 (2)	9.58 (6)	12.9 (63)	0.054 (46)	239

	Metolachlor	118 (2)	16.8 (6)	7.56 (63)	0.108 (46)	70.0

Table 5. Rainfall, runoff, and leaching volumes in Ben Hur studies, 1998-2000.[a]

Study	Rainfall mm (Days)	Runoff Volume mm (Days) (% of Rain)	Leaching Volume mm (Days) (% of Rain)	Runoff / Leaching
1998	106 (55)	8.36 (15) (7.9)	18.4 (56) (17.4)	0.45
1999	282 (62)	37.1 (61) (13.2)	65.8 (63) (23.3)	0.56
2000	88.2 (43)	1.22 (43) (1.4)	22.2 (46) (25.2)	0.05

[a] All studies, conventional tillage corn.

Table 6. Atrazine and Metolachlor in runoff and leaching studies, Ben Hur, 1998-2000.

Study		1st Runoff Conc. µg/L (Day)	1st Leaching Conc. µg/L (Day)	Loss, % of Appl. Runoff (Days)	Loss, % of Appl. Leaching (Days)	Runoff / Leaching
1998	Atrazine	145 (15)	67.0 (16)	0.87 (15)	0.49 (56)	1.78
	Metolachlor	83.1 (15)	46.2 (16)	0.37 (15)	0.25 (56)	1.48
1999	Simazine	2.64 (53)	55.0 (15)	0.015 (61)	0.20 (63)	0.08
	Metolachlor	4.29 (53)	46.6 (15)	0.034 (61)	0.22 (63)	0.15

2000	Simazine	73.2 (43)	69.5 (4)	0.085 (43)	0.16 (46)	0.53
	Metolachlor	63.4 (43)	70.6 (4)	0.074 (43)	0.22 (46)	0.34

Table 7. Runoff/leaching ratios.

Studies	Parameter	Runoff/Leaching
1995-1997	Water Volume	3.30 ± 1.53
1998-2000	Water Volume	0.35 ± 0.27
1995-1997	Atrazine	100 ± 120
1995-1997	Metolachlor	50.9 ± 27.1
1998-2000	Atrazine-Simazine	0.80 ± 0.88
1998-2000	Metolachlor	0.66 ± 0.72

Table 8. Percent of application losses of herbicides.

Chemical	Wet Season Runoff	Dry Season Runoff
Atrazine-Simazine	9.13 ± 3.77	0.32 ± 0.47
Metolachlor	5.80 ± 2.03	0.16 ± 0.19
	Wet Season Leachate	Dry Season Leachate
Atrazine-Simazine	0.17 ± 0.11	0.28 ± 0.18
Metolachlor	0.13 ± 0.04	0.23 ± 0.02