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Leaching Losses of Norflurazon through Mississippi River Alluvial Soil

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Norflurazon [4-chloro-5-(methylamino)-2-(3-(trifluoromethyl)phenyl)-3(2*H*)-pyridazinone] is a preplant or preemergence herbicide labeled for grass and broadleaf weed control in several crops including cotton and soybeans (Herbicide Handbook, 1989). In Louisiana the chemical is commonly applied to cotton but used only occasionally on soybeans. In Louisiana about 80,000 kg of norflurazon are applied to about 240,000 ha of cotton (Gianessi and Puffer, 1991).

Few studies of norflurazon leaching through soil have been reported. Schroeder and Banks (1986a) detected less than 12% of the remaining herbicide at depths below 15 cm in Georgia soils 110 days after application. These investigators did not make routine measurements of the compound in the soil profile throughout their study. Hubbs and Lavy (1990) reported less, compared to atrazine, upward movement ("wick" effect) of norflurazon in subirrigated columns of Hebert silt loam or Sharkey clay from Arkansas. After 10 days of subirrigation of the silt loam, almost 75% of recovered atrazine was at the top of the column (7.5-10 cm); 60% of the norflurazon was between 2.5-5.0 cm, and about 20% was between 5.0 and 7.5 cm. None of the norflurazon had moved as far as atrazine. After 8 weeks of subirrigation in the silt loam about 65% of remaining norflurazon was at the top of the column, whereas in the clay soil about 75% of the herbicide was at the 2.5-5.0 cm level. These investigators also reported on soil TLC work with these herbicides and soils; relative RF values were consistent with the above column results.

The results of Hubbs and Lavy (1990) indicate that norflurazon in the field leaches to a smaller extent than atrazine but point to the possibility that norflurazon has the potential for measurable leaching into the soil profile. Properties directly related to leaching potential for the two herbicides are similar: water solubility: 33 mg/L for atrazine, 28 mg/L for norflurazon (Herbicide Handbook, 1989); Koc: 160 cm^3/g (Jury et al., 1987) for atrazine versus 248 cm^3/g (Alva and Singh, 1990) for norflurazon; half life in southeastern soils: 3 weeks to 6 months for atrazine (Hiltbold and Buchanan, 1977; Southwick et al.,

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1990) and 6 weeks to 6 months (Herbicide Handbook, 1989) for norflurazon. The similarity of these properties would indicate that the two chemicals have somewhat similar leaching potentials. Water solubilities and soil adsorption coefficients slightly favor leaching of atrazine over norflurazon.

We have conducted a study of leaching of norflurazon on subsurface drained plots on Mississippi River alluvial soil. We describe here the results of this work. We have reported on an earlier investigation (Southwick et al., 1990) on the same plots of atrazine movement through the soil profile. An important advantage of the use of subsurface drains in field scale leaching studies is that the drains smooth out by integration the spatial variability that other sample collection methods, such as suction lysimeters, reveal (Kladivko et al, 1991, citing Richard and Steenhuis, 1988).

MATERIALS AND METHODS

Field work was conducted on 3 plots at the Louisiana Agricultural Experiment Station's Ben Hur Farms about 6 km south of Baton Rouge in East Baton Rouge Parish. The plots, approximately 4.0 ha each, were laid out on Commerce clay loam (36% sand, 31% silt, 33% clay) graded to 0.1% slope. Three subsurface drains (10-cm diameter corrugated, perforated polyethylene tubes) 1 m deep were positioned 30 m apart for the length of each plot; the drains directed soil leachate into a single sump at the low end of each plot. Sump samples were collected by automatic samplers set to take 250 mL samples every 3 hr during water flow; samples were composited weekly.

Water samples were stored at 5°C until extraction. Extraction of norflurazon from water samples was accomplished by adding 2 g sodium chloride to a 250-mL aliquot of the sample and stirring (magnetic) with 100 mL benzene for 1 hr. By this method the herbicide was obtained in 71% recovery. Soil samples (2.5 cm diameter by 15 cm deep) were collected (20 subsamples per plot) with a soil sampling tube. The soil was dried at ambient temperature for 3-4 days, ground to pass a 2 mm sieve, and frozen until extraction. Removal of norflurazon from the soil in greater than 90% recovery was accomplished by Soxhlet extraction of 30-g subsamples for 4 hr with 200 mL of ethyl acetate. Water and soil extracts were analyzed by gas chromatography (electron capture detection, 0.53 mm i.d. x 15 m DB-210 megabore column) with the following conditions: injector at 240°C, column at 195°C, detector at 350°C, helium carrier gas at 10 cc/min. Norflurazon retention time was 16.9 min.

On June 1, 1988, and on April 26, 1989, Zorial Rapid 80 (Sandoz Crop Protection Corp.) was applied by ground rig at 2.24 kg/ha norflurazon. The application was incorporated to 10-15 cm. After chemical application, the plots were planted to soybeans [Glycine max (L.) Merr.]. To our knowledge, 1988 was the first year that norflurazon was applied to the plots, since before this year the land was used for corn production.

RESULTS AND DISCUSSION

Norflurazon concentrations in the top 15 cm of soil are presented in Table 1. For the 1988-89 season the herbicide soil concentration at the end of 293 days was 10% of its initial value; DT_{50}(time to 50% disappearance) was about 40 days. In the later (1989-90) study, at day 352 norflurazon in the soil had decreased to 29% of the beginning concentration; DT_{50} for this season was about 120 days. Rahn and Zimdahl (1973) in a laboratory study observed a half life of 70 days for norflurazon in a Colorado sandy loam at 35°C. Schroeder and Banks (1986b) published graphs that showed half lives of about 20-35 days for the herbicide in Georgia soils at 20-30°C in a greenhouse study. At 365 days posttreatment (1.7 kg/ha) norflurazon was present in the soil in the range 50-500 ng/g. In our 1988-89 study, 293 days after treatment norflurazon was present at 39 ng/g; in the second investigation, at 352 days posttreatment the herbicide soil concentration was 119 ng/g (Table 1). The Herbicide Handbook (1989) lists a soil half life of 45-180 days for the chemical in southeastern soils.

Table 1. Norflurazon in top 15 cm of soil after application of 2.24 kg/ha

1988 - 1989		1989 - 1990	
Days after Application on 6/1/88	ng/g (SD)	Days after Application on 4/26/89	ng/g (SD)
1	372 (33)	5	404 (175)
20	224 (133)	34	301 (47)
44	167 (43)	76	301 (134)
106	160 (71)	134	187 (52)
169	29 (2)	224	150 (3)
293	39 (19)	352	119 (51)

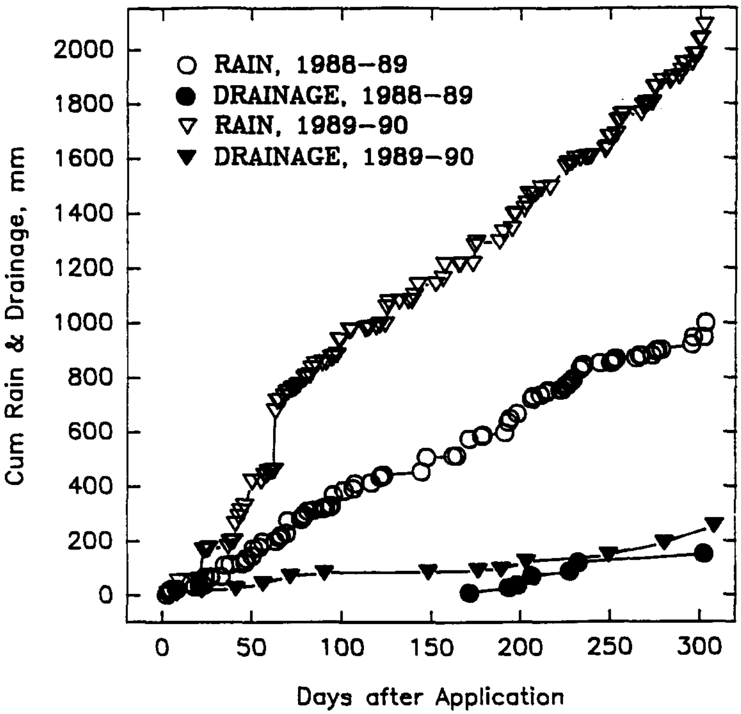

Figure 1. Cumulative rainfall and subsurface drainage.

Rainfall and drainage for the two seasons are shown in Figure 1. In the earlier study 1000 mm of rain fell in 303 days after application, but the first leaching event did not occur until day 171. Cumulative leaching through day 302 amounted to 155 mm. For the later study 2084 mm rainfall was recorded in 302 days; flow into the subsurface drains from day 8 (first sample) to day 308 was 257 mm.

Figure 2 illustrates the concentration of norflurazon in the drains for the two studies. In the 1988-89 season the peak concentration (1.42 μg/L) occurred on day 206 after 51 mm of rain fell over the preceding 8 days; at that time total rainfall since application was 723 mm. In the 1989-90 study maximum seasonal concentration (10.81 μg/L) at day 22 occurred after 51 mm of rain fell since the first leaching event on day 8 and after a total of 62 mm since application. A second peak (4.58 μg/L) occurred on day 56. The maximum (4.66 μg/L) at day 202 was preceded by 73 mm of rain over an 11-day period and by a total of 1416 mm of rain since application.

Cumulative leaching losses of norflurazon into the subsurface drains for the two seasons are shown in Figure 3. The 1988-89 study recorded a total loss (for days 171-302) of 0.68 g/ha, which amounted to 0.03% of the application (2.24 kg/ha).

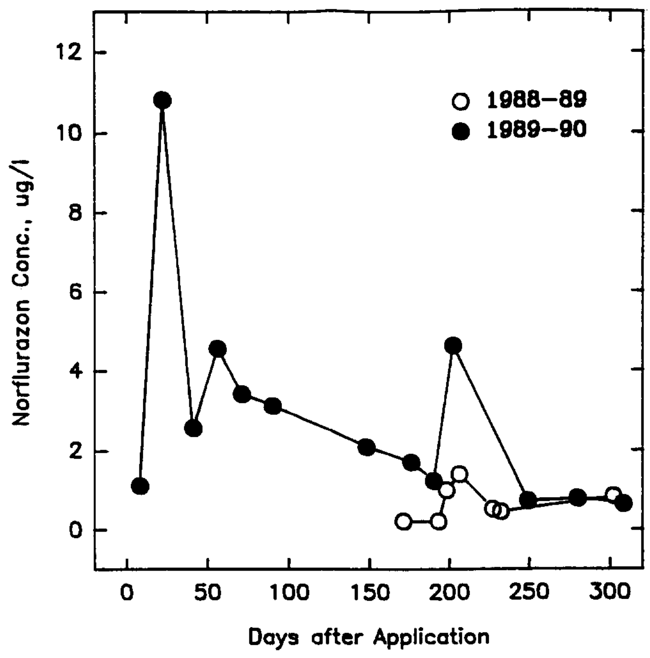

Figure 2. Concentration of norflurazon in subsurface drains.

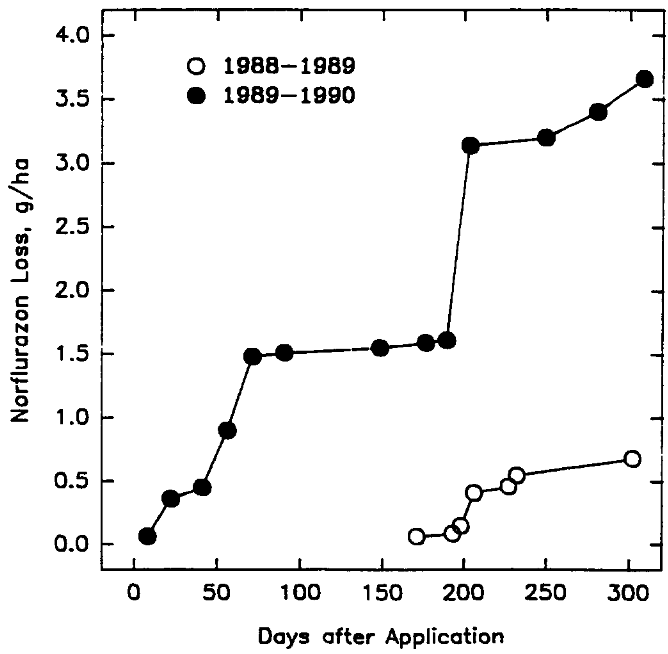

Figure 3. Cumulative norflurazon loss in drains.

Most of the loss (0.46 g/ha, 68% of the total) occurred between days 193 and 232 during a period of 194 mm of rain and 92 mm of subsurface drainage. The second season showed a cumulative loss (days 8-308) of 3.66 g/ha, 0.16% of the amount applied. This loss occurred mainly in two periods, days 8-71 (1.42 g/ha, 39% of total) during a time of 740 mm of rainfall and 59 mm of subsurface drainage, and days 189-203 (1.53 g/ha, 42% of total) when 140 mm of rain fell and 31 mm of drainage into the sumps occurred. For both seasons, these periods of maximum leaching losses shown in Figure 3 coincided with the times of maximum herbicide concentrations in the drain water illustrated in Figure 2.

Table 2. Summary of atrazine and norflurazon leaching studies.

	Herbicide in Soil	------------Highest Concentration in Drains-----------			
	DT_{50} Days	Time[a] Days	Cum. Rain mm	Cum. Drain. mm	Conc. μg/L
Atrazine, 1987	36	12	47	10	3.53
Norflurazon, 1988-89	40	206	723	74	1.42
Norflurazon, 1989-90	120	22	62	20	10.81

	--------------------Total Leaching Loss------------------			
	Time[a] Days	Cum. Rain mm	Cum. Drain. mm	Loss g/ha (%)[b]
Atrazine, 1987	243	1091	133	0.62 (0.04)
Norflurazon, 1988-89	302	1000	155	0.68 (0.03)
Norflurazon, 1989-90	308	2084	257	3.66 (0.16)

[a]Time after application

[b]% of application

Table 2 summarizes the results of our work with norflurazon and presents for comparison data acquired for atrazine (Southwick et al., 1990). The 1988-89 norflurazon study was characterized by cumulative rainfall and sub-surface drainage that were similar to those for the 1987 atrazine investigation, and the herbicide leaching losses were similar in these two seasons. Comparing the 1989-90 norflurazon season with atrazine, the difference in time to peak concentration in the drains along with the differences in rainfall and subsurface drainage associated with these maximum concentrations might indicate slightly retarded leaching of norflurazon with respect to atrazine. In the opposite direction, twice as much rainfall and subsurface drainage in the second norflurazon season produced five times the leaching losses of this herbicide compared to atrazine. The studies of Table 2 were conducted on the same field plots. Nevertheless, since the investigations were conducted in different seasons, the significance of the similarities and differences of the leaching results exhibited by the two compounds in our work is unclear. Our norflurazon results do suggest, however, that soil leaching of this herbicide could be an important disappearance pathway.

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REFERENCES

Alva AK, Singh M (1990) Sorption of bromacil, diuron, norflurazon, and simazine at various horizons in two soils. Bull Environ Contam Toxicol 45(3):365-374.

Gianessi LP, Puffer CA (1991) The use of herbicides in U.S. crop production: use coefficients listed by active ingredient by state. Resources for the Future, Inc. Washington, DC. p. 41.

Herbicide handbook of the Weed Science Society of America (1989). Weed Science Society of America Champaign, Ill.

Hiltbold AE, Buchanan, GA (1977) Influence of soil pH on persistence of atrazine in the field. Weed Sci 25(6):515-520.

Hubbs CW, Lavy TL (1990) Dissipation of norflurazon and other persistent herbicides in soil. Weed Sci 38(1):81-88.

Jury WA, Winer AM, Spencer WF, Focht DD (1987) Transport and transformations of organic chemicals in the soil-air-water ecosystem. Rev Environ Contam Toxicol 99:119-164.

Kladivko EJ, Van Scoyoc GE, Monke EJ, Oates KM, Pask W 1991. Pesticide and nutrient movement into subsurface tile drains on a silt loam soil in Indiana. J Environ Qual 20(1):264-270.

Rahn PR, Zimdahl RL (1973) Soil degradation of two phenyl pyridazinone herbicides. Weed Sci 21(4):314-317.

Richard TL, Steenhuis TS. 1988. Tile drain sampling of preferential flow on a field scale. J Contam Hydrol 3(2-4):307-325.

Schroeder J, Banks PA (1986a) Persistence of norflurazon in five Georgia soils. Weed Sci 34(4):595-599.

Schroeder J, Banks PA (1986b) Persistence and activity of norflurazon and fluridone in five Georgia soils under controlled conditions. Weed Sci 34(4):599-606.

Southwick LM, Willis GH, Bengtson, RL, Lormand, TJ (1990). Atrazine and metolachlor in subsurface drain water in Louisiana. J Irr Drain Engin 116(1):16-23.

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