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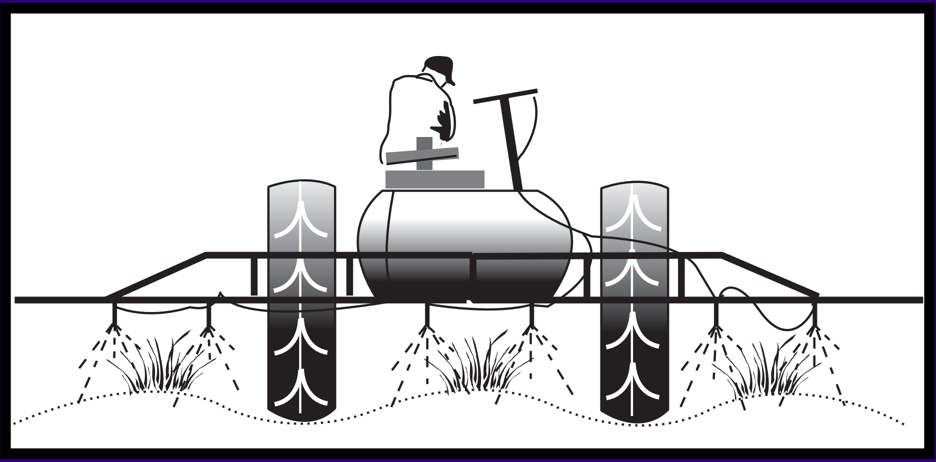

RUNOFF LOSSES OF ATRAZINE, METRIBUZIN, AND NUTRIENTS AS AFFECTED BY MANAGEMENT PRACTICES FOR SUGARCANE

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INTRODUCTION

Atrazine and metribuzin are two herbicides used extensively in Louisiana sugarcane production. Atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] and metribuzin [4-amino-6-*tert*-butyl-3-(methylthio)-*as*-triazin-5(4H)-one] are both in the triazine family of herbicides. Chemical weed control programs for sugarcane usually require two herbicide applications, one before crop emergence and another postemergence before the crop canopy closes. Sugarcane producers in southern Louisiana refer to the latter application as the layby treatment. Such herbicide treatments follow the last cultivation before harvest. Weed development after canopy closure is usually controlled by shading and competition from sugarcane plants. Currently, metribuzin is recommended as a preemergence and postemergence (layby) treatment for controlling seedling johnsongrass, other seedling grasses, and most broadleaf weeds in sugarcane. Atrazine is recommended as a preemergence treatment to control winter or early spring weeds or as a postemergence treatment for layby or fallow fields.

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[1] This study was funded in part by the Louisiana Department of Environmental Quality contract number 24400-93-32, Jan Boydstun, project officer.

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Atrazine has been used extensively for more than 40 years and is perhaps one of the most widely applied herbicides in the world today. Atrazine has been detected in groundwater samples collected from agricultural lands. Although atrazine concentration levels in the groundwater tend to be low, its long persistence suggests that it reaches the water table and is for that reason subject to accumulation in groundwater (Johnson et al., 1995). The lifetime health advisory level for atrazine in drinking water is 3 parts per billion (ppb) (Wauchope et al., 1992).

Metribuzin is a commonly used herbicide and is characterized by its high water solubility (1200 mg per liter), moderate half life (40 days), and low affinity or adsorption capacity to the soil (K_{oc} of 60). The lifetime health advisory level for metribuzin in drinking water is 200 ppb (Wauchope et al., 1992).

A primary objective of this investigation was to evaluate the effectiveness of selected pesticide management practices on the movement of atrazine and metribuzin in surface runoff from sugarcane fields in south Louisiana. It is estimated that of all the acreage of sugarcane grown in Louisiana, about half receives atrazine and metribuzin as part of the annual production practices. These application practices, combined with the high annual rainfall of south Louisiana, could result in significant amounts of herbicide reaching non-target sites in the environment. In a field study of herbicide fate in south Louisiana soils, Southwick et al. (1992) reported effluent outflow atrazine concentrations of 82-403 ppb in subsurface drains within five to 11 days after application on a Sharkey clay soil. In a similar study, Southwick et al. (1995) found high concentrations of atrazine (81 ppb) and metribuzin (94 ppb) within eight to 10 days after application. In addition, atrazine concentrations in the surface soil of this Sharkey clay (0-15 cm) of 1432, 503, 208, 93, and 49 ppb were found 2, 14, 35, 73, and 84 days after application. As a result, Southwick et al. (1995) and Johnson (1995) suggested that preferential or macropore flow was a significant process in this Sharkey clay soil.

Numerous research efforts have been made characterizing fertilizer nutrients interactions and runoff losses within the soil environment. Campbell et al. (1985) studied nitrogen and phosphorus losses from a sandy, shallow water table soil used for potato production in Florida. Inorganic nitrogen losses from the subsurface drainage-irrigation system were about 35 percent less than from the water-furrow irrigation system, and orthophosphate losses were about 60 percent less. Hubbard et al. (1986) applied nitrogen to small plots with a sandy soil at rates from 87 to 336 kg/ha to compare nitrate-nitrogen concentrations and loads in shallow groundwater as related to application rate. Mean nitrate concentrations at a depth of 2.1 m ranged from 8.8 mg/1 under 87 kg/ha N to 23.7 mg/1 under 336 kg/ha N. They found the nitrate concentration to be 20 mg/1 at a depth of 2.1 m where intensive multiple cropping systems had been used for five years with center pivot irrigation. They did not get any results at a depth of 3.4 m.

In Louisiana, Bengtson et al. (1988) conducted an eight-year subsurface drainage runoff erosion experiment on corn grown on a clay loam alluvial soil with 0.1 percent slope. Surface runoff, soil erosion, and total phosphorus and total potassium in runoff were reduced 34 percent, 30 percent, 36 percent, and 32 percent, respectively, by subsurface drainage. There was no significant difference between total nitrogen losses from the subsurface-drained and surface-only drained systems.

In this publication, we focused on the fate of two herbicides; atrazine and metribuzin, in the soil and runoff water during a three-year growing cycle (plantcane, first stubble, and second stubble crops) for sugarcane in south Louisiana. A second objective was to quantify fertilizer nutrient losses as well as soil losses as affected by selected management practices.

MATERIALS AND METHODS

This study was initiated in 1992 as part of a Louisiana Department of Environmental Quality (LA-DEQ) Sugarcane Demonstration Project (section 319). The major goal was to compare losses of applied fertilizers (N, P, and K), herbicides atrazine and metribuzin, and insecticides (azinphosmethyl) in surface runoff water on sugarcane fields under different management practices. The study was carried out at St. Gabriel Research Station, LSU AgCenter, on a Commerce silt loam soil (fine-silty, mixed, nonacid, thermic, Aeric Fluvaquent). Three treatments were established: a medium treatment receiving recommended levels of N, P, and K and number/method of herbicide and insecticide[5] applications; and high and low treatments, receiving above and below the medium levels of chemical applications, respectively. Six 0.22-ha plots were selected (two plots for each treatment). Each plot consisted of nine raised rows 150 m long, 0.40 m high, and 1.82 m spacing. Two additional rows served as levees separating adjacent plots and providing drainage from areas outside the plots. At the lowest corner of each plot a sump made of corrugated iron was established (1.50 m diameter, 1.80 m deep) to collect runoff water. Sump pumps were installed in each sump, equipped with flow meters and solution samplers.

All plots were planted with the sugarcane variety CP70-321 in September 1992. The high, medium, and low treatments were fertilized every spring at the rates of 202-90-134 kg/ha, 134-45-90 kg/ha, and 67-0-0 kg/ha of N-P_2O_5-K_2O. Atrazine (4L) was applied

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[5] Results on the fate of azinphosmethyl, its rate of disappearance on leaves and soils, and runoff losses are available from Selim et al. (1995), Granovsky et al. (1996), and Selim et al. (1997). Moreover, for information regarding the effect of cover crops (winter wheat, soybeans, and fallow) on reducing erosion of sediments and nutrient losses in surface runoff during the fallow (fourth) year of the sugarcane growing cycle, the reader may refer to Bengtson et al. (1998).

as a winter herbicide on January 6, 1994, and December 20, 1994. Atrazine was applied with a spray-rig with adjustable nozzles 45 cm above the ground surface. The amounts applied were 0.90, 0.45, and 0.30 kg/ha for the high, medium, and low treatments, respectively. For the high treatment, broadcast application of atrazine was carried out. For the medium and low treatments, atrazine was applied as a band in top of the rows. For the medium treatment, the band width was 91 cm; a band width of 60 cm was maintained for the low treatment. Metribuzin was applied each spring on March 29, 1993, March 18, 1994, and May 2, 1995, as a pre-emergence herbicide and was applied using a spray-rig with adjustable nozzles in a similar manner to atrazine. Specifically, metribuzin was applied as broadcast, 91 cm band, and 60 cm band width for the high, medium, and low treatments, respectively. The amounts of metribuzin (active ingredient) applied were 0.81, 0.45, and 0.27 kg/ha, for the broadcast, 91 cm band, and 60 cm band width, respectively. After each herbicide application (atrazine or metribuzin), composite samples of surface soil (25 mm depth) were taken along one of the five center rows for each of the six plots. The rows within each plot were alternated randomly between the sampling dates. Sampling was carried out daily for the first few days, and from five to seven days apart thereafter. In addition, subsurface soil samples were taken to a depth of 90-cm (15-cm depth increments) during the 1994 growing season. Runoff water was automatically sampled following rainfall that caused sufficient runoff to occur. All runoff water samples were stored at 4 degrees C until laboratory analysis for nutrients and pesticides.

EXTRACTIONS:

The laboratory procedure for extraction of pesticides from soil and runoff water was as follows. Extractions from field (moist) soil were carried out using 0.01 N NaCl methanol/water solution (4:1 volume:volume), shaking for 24 hours, centrifuging, decanting, and removing water using anhydrous sodium sulfate. The extracts were subsequently evaporated and transferred in hexane to 2.0 mL vials (Southwick et al., 1995). Runoff water samples (250 mL) were extracted using dichloromethane in a separatory funnel. The remaining steps were similar to those for soil extractions.

The herbicides were measured using a Hewlett-Packard 5890A series II gas chromatograph with He as carrier gas and ^{63}Ni electron capture detector. A coiled fused silica capillary column (PAS-1701, 25 m in length and 0.32 mm i.d.) was used with a column flow of 1 mL/min. Oven temperature was programmed to rise from 80 to 190 degrees C at 30 degrees C/min and then to 260 degrees C at a rate 3.6 degrees C/min. The injection and detector temperatures were maintained at 250 and 300 degrees C, respectively. The retention times for atrazine and metribuzin were 7.960 ± 0.02 min and 9.698 ± 0.02 min, respectively. The lower limits of detection were 0.05 and 0.10 ppb for runoff water for atrazine and metribuzin, respectively. For nitrogen, phosphorus, and potassium in sediment and runoff waters, total nitrogen was analyzed using the Kjeldahl method whereas P and K were determined by atomic absorption.

RESULTS AND DISCUSSION

SURFACE RUNOFF AND SOIL LOSSES:

For 1993, 1994, and 1995, the average annual rainfall was 1449 mm (57.06 in), close to the normal of 1445 mm (56.87 in). Because of field installation, runoff losses of soil and water were not measured until July 1993 (see Tables A1-A5 in the Appendix). Average rainfall, surface runoff, and soil losses are shown in Figs. 1 and 2. The average annual surface runoff was 689, 684, and 687 mm (27.14, 26.87, and 27.05 in) for the high, medium, and low treatments, respectively. Analysis of variance indicated there were no significant differences of runoff among all the treatments (p=0.258). Moreover, for all treatments, there were no significant differences among the 1993, 1994, and 1995 runoff results (p=0.994). The highest monthly runoff was in March, with 193 mm (7.59 in), and the lowest was in August and September, with 68 mm (2.68 in) and 56 mm (2.22 in), respectively.

Average annual soil losses were 17.30, 17.29, and 18.07 t/ha (7.74, 7.72, and 8.04 t/ac) for the high, medium, and low treatments, respectively. Analysis of variance indicated there were no significant differences among the different treatments (p=0.953). Highest monthly soil losses were in January and March, with 3.36 t/ha (1.50 t/ac), and the lowest were in August and September, with 0.02 t/ha (0.01 t/ac). Significant differences (p=0.0044) were obtained for sediment soil losses among the different years (plant, first-stubble, and second stubble). Specifically, significantly higher soil losses were recorded for the first stubble year (1994) compared to the second stubble (1995). For July to December, the plant cane year (1993) yielded significantly higher soil loss than 1994 and 1995 for all three treatments. Soil preparation and loosening during planting during summer and fall of 1992 resulted in optimum soil losses during 1993 with significant decreases during the first and second stubble years.

NUTRIENT RUNOFF LOSSES:

Figure 3 shows average monthly accumulated nitrogen losses in runoff waters during 1993-1995. Average annual nitrogen losses were 23.31, 18.07, and 11.14 kg/ha (20.82, 16.10, and 9.94 lb/ac) for the high, medium, and low treatments, respectively (see Table A3 in the Appendix). Analysis of variance indicated there were significant differences of nitrate nitrogen losses in the runoff among all the treatments (p=0.05). Specifically, a significant difference of nitrogen losses between the high and low treatments occurred (p=0.0149), whereas there was no significant difference between the medium and either the low or high treatments. As a result, the amount of nitrogen losses in surface runoff is influenced by the amount of fertilizer nitrogen applied. The highest monthly nitrogen losses were in May and June, with 4.19 and 6.46 kg/ha (3.74 and 5.77 lb/ac), respectively, and the lowest were in August and September, with 0.05 kg/ha (0.04 lb/ac). Analysis of variance also indicated there were significant differences among the 1993, 1994, and 1995 nitrate nitrogen losses (p=0.044). The results indicate there was a significant difference between 1994 and 1995 nitrogen runoff losses (p=0.0138). No differences were found between 1993 and either 1994 or 1995 losses, most likely because of residual nitrogen in the soil from uniform application of fertilizer during the previous growing sugarcane cycle (1988-1991).

Figure 4 shows average monthly accumulated phosphorus losses in runoff waters in 1993-1995. Average annual phosphorus runoff losses were 14.89, 13.80, and 12.65 kg/ha (13.30, 12.30, and 11.30 lb/ac) for the high, medium, and low treatments, respectively (see Table A4 in the Appendix). Analysis of variance indicated there were significant differences of phosphorus losses in the runoff among the 1993, 1994, and 1995 (p=0.008). There were no significant differences of the amount of phosphorus losses among the three treatments (p=0.84). Significantly less P loss occurred in 1993 than in 1994 or 1995; more P losses occurred in 1994 than in 1995, but the differences were not significant (P=0.183). Highest monthly phosphorus losses were in March and May, with 1.98 and 2.45 kg/ha (1.77 and 2.19 lb/ac), respectively, and the lowest were in July, August, and September, with 0.05 kg/ha (0.04 lb/ac). This may be the result of the strong soil adsorption capacity to phosphorus and the high amount of extractable phosphorus in this Commerce soil.

Current soil test recommendation for sugarcane is that no P be added to this soil (LSU AgCenter Soil Testing Lab, 1995).

Average annual potassium losses were 100.71, 104.36, and 79.34 kg/ha (see Table A5 in the Appendix) for the high, medium, and low treatments, respectively (see Table A5 in the Appendix). These results suggest that reducing the amount of potassium applied to zero, as was the case for the low treatment, reduced the amount of potassium losses from the surface runoff. Figure 5 shows average monthly accumulated potassium losses in runoff waters during 1993-1995. However, there were no significant differences among three treatments (p=0.34). Analysis of variance also indicated there were significant differences of potassium losses in the runoff among 1993, 1994, and 1995 (p=0.006). Highest monthly potassium losses were in January and March, with 17.74 and 15.00 kg/ha (15.84 and 13.40 lb/ac), respectively, and the lowest were in August and September with 0.40 kg/ha (0.35 lb/ac). This may be the result of the high cation exchange capacity of and the high amount of extractable K in this Commerce soil (LSU AgCenter Soil Testing Lab, 1995). Similar to phosphorus, soil test recommendation for sugarcane is that no additional potassium to be added to Commerce soil.

ATRAZINE RUNOFF LOSSES:

Since the intensity of herbicide application was maintained constant (amount per area of coverage) for all three treatments, as a result for the medium and low treatments one-half and one-third the amount of herbicides received on an acre or hectare basis compared to the broadcast application, respectively. Actual amounts of atrazine active ingredient applied were 2.2, 1.1, and 0.7 kg/ha (2, 1 and 0.66 lb/acre) for the high, medium, and low treatments, respectively.

Atrazine concentration levels in the runoff ranged from 600 to 700 ppb measured six days following applications for the high treatment during the 1994 growing season. Figures 6 and 7 show averaged atrazine runoff concentration for the 1994 and 1995 growing seasons. For the medium treatment, the concentration level was drastically reduced to a range of 120 to 140 ppb, and for the low treatment the concentrations did not exceed 80 ppb. Some three months following applications, the amount detected in the surface water was in the 20-30 ppb range. During the 1995 growing season, atrazine concentration in runoff waters eight and 11 days after application was in the range of 12-46 ppb for the low treatments and 100 to 480 ppb for the high treatments. One month after application, atrazine concentrations decreased considerably for all treatments. Concentration levels reached 15-20 ppb in the runoff for low treatment and 50 to 75 ppb for the high treatment. The differences among treatments also diminished, although higher concentrations were consistently observed for plots receiving larger applications (high > medium > low). Two months after application, atrazine concentrations in the runoff waters were further reduced to 4 to 10 ppb for all plots, without noticeable difference among the different treatments.

Based on effluent herbicide concentrations in the runoff and the volume of the effluent as a measure of the runnoff from each plot, we were able to calculate the total amount of herbicide losses in the runoff for each treatment. During the 1994 growing season, the total amounts of atrazine losses in runoff waters were 53, 92, and 249 g/ha, for the low, medium and high treatments, respectively. These runoff losses represent 7.6% to 11% of the applied amounts of atrazine among the three treatment (Table 1). Therefore, a significant reduction of the total atrazine losses in runoff water was achieved for band application in comparison to full broadcast. In fact, in 1994 the amount of losses were reduced by 63% for the 91 cm band width and 78% for the 60 cm band width compared to full broadcast. For 1995, atrazine losses were considerably lower than for the 1994 growing season and ranged from 1.91% to 2.85% of that applied. It

Table 1. Amount of losses of atrazine in runoff water during 1994 and 1995.

Treatment	1994		1995	
	g/Ha	% loss	g/Ha	% loss
Low	53	7.6	14.1	1.91
Medium	92	8.0	22.9	2.04
High	249	11.0	64.5	2.85

is important to emphasize here that significantly lower atrazine losses were determined for the medium and low treatments compared to the high treatment where full broadcast application was carried out. Moreover, rainfall distribution patterns and timing of application did not influence the amount susceptible for runoff among treatments.

ATRAZINE IN THE SURFACE SOIL:

Amounts of extractable atrazine in the soil surface also decreased rapidly with time following application as shown in Fig. 8 for 1994. Maximum concentration occurred three to four days following application for all three treatments. Lowest concentrations in the soil were observed for the low treatment, whereas maximum concentrations were observed for the high treatment. These results on atrazine illustrate the importance of method of application or placement of applied agricultural chemicals. Values of 3000-5000 ppb were observed for the high treatment compared to 1000-2000 for the low treatment. The continued decrease of extractable atrazine from the soil is indicated by the sharp decrease with time to levels below 50 ppb within 90 days following application. This decrease is caused by biodegradation, surface runoff, and downward movement into the soil profile (Ma and Selim, 1995). Persistent levels of atrazine as much as 95 ppb were observed some 182 days following applications. Moreover, the resulting concentration in the runoff water is directly influenced not only by the amount but also the area of coverage.

During 1995, the extractable atrazine in the top 2.5 cm (1-inch) soil layer varied widely between the different treatments and sampling dates. This variation is caused by intrinsic soil heterogeneity of soil properties, uniformity of atrazine spray applications, as well as alternating the rows (among the middle five rows) selected for sampling. Concentrations in surface soil ranged between 1500-3000 parts per billion (ppb) following application (see Fig. 9). The soil samples were taken from the crown and sides of the middle rows and not from the furrows. The latter received atrazine application only on high treatment plots that received a full broadcast application. The tops and sides of each row were presumably covered both by a full broadcast (high treatment) and by the 36-inch band application. For this reason the difference in soil atrazine levels immediately after the spray was expected to be minimal between the high and medium treatments, with somewhat larger difference with the low treatment plots. The tendency for lower average concentrations on the low treatment plots was clear.

Atrazine concentrations levels in runoff waters and residue concentrations in the surface soil in early 1994 were compared to the results from 1995. The concentrations computed separately for treatments were averaged between the two earliest runoff events following the atrazine spray for the two years. Although the differences are statistically insignificant, concentration results indicate that approximately twice as much atrazine in the runoff and surface soil was detected in high and medium treatment plots in 1994 versus 1995. The amounts of rainfall and time elapsed after both applications were similar for the runoff events for both years. It is likely that the soil moisture content at time of atrazine application was considerably different for both years. On December 20, 1994, the soil remained relatively dry for six to seven days following application. In contrast, on January 6, 1994, the soil moisture content was considerably higher. Drier soil results in enhanced degradation losses of atrazine and smaller amounts susceptible for runoff. Mass balance calculations and amounts of atrazine losses in the runoff water for 1994 and 1995 are given in Table 1.

Table 2. Amount of losses of metribuzin in runoff water during 1994 and 1995.

Treatment	1994		1995	
	g/Ha	% loss	g/Ha	% loss
Low	2.2	0.33	23.	3.42
Medium	3.8	0.33	87.	8.70
High	6.0	0.28	150.	7.44

METRIBUZIN RUNOFF LOSSES:

Figures 10 and 11 show metribuzin runoff concentration for the 1994 and 1995 growing seasons. In 1994, some two weeks of no rainfall followed the March 18 metribuzin application. Metribuzin concentrations in runoff waters after March 27 and April 4 rainfalls (1.5 and 2.5 cm, respectively) were negligible. Significant concentrations were observed in runoff waters following rainfall on April 12 and 15. The concentration of metribuzin following these events ranged from 10 to 20 ppb. After June 1, metribuzin concentrations decreased some two months after metribuzin application to levels below 1 ppb. During 1995 growing season, the first runoff occurred six days following metribuzin application (May 8). High concentrations of metribuzin in the runoff were found for all treatments (250-450 ppb from the high, 130-260 ppb from the medium, and 80-110 ppb from the low treatment plots, respectively). The only sample now available indicates that 17 days after the application, metribuzin concentration in surface water decreases rapidly to 80 ppb for the high treatment plot. The latter result is consistent with the maximum of 60 ppb observed on a high treatment 28 days after the metribuzin was applied in 1994. Two months later (June 29), such concentrations decreased to less than 4 ppb for all treatments. In fact, metribuzin concentrations were less than 1 ppb in runoff waters five months following application. As shown in Table 2, cumulative amounts of metribuzin losses in runoff water were highest for full broadcast (0.3%-7.4% of the amount applied) and lowest for the 60 cm band treatment (0.3%-3.4%).

METRIBUZIN IN THE SURFACE SOIL:

Results of extractable metribuzin from the soil surface also decreased rapidly with time (see Figs. 12 and 13). Maximum concentration occurred two to three days following application for all three treatments. Lowest concentrations in the soil were observed for the low treatment, whereas maximum concentrations were observed for the high treatment. The results indicate highest concentrations in the range of 3000 to 7000 ppb. The amount of extractable or residual metribuzin showed a consistent decrease with time. In fact, two weeks following application, these concentrations decreased to a range of 500-1000 ppb. In addition, three months following application, extractable amounts decreased drastically to a range of 0.4 to 5 ppb. The 1995 metribuzin application was followed by intensive sampling of surface soil for a total of nine sampling dates (1, 2, 3, 6, 10, 15, 23, 41, and 51 days after the application), including one time of subsurface sampling (June 22, 1995). Three runoff events were assessed following the metribuzin application (6, 10, 17 days after application), but only a single sample was taken from the third event. Mass balance calculations and amounts of metribuzin losses in the runoff water for 1994 and 1995 are given in Table 2.

ATRAZINE AND METRIBUZIN HALF-LIVES:

Degradation rates for atrazine in surface soil were estimated using the measurements determined in 1994-1995 during the course of this study. The assumption of first order or exponential decay was used. The estimated degradation rates for the two herbicides differed considerably between the years. For metribuzin the half-lives estimates were 7.6±0.3 days in 1995 and 10.0±0.6 days for 1994. For atrazine the half-life estimates were 16.1±1.7 days for 1995 and 45.6±6.4 days in 1994. Therefore, a three-fold difference was observed between various years for both herbicides.

Our attempt to calculate the half-life for a herbicide in surface soil captures several processes, each having a different rate (degradation of the herbicide in soil solution, degradation of the adsorbed herbicide, volatilization, downward movement, etc.). Therefore, the values of half-lives presented here are overall rate of herbicide ‘disappearance’ from the surface soil. Southwich et al. (1995) reported a half-life of 22.3 days for metribuzin in a Sharkey soil. They also reported half-lives for atrazine of 14.4 and 21 days for winter and summer applications, respectively. Based on reported data for several soils, Wauchope et al. (1992) reported half-life values of 60 and 40 days for atrazine and metribuzin, respectively.

SUMMARY AND CONCLUSIONS

ATRAZINE

Atrazine was applied as a winter application for weed control following harvest. It was applied as a broadcast for the high treatment, banded with 91 cm (36-inch) band width for the medium treatment, and 60 cm (24 inch) band width for the low treatment.

- The amounts of atrazine losses in runoff waters varied during 1994 and 1995 because of rainfall distributions. In 1994, atrazine concentration levels in the runoff ranged from 600-1100 ppb as measured six days following applications. For the medium and low treatments, the concentration levels were drastically reduced to the 120 - 140 ppb and 40-80 ppb range, respectively. Some three months following applications, the amount detected in runoff water was in the 20-30 ppb range for all treatments.
- During 1995, atrazine in runoff waters eight and 11 days after application was in the range of 12-46 ppb for the low treatments and 100-480 ppb for the high treatments. Two months after application, atrazine concentrations were reduced to 4-10 ppb for all plots, without noticeable difference among the different treatments.
- Cumulative amounts of atrazine losses in runoff waters were highest for full broadcast (2.8%-11% of that applied) and lowest for the 60 cm (24-inch) band treatment (1.9%-7.6%). These data have an important implication on BMP of agricultural chemicals for sugarcane.
- The recommended band application of atrazine minimizes losses in runoff water over broadcast application.

METRIBUZIN

Metribuzin was applied as a pre-emergence herbicide and was applied in a similar manner to atrazine, that is, a broadcast for the high treatment, banded with 91 cm (36-inch) band width for the medium treatment and 60 cm (24 inch) band width for the low treatment.

■ In 1994, measured maximum concentration in the runoff was 20 - 60 ppb from the high, 10 -20 ppb for the medium, and 5-10 ppb from the low treatment. During 1995, higher metribuzin concentrations in the runoff were measured (250-450, 130-260, and 80-110 ppb for the high, medium, and low treatment plots, respectively). Two months later, such concentrations decreased to less than 4 ppb. Metribuzin concentrations were less than 1 ppb in runoff waters five months following application.

■ Cumulative amounts of metribuzin losses in runoff water were highest for full broadcast (0.3%-7.4% of the amount applied) and lowest for the 60 cm (24-inch) band treatment (0.3%-3.4%).

FIGURES 1 - 13

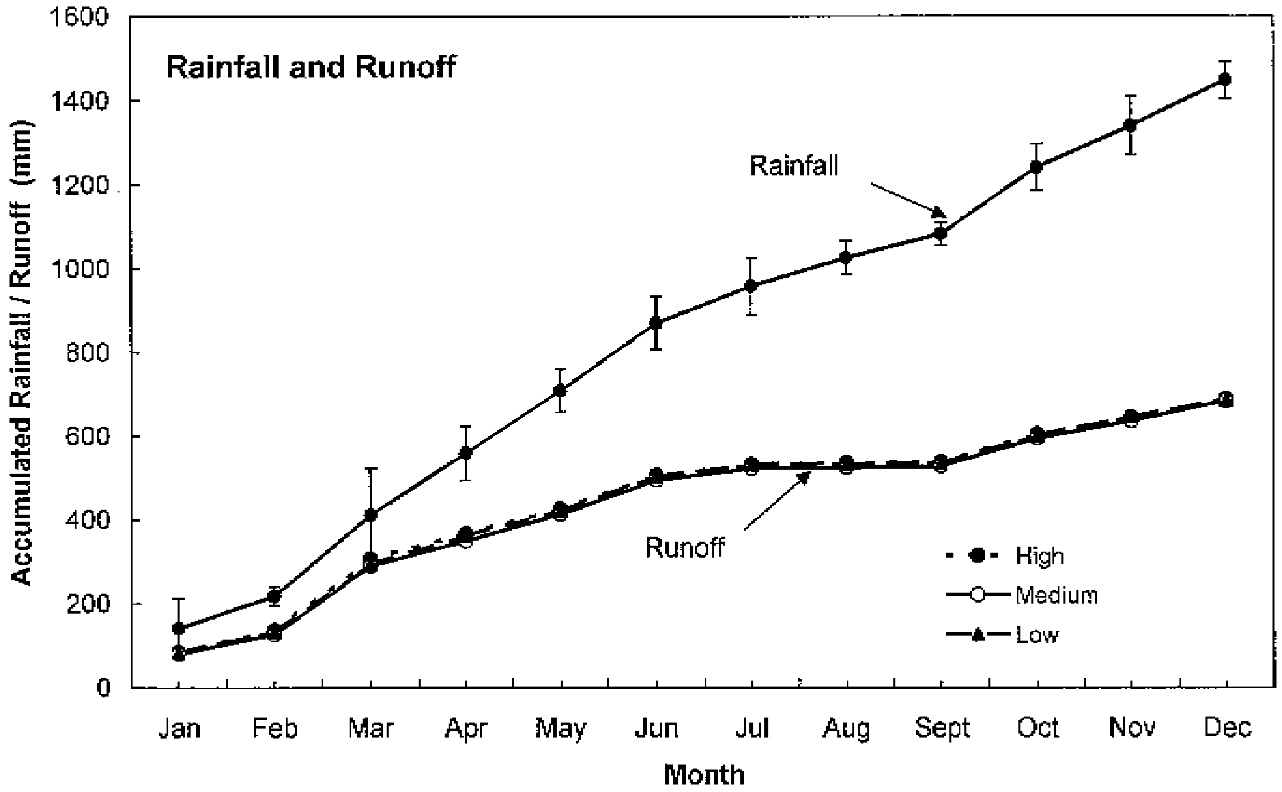

Fig. 1. Average accumulated rainfall and runoff amounts (mm) for 1993 - 1995. Error bars are for monthly rainfall (one standard deviation).

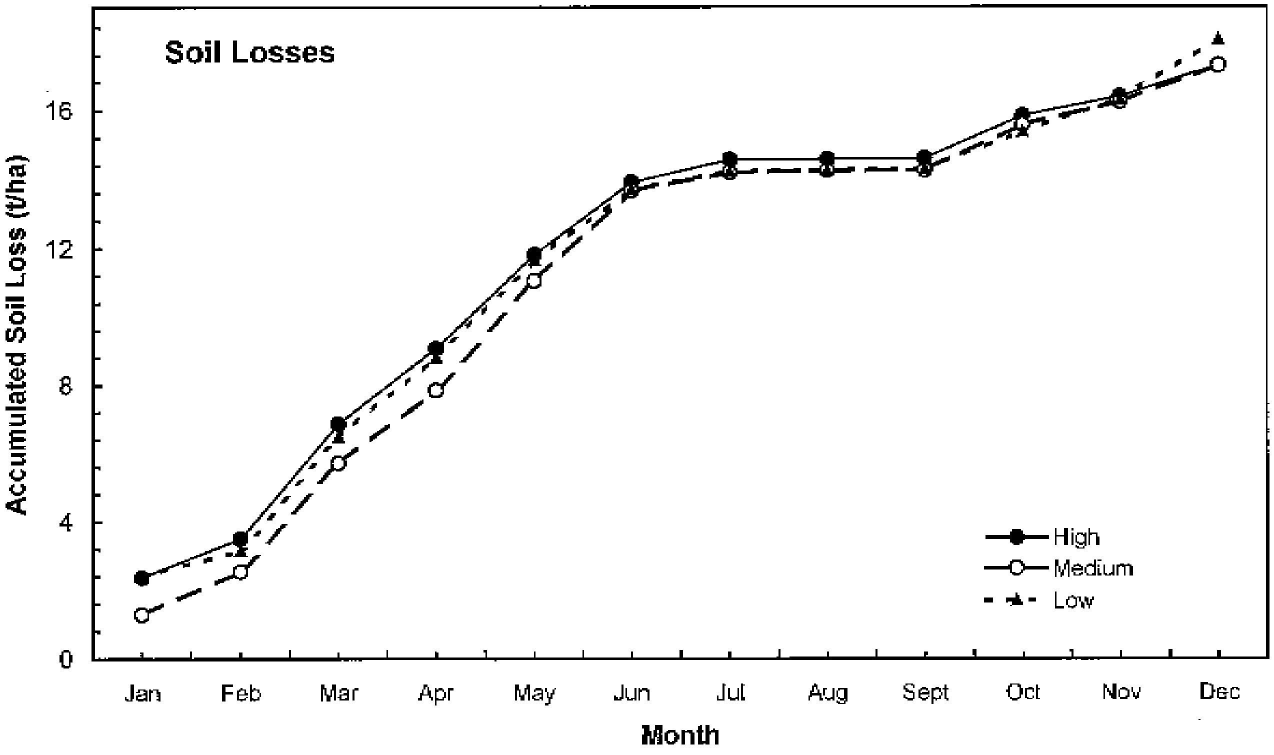

Fig. 2. Average accumulated soil losses for the high, medium, and low treatments for 1993-1995.

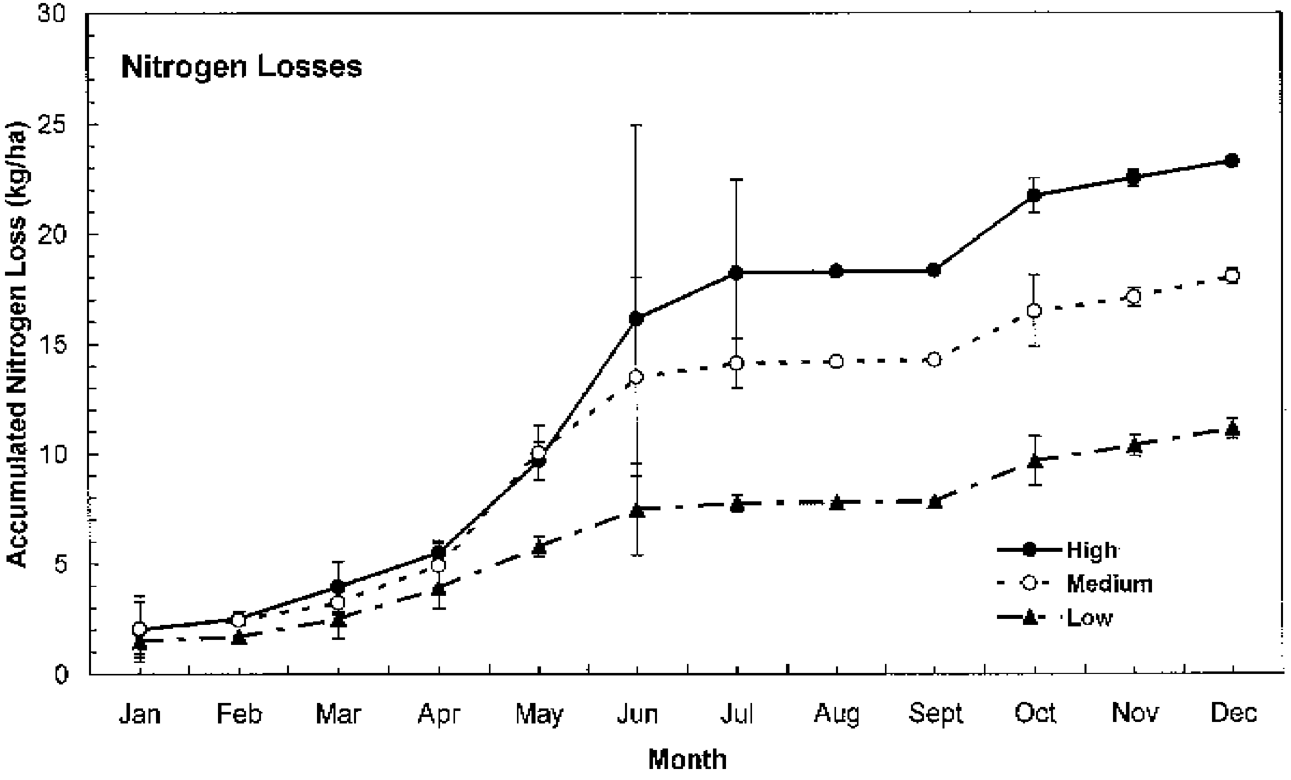

Fig. 3. Accumulated nitrogen losses from the high, medium, and low treatments for 1993-1995. Error bars are for monthly losses (one standard deviation).

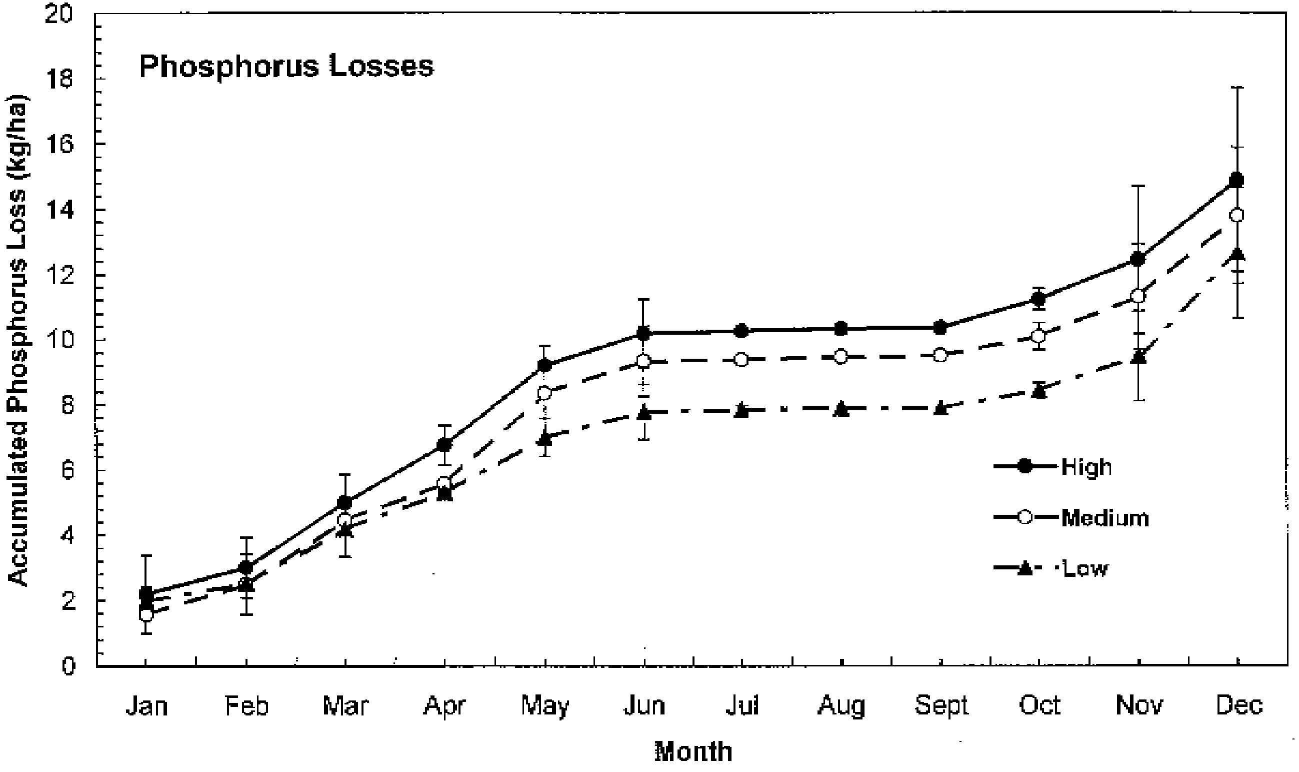

Fig. 4. Accumulated phosphorus losses from the high, medium, and low treatments for 1993-1995. Error bars are for monthly losses (one standard deviation).

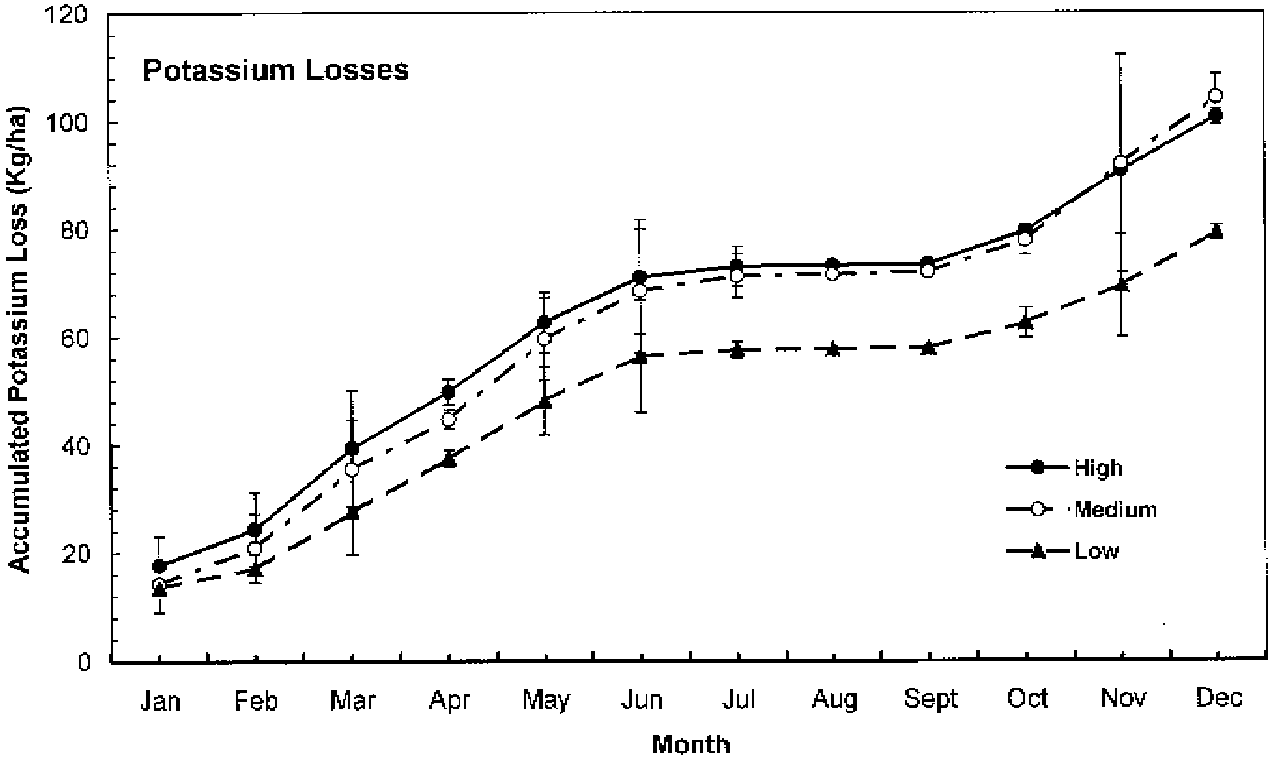

Fig. 5. Accumulated potassium losses from the high, medium, and low treatments for 1993-1995. Error bars are for monthly losses (one standard deviation).

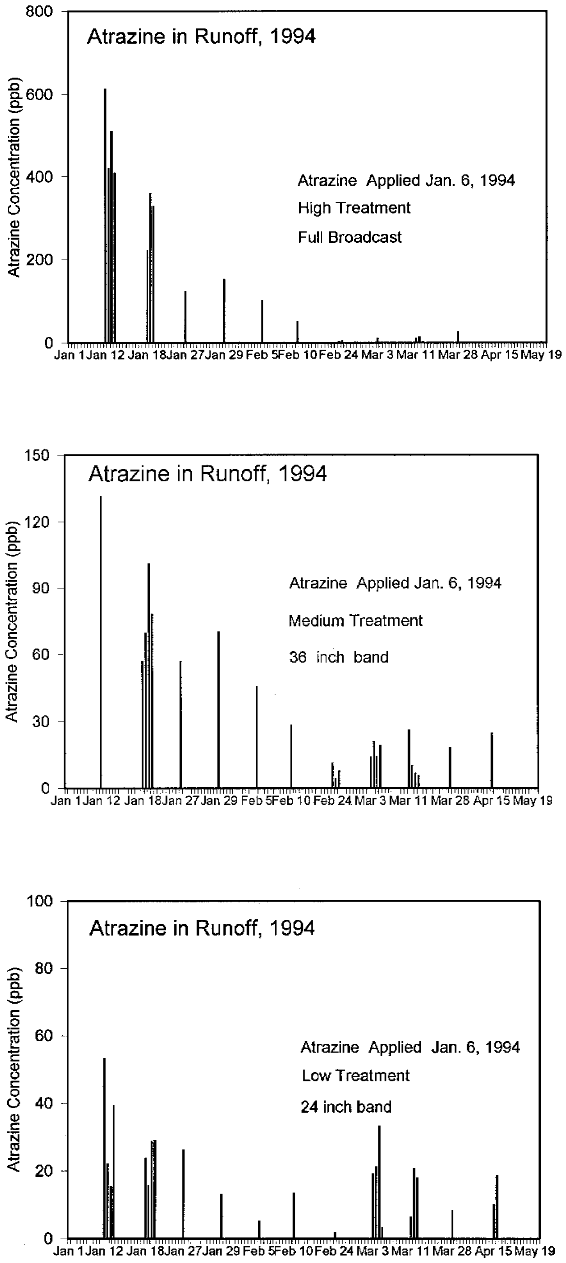

Fig. 6. Atrazine concentrations in water runoff from the high, medium, and low treatment plots during 1994 (average of two replications).

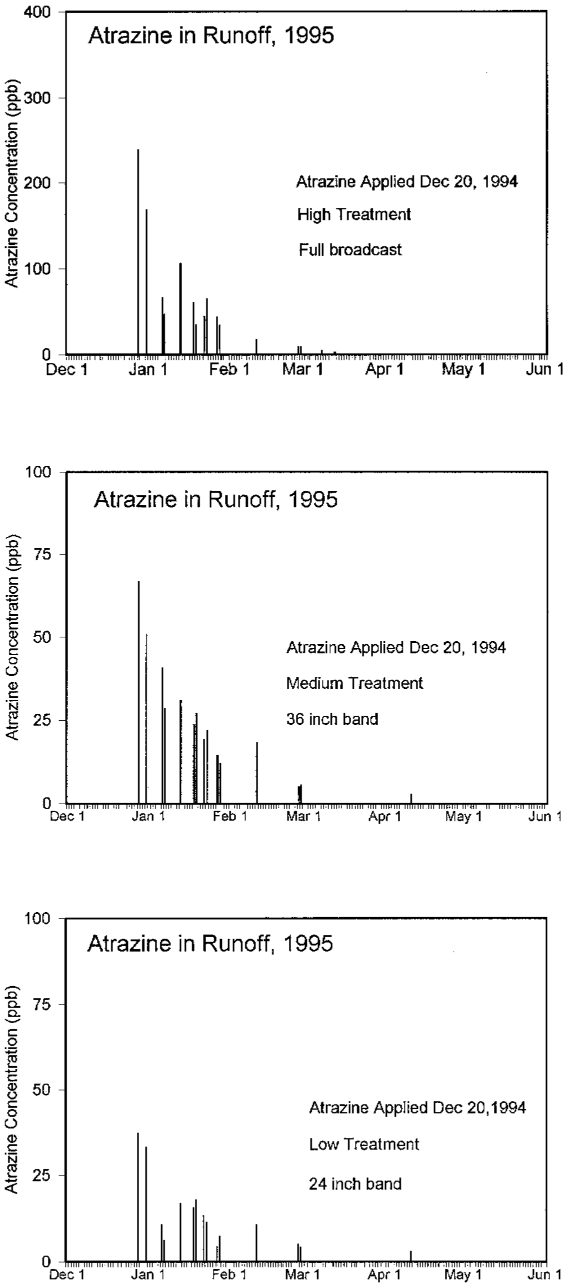

Fig. 7. Atrazine concentrations in water runoff from the high, medium, and low treatment plots during 1995 (average of two replications).

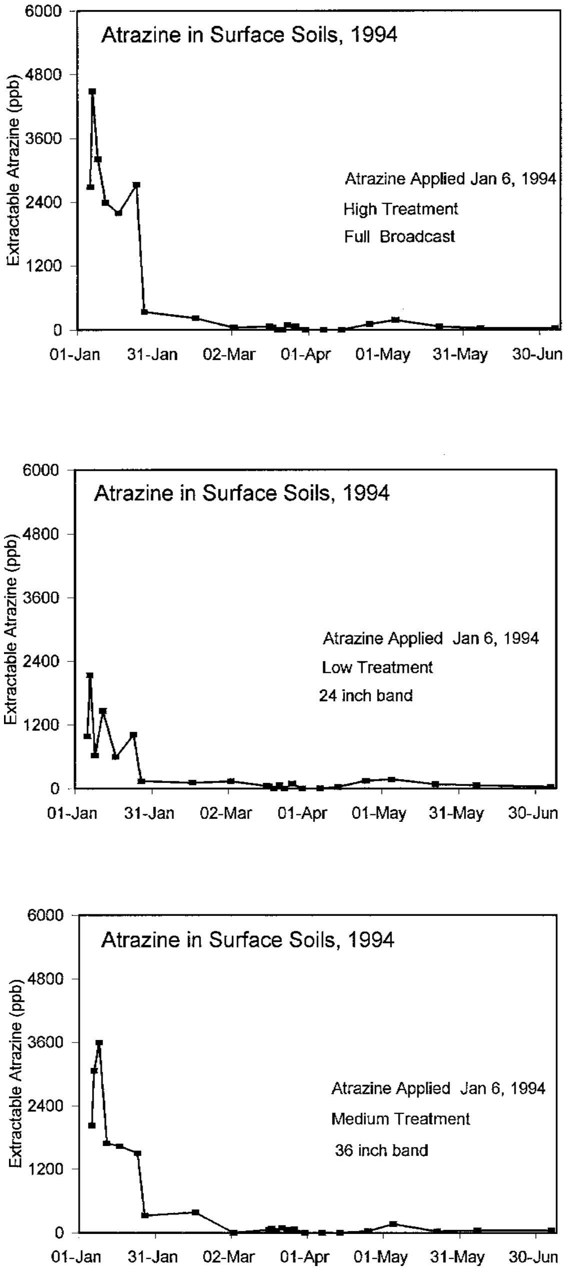

Fig. 8. Extractable atrazine concentrations from the surface soil from the high, medium, and low treatment plots during 1994 (average of two replications).

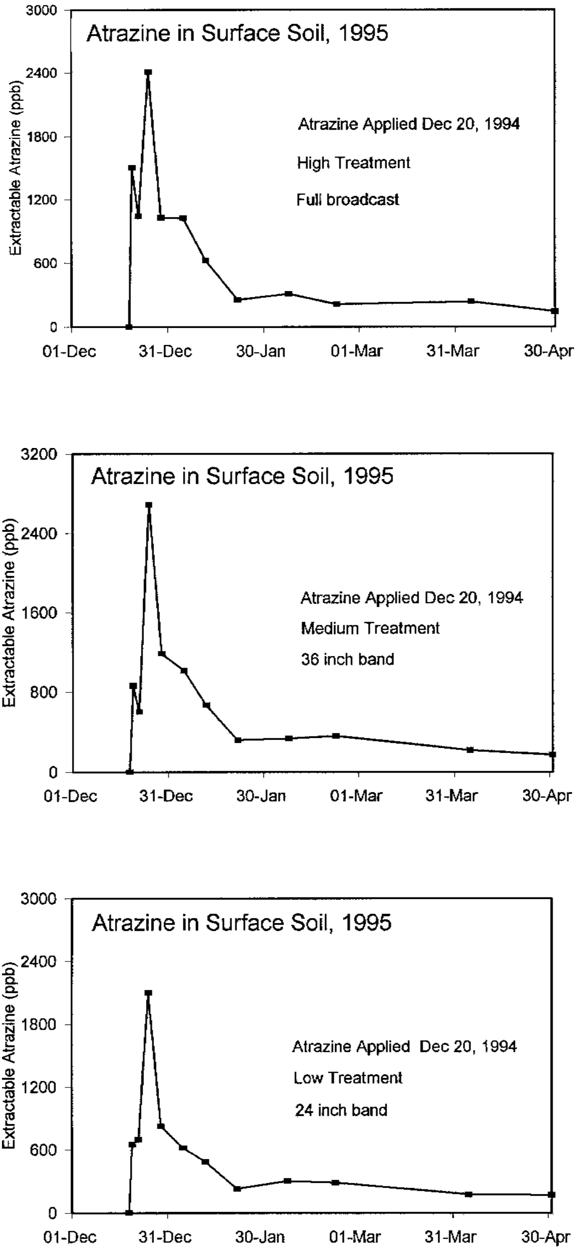

Fig. 9. Extractable atrazine concentrations from the surface soil from the high, medium, and low treatment plots during 1995 (average of two replications).

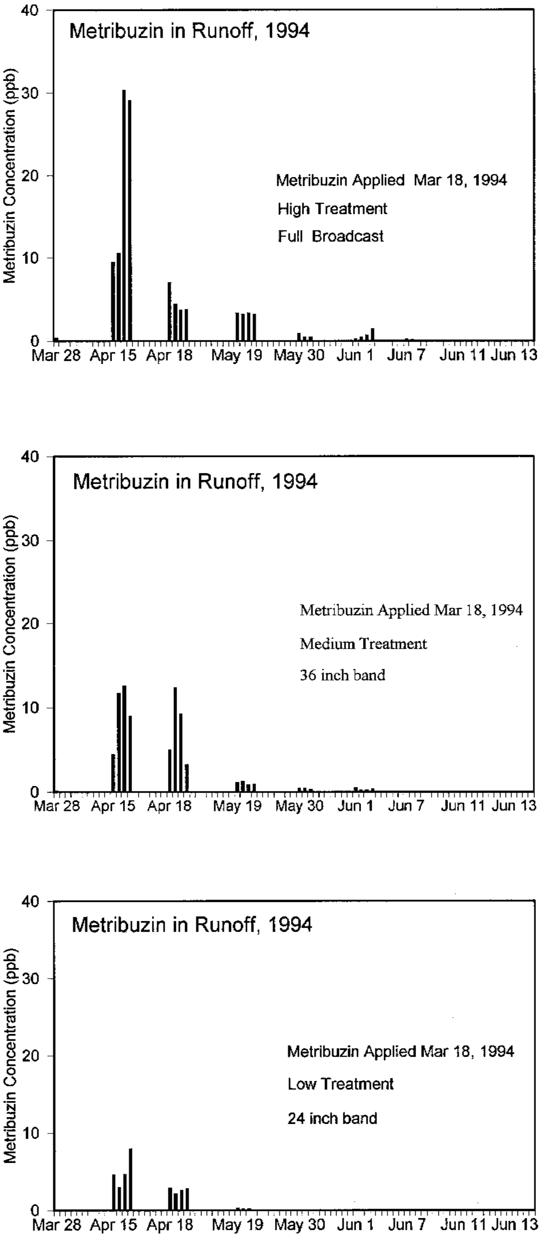

Fig.10 Metribuzin concentrations in water runoff from the high, medium, and low treatment plots during 1994 (average of two replications).

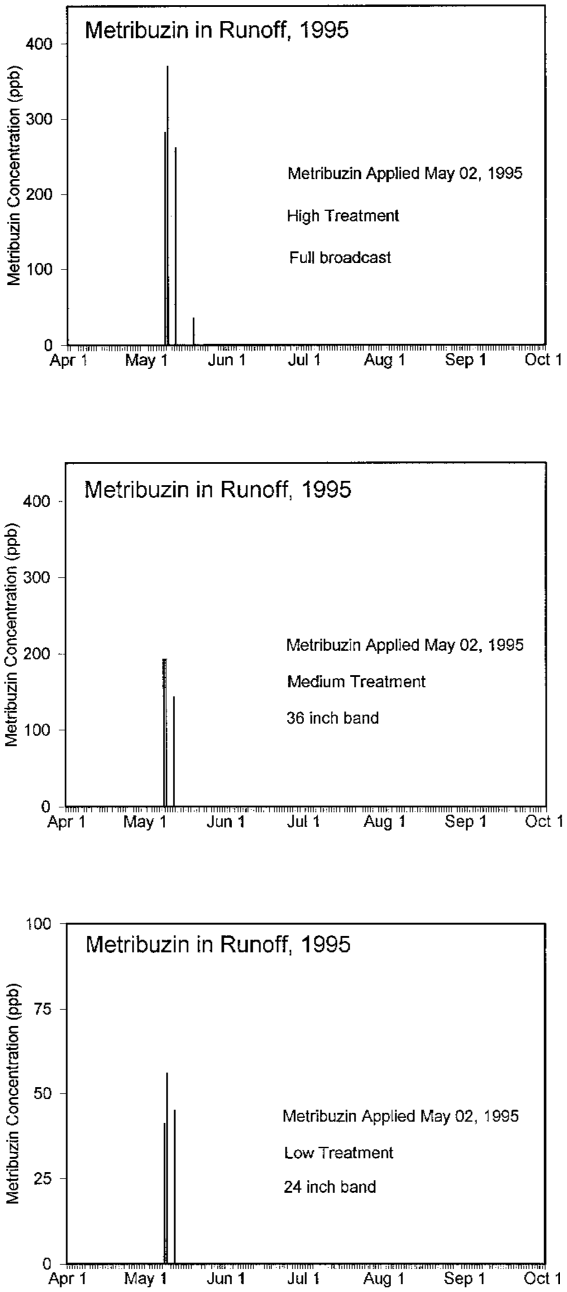

Fig.11 Metribuzin concentrations in water runoff from the high, medium, and low treatment plots during 1995 (average of two replications).

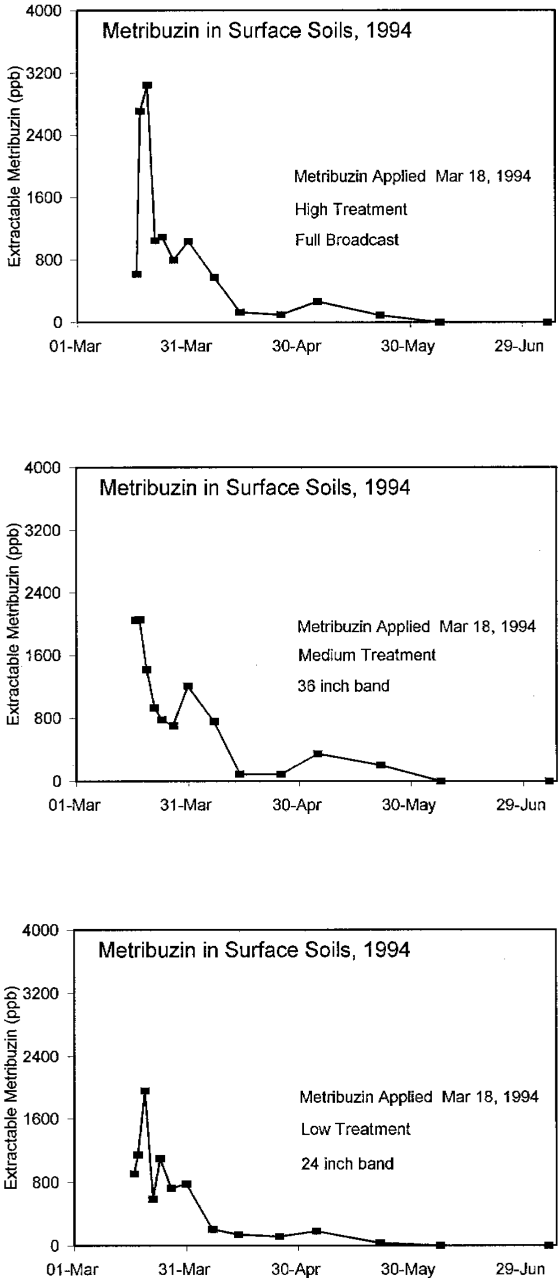

Fig.12 Extractable metribuzin concentrations from the surface soil from the high, medium, and low treatment plots during 1994 (average of two replications).

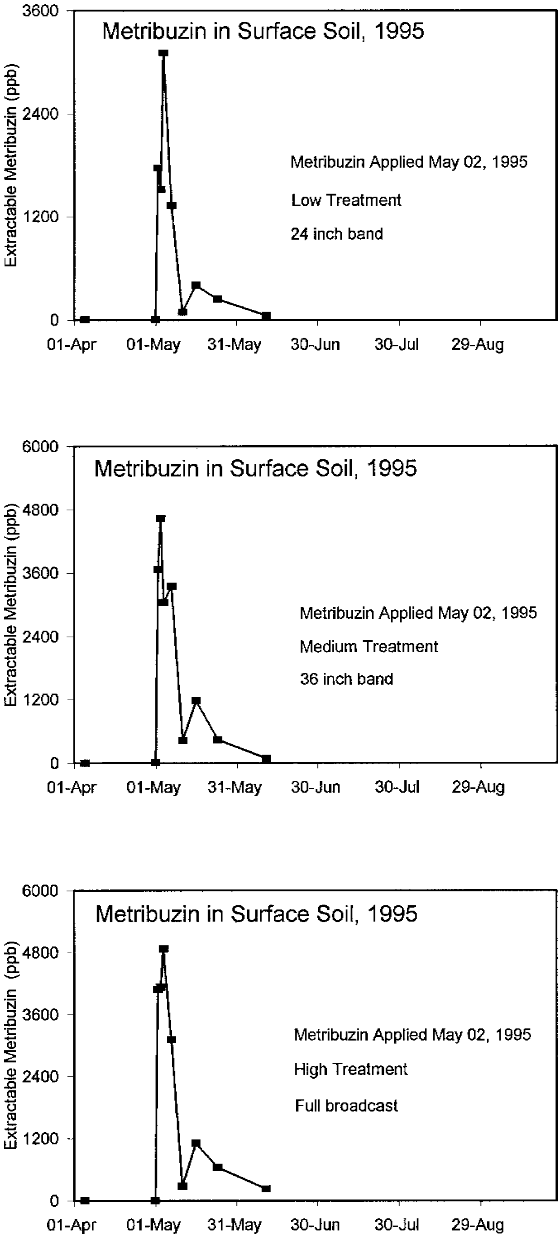

Fig.13 Extractable metribuzin concentrations from the surface soil from the high, medium, and low treatment plots during 1995 (average of two replications).

TABLES A1-A5

Table A1. Monthly surface runoff water losses from all treatments (mm).

	Low Treatment				Medium Treatment				High Treatment			
Month	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995
JAN	3.300		3.942	2.659	3.178		3.604	2.753	3.337		3.891	2.783
FEB	1.928		3.212	0.644	1.804		2.934	0.674	2.035		3.393	0.677
MAR	6.340		2.729	9.951	6.414		2.922	9.906	6.705		3.096	10.313
APR	2.677		1.846	3.509	2.384		1.516	3.253	2.380		1.334	3.426
MAY	2.318		2.598	2.039	2.507		2.956	2.058	2.327		2.608	2.047
JUN	3.229		5.952	0.505	3.139		5.890	0.388	3.167		5.921	0.413
JUL	1.107	0.196	3.124	0.003	1.109	0.194	3.125	0.009	1.069	0.203	3.001	0.002
AUG	0.089	0.000	0.000	0.265	0.099	0.000	0.000	0.296	0.104	0.000	0.000	0.312
SEP	0.083	0.000	0.248	0.000	0.102	0.000	0.306	0.000	0.078	0.000	0.234	0.000
OCT	2.591	6.376	0.469	0.929	2.586	6.282	0.593	0.884	2.591	6.327	0.469	0.979
NOV	1.762	1.468	0.023	3.794	1.677	1.409	0.058	3.565	1.605	1.433	0.017	3.367
DEC	1.625	0.859	1.457	2.559	1.872	1.072	1.705	2.839	1.744	0.998	1.440	2.794
TOTAL	27.048A*	8.898	25.597	26.857	26.87A	8.955	25.606	26.623	27.141A	8.960	25.402	27.111

*Totals followed by the same letter are not significantly different at 95% probability.

Table A2. Monthly surface soil losses from all treatments (kg/ha).

	Low Treatment				Medium Treatment				High Treatment			
Month	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995
JAN	2420.60		4263.35	577.85	1308.5		2097.9	1014.6	2377.9		4133.6	622.2
FEB	748.90		1454.00	43.75	1263.2		2464.6	1094.4	1137.4		2207.9	67
MAR	3331.00		3414.85	3247.05	3178.7		2645.7	1039.5	3361.5		2528.9	4194.2
APR	2327.40		2951.10	1703.60	2124.3		2293.6	1384.2	2213.4		1711.5	2715.4
MAY	2856.00		3971.80	1740.25	3210.4		4298.6	2334.0	2725.1		3253.4	2196.9
JUN	2036.50		3822.65	250.25	2611.5		5000.6	2841.5	2113.8		3951.1	266.5
JUL	506.80	97.00	1422.80	0.45	509.2	117.5	1407.9	693.1	654.6	119	1844.1	0.7
AUG	33.80	0.00	0.00	101.25	54.1	0.0	0.0	6245.2	21.6	0	0	64.7
SEP	14.20	0.00	42.45	0.00	22.1	0.0	66.2	44.7	16.1	0	48.2	0
OCT	1074.90	3171.00	21.50	32.15	1296.9	3799.5	31.6	12.5	1243.5	3656	16.8	57.6
NOV	930.20	730.00	1.10	2059.40	669.2	852.0	3.0	1.3	539.4	848	0.7	859.5
DEC	1745.20	427.00	458.80	4349.65	1049.8	649.0	517.9	230.8	905.6	510.5	442.3	1763.9
TOTAL	18025.1A*	4425.00	21824.40	14105.70	17297.8A	5418.0	20827.4	16935.5	17339.7A	5133.5	20148.3	12808.3

*Totals followed by the same letter are not significantly different at 95% probability.

Table A3. Monthly surface nitrogen losses from all treatments (kg/ha).

	Low Treatment				Medium Treatment				High Treatment			
Month	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995
JAN	1.504		1.911	1.097	2.057		3.113	1.002	2.023		2.913	1.132
FEB	0.204		0.233	0.175	0.364		0.496	0.233	0.52		0.73	0.309
MAR	0.797		0.161	1.433	0.804		0.423	1.185	1.428		0.611	2.245
APR	1.401		2.064	0.738	1.682		2.397	0.967	1.531		1.917	1.145
MAY	1.862		2.186	1.537	5.116		5.996	4.235	4.192		3.583	4.802
JUN	1.712		3.184	0.241	3.435		6.632	0.238	6.464		12.676	0.252
JUL	0.266	0.143	0.654	0.002	0.639	0.172	1.739	0.007	2.088	0.268	5.993	0.002
AUG	0.045	0	0	0.134	0.068	0	0	0.203	0.059	0	0	0.178
SEP	0.024	0	0.072	0	0.067	0	0.202	0	0.047	0	0.141	0
OCT	1.841	4.85	0.1	0.575	2.221	5.459	0.384	0.82	3.392	8.366	0.35	1.461
NOV	0.713	1.181	0.004	0.955	0.655	1.224	0.041	0.701	0.818	1.892	0.013	0.55
DEC	0.768	0.624	0.396	1.285	0.937	0.93	0.604	1.278	0.773	1.314	0.559	0.445
TOTAL	11.136B*	6.797	10.965	8.168	18.044A	7.784	22.024	10.868	23.333B	11.839	29.484	12.519

*Totals followed by the same letter are not significantly different at 95% probability.

Table A4. Monthly surface phosphorus losses from all treatments (kg/ha).

	Low Treatment				Medium Treatment				High Treatment			
Month	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995
JAN	1.998		2.306	1.69	1.564		1.657	1.471	2.191		3.034	1.348
FEB	0.539		0.856	0.222	0.926		1.585	0.268	0.808		1.453	0.164
MAR	1.643		1.04	2.245	1.962		1.678	2.247	1.985		1.375	2.595
APR	1.137		1.109	1.165	1.107		1.109	1.105	1.773		1.34	2.206
MAY	1.683		2.092	1.274	2.792		3.81	1.774	2.452		2.541	2.363
JUN	0.784		1.383	0.185	0.971		1.739	0.203	0.971		1.718	0.224
JUL	0.079	0.039	0.197	0.001	0.046	0.045	0.091	0.003	0.077	0.064	0.166	0.001
AUG	0.035	0	0	0.105	0.074	0	0	0.221	0.061	0	0	0.183
SEP	0.016	0	0.049	0	0.049	0	0.146	0	0.033	0	0.098	0
OCT	0.555	1.283	0.173	0.209	0.582	1.404	0.099	0.242	0.884	1.975	0.108	0.569
NOV	1.057	0.296	0.07	2.806	1.228	0.314	0.087	3.282	1.227	0.448	0.019	3.215
DEC	3.163	0.172	6.224	3.093	2.479	0.238	5.568	1.631	2.438	0.313	5.488	1.512
TOTAL	12.687A	1.79	15.496	12.994	13.778A	2	17.566	12.448	14.898A	2.799	17.338	14.377

*Totals followed by the same letter are not significantly different at 95% probability.

Table A5. Monthly surface potassium losses from all treatments (kg/ha).

	Low Treatment				Medium Treatment				High Treatment			
Month	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995	Average 1993-1995	1993	1994	1995
JAN	13.645		16.812	10.478	14.316		15.03	13.601	17.735		21.468	14.003
FEB	3.542		5.33	1.755	6.604		11.05	2.157	6.63		11.469	1.791
MAR	10.418		4.794	16.043	14.568		8.079	21.057	15.016		7.394	22.638
APR	9.96		11.031	8.888	9.301		10.556	8.047	10.548		8.861	12.235
MAY	10.658		15.12	6.216	14.849		20.254	9.443	12.83		16.766	8.895
JUN	8.258		15.634	0.883	8.909		17.014	0.805	8.384		15.9	0.868
JUL	1.063	0.363	2.822	0.004	2.736	0.456	7.732	0.021	1.92	0.507	5.249	0.005
AUG	0.169	0	0	0.508	0.291	0	0	0.874	0.179	0	0	0.536
SEP	0.197	0	0.59	0	0.49	0	1.469	0	0.22	0	0.659	0
OCT	4.596	11.722	0.798	1.267	5.819	14.699	1.131	1.628	6.077	15.884	0.639	1.7[illegible]
NOV	6.945	2.724	0.039	18.074	14.202	3.305	0.094	39.206	11.282	3.596	0.027	30.224
DEC	9.886	1.57	14.915	13.172	12.282	2.521	18.069	16.256	9.912	2.511	14.665	12.559
TOTAL	79.346A	16.378	87.884	77.285	104.365A	20.981	110.476	113.094	100.731A	22.497	103.095	105.46

*Totals followed by the same letter are not significantly different at 95% probability.

REFERENCES

Bengtson, R.L., H. M. Selim, and R.D. Ricaud. 1998. Water quality from sugarcane production on alluvial soils. TRANSACTIONS of Am. Soc. Agric. Engin. 41:1331-1336.

Granovsky, A.V., L. Ma, R. Ricaud, R.L. Bengtson, and H. M. Selim. 1996. Fate of azinphosmethyl in a sugarcane field: distributions in canopy, soil and runoff. J. Environ. Qual. 25:1210-1216.

Johnson, D. J., H. M. Selim, L. Ma, L. M. Southwick, and G. H. Willis. 1995. Movement of atrazine and nitrate in sharkey clay soil: Evidence of preferential flow. Bull. no. 846, Louisiana Agric. Exp. Stat. (24p).

Selim, H.M. and R.L. Bengtson. 1997. Sugarcane demonstration project; Final Report to the La. Dept. of Environmental Quality. Louisiana State University Agricultural Center, Baton Rouge.

Selim, H.M., R.L. Bengtson, R.D. Ricaud, L. Ma, A.G. Granovsky, L.M. Southwick, and H.P. Schexnayder. 1995. Sugarcane demonstration project: nutrient and pesticide management strategies. In: Proceedings of the Conference on Environmental Issues, Louisiana State University Agricultural Center, Baton Rouge, July 24-25. Pp. 127-131.

Southwick, L.M., G.H. Willis, and H.M. Selim. 1992. Leaching of Atrazine from Sugarcane in southern Louisiana. J. Agric. Food Chem. 40:1264-1268.

Southwick, L.M., G.H. Willis, D.C. Johnson, and H.M. Selim. 1995. Leaching of nitrate, atrazine and metribuzin to sugarcane in south Louisiana. J. Environm. Quality. 24:684-690.

Wauchope, R.D., T.M. Buttler, A.G. Hornsby, P.W.M. Augustijn-Beckers, and J.P. Burt. 1992. The SCS/ARA/CES Pesticide Properties database for environmental decision-making. Rev. Environ. Contamin. Toxicol. 123:1-164.

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RUNOFF LOSSES OF ATRAZINE, METRIBUZIN, AND NUTRIENTS AS AFFECTED BY MANAGEMENT PRACTICES FOR SUGARCANE

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