IMPACT OF VEGETATIVE GRASS FILTER STRIPS ON HERBICIDE LOSS IN RUNOFF

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INTRODUCTION

The 1985 and 1990 U.S. Farm Bills mandated producers develop a conservation plan for their slightly to moderately erodible land. Griffith et al. (1986) found that by employing a no-till (NT) production system, soil erosion could be reduced by as much as 91%. However, producers have been reluctant to change to a strict NT system because of perceived difficulties in planting and stand establishment. A viable option for producers on slightly to moderately sloping land has been establishment of permanent grass filter strips at intervals down the slope. These filter strips are 2 to 4 m in width and are composed of various perennial grass species. Water movement is slowed substantially as it moves across these grassy strips, and the sediment load is greatly reduced. This option is popular because producers may use conventional tillage programs between these strips and realize the benefits of conventional tillage, while at the same time reducing soil erosion losses.

Vegetative filter strips can effectively reduce sediment and nutrient load from edge-of-field runoff waters (Aull 1980). Dillaha et al. (1989) noted a reduction in suspended solids of as much as 84%, phosphate by 79%, and nitrate by 73% with the employment of a vegetative filter strip. These filter strips have also been useful in trapping sediments, nutrient, and microbial contaminants from feedlot runoff (Cartmell 1973; Young et al. 1980). Vegetative filter strips have also been evaluated for reducing nutrients and suspended solids from residential development sites (Woodard and Rock 1989). A riparian buffer strip can reduce nitrate concentration in groundwater (Haycock and Pinay 1993). In a number of instances, vegetative filter strips are considered viable options for Best Management Practices (BMPS) (Baker and Johnson 1983). Producer acceptance of these filter strips has been good, but establishment and management techniques are yet to be clearly defined (Dillaha et al. 1989).

Soybean producers in the southern states primarily rely on conventional tillage systems, but conservation tillage is increasing. Doublecropped soybean following wheat (Triticum aestivum L.) in either tilled or no-till systems coupled with grass filter strips can produce greater net returns (Hairston et al. 1984), while at the same time reduce soil erosion. Even though soil erosion is limited in these cropping systems, the question remaining is whether herbicide loss in runoff is affected. Some studies have shown that herbicide losses increase with tillage (Felsot et al. 1990; Shaw et al. 1992), whereas others have reported decreases (Baker et al. 1978; Sukolapong et al. 1985). Research on the Blackland Prairie soils of Mississippi has also indicated variability in herbicide loss from conventional tillage and no-till systems (Webster and Shaw 1995). Metolachlor losses were higher from no-till than conventional tillage two out of three years, but metribuzin losses were higher from conventional tillage systems when compared to no-till. Thus, herbicides with different properties may be variable in their response to tillage practices. Baughman et al. (1995) also reported variability of herbicide losses on this soil from no-till and conventional tillage between years. These differences have been attributed to many factors, including soil type, antecedent soil moisture, and rainfall intensity.

In order to accomplish the goal of optimal weed control in a soil conservation program, increased reliance on chemical means of weed control is necessary (Shaw and Rainero 1990). There is a large amount of information on the effectiveness of vegetative filter strips on reducing nutrients and suspended solids from runoff, but little research has been reported on herbicide loss. The objective of this research was to evaluate the effectiveness of vegetative filter strips on reducing the loss of metolachlor and metribuzin in runoff from three soybean production systems. This research was conducted for 3 years to assess the impact of variable environments in losses from the three systems with and without a filter strip.

PROCEDURES

This research was conducted at the Black Belt Branch Experiment Station near Brooksville, Mississippi, on 4 m by 22 m soil erosion plots with a slope of 3.0%. Plots were located on a Brooksville silty clay (fine montmorillonitic, thermic Aquic Chromudert; 3.2% organic matter and pH 6.4 in the Ap horizon). The Brooksville series shrinks and cracks during dry periods, but saturated hydraulic conductivity is slow (less than 1.5 to 5 mm h^{-1}) (Brent 1986). Plots were bordered with a metal strip to exclude outside runoff, and each plot was equipped with a

15 cm H-type flume. Seedbeds for wheat (prior to wheat planting) and CT soybean plots were prepared by disking twice with a tandem disk harrow perpendicular to the slope. Final preparation was two passes with a bed conditioner equipped with rolling baskets and S-tine harrows. The doublecrop system was planted with 100 kg ha^{-1} 'Pioneer 2548' wheat in 25 cm rows planted parallel to the plot slope, with 16 rows per plot. Paraquat (1,1'-dimethyl-4-4'-bipyridinium ion) at 0.84 kg ai ha^{-1} was applied to 25 cm wheat in order to desiccate before planting. The tall fescue strips were established by transplanting native stands from an area adjacent to the runoff plots. 'Terra-Vig 515' soybean was planted at 56 kg ha^{-1} in 76 cm rows parallel to the slope, with 5 rows per plot.

Three soybean production systems were used in this research, each coupled with and without a grass filter strip: 1) no-till monocrop, 2) conventional till monocrop, and 3) no-till doublecrop following wheat. The research was conducted over 3 consecutive years, and years were used as replications. All plots were planted on June 20, 1991, May 19, 1992, and June 8, 1993. Metolachlor (3.4 kg ai ha^{-1}) and metribuzin (0.42 kg ai ha^{-1}) were applied immediately after soybean planting using a CO_2-pressurized backpack sprayer and a spray volume of 180 L ha^{-1}. Paraquat at 0.84 kg ai ha^{-1} was also applied to NT plots in order to kill existing vegetation at planting. Plots were maintained free of weeds after soybean emergence by hand hoeing as necessary.

A portable rainfall simulator patterned after those described by Bubenzer (1979) and Shelton et al. (1985) was used when necessary to supplement natural rainfall to obtain a minimum of 50 mm rainfall at 2-week intervals. The rainfall simulator covered a single runoff plot and was equipped with 24 fixed nozzles. Nozzles were mounted in 12 perpendicular rows, with 2 nozzles per row spaced 2 m apart and 3 m above the soil surface. Maximum output of the unit was equivalent to a 76 mm h^{-1} rainstorm at 0.08 MPa water pressure. Rainfall events could occur on all plots within a single day. All runoff was collected from each plot and quantified. In 1991, 5 natural rainfall events resulted in runoff: 5 d after treatment (DAT) - 25 mm; 29 DAT - 41 mm; 37 DAT - 10 mm; 52 DAT - 61 mm; and 59 DAT - 23 mm; and 1 simulated event: 12 DAT - 28 mm. In 1992, 5 natural rainfall events resulted in runoff: 6 DAT - 47 mm; 17 DAT - 107 mm; 22 DAT - 18 mm; 25 DAT - 28 mm; 62 DAT 27 mm; and 105 DAT - 83 mm; and 1 simulated event: 2 DAT - 44 mm. In 1993, 8 natural rainfall events resulted in runoff: 17 DAT - 69 mm; 18 DAT - 13 mm; 21 DAT - 15 mm; 49 DAT - 51 mm; 58 DAT - 53 mm; 59 DAT - 43; 60 DAT - 39 mm; and 85 DAT - 48 mm; and 2 simulated events: 2 DAT - 44 mm; and 38 DAT - 44 mm.

Runoff effluent was agitated, and a 1-L composite sample was obtained from each runoff plot and stored immediately at 5 C. A 500 ml aliquot of the runoff effluent was placed in a liquid-liquid extractor with 250 ml methylene chloride. The sample was diluted with deionized water to allow continuous extraction. The extractor was then placed on a 500 ml flat-bottomed flask that contained 300 ml methylene chloride and heated at 215 C for 16 hours. Samples were dried by rotary evaporation and brought to a volume of 10 ml with hexane. The samples were analyzed by gas chromatography. The GC was equipped with a ^{63}Ni electron capture detector, a 30 m long by 0.53 mm i.d. capillary column with a (5%-phenyl)-methylpolysiloxane stationary phase, and a Spectra-Physic Chromejet integrator to compare sample peaks against standard peaks to quantify metolachlor and metribuzin. General operation conditions for extractions: carrier gas, filter-dried helium, 99.99% purity, flow rate 4.5 ml min^{-1}; makeup gas, filter-dried 95:5 argon:methane, 99.99% minimum purity, flow rate 60 ml min^{-1}; inlet temperature 200 C; column oven temperature program, initial temperature 150 C for 5 min, elevated 5 C min^{-1} to 170 C and held for 10 min, elevated 10 C min^{-1} to 220 C and held for 10 min; detector temperature 300 C. Residues were determined with a lower detection limit of 250 and 100 ppt for metolachlor and metribuzin, respectively.

Concentration values were combined with total runoff to determine total loss of each herbicide per runoff event on a per ha basis and subsequently total loss due to off-site movement in runoff. Concentration data were subjected to regression analysis to describe concentration of each herbicide in runoff and to determine if the filter strip reduced herbicide in runoff solution. The regression equations were of the form $Y = b_o - b_1X$ where Y is the $\log_{10}$ of herbicide concentration in runoff, b_o, and b_1 were partial regression coefficients, and X is the $\log_{10}$ of days after treatment. General linear hypothesis to test additivity as described by Myers (1989) was used to test slope equality of the aforementioned equations to determine the difference in concentration loss patterns between production systems and filter strips. If no difference in concentration loss pattern was observed from each production system filter strip combination, the predicted lines were then subjected to analysis of covariance to determine if a difference occurred in the herbicide concentration at the initial runoff event.

Sediment samples were collected during the sampling period (0 - 59 DAT in 1991, 0 - 105 DAT in 1992, and 0 - 85 DAT in 1993) to evaluate these systems for suspended solid losses during these intervals. Suspended solid amounts contained in water were determined by filtering the second 1-L sample. The filter paper that contained the solids was dried for 24 h at 66 C and weighed for total loss per sample and combined with total runoff from the plot in order to determine total loss of solids per runoff event on a per ha basis. Regression analysis was used to describe loss of suspended solids. The equations were of the form $Y = b_o - b_1X$ where Y is the suspended solids in runoff, b_o, and b_1 were partial regression coefficients, and X is the cumulative runoff. Comparisons between soil loss amounts were evaluated by the aforementioned procedure by Myers (1989).

RESULTS AND DISCUSSION

Total rainfall amounts during the sampling period for 1991 through 1993 were 216 mm, 354 mm, and 419 mm, respectively (Table 1). The first runoff in 1991 occurred 5 days after treatment (DAT) and 2 DAT in 1992 and 1993. In 1991, the first rainfall was a natural event, thus delaying the simulated rainfall event.

The addition of a vegetative grass filter-strip reduced runoff amounts compared to the same tillage system without a filter strip in all instances except in 1991 with NT doublecrop (Table 1). In 1991, the highest runoff was from the NT monocrop without a filter strip, at 904,500 L ha^{-1} during the sampling period. However, a filter strip reduced total runoff to 319,800 L ha^{-1}. This reduced losses to the equivalent of a NT doublecrop system. Similar results were noted with the CT monocrop production system. Filter strips slow water movement and can act as a natural dam or terrace, allowing more time for water to infiltrate into soil. By employing a vegetative filter strip on NT or CT monocrop production systems, runoff can be reduced to levels equal to or less than a NT doublecrop system. This information is crucial in allowing producers to continue preferred production practices, while at the same time reducing runoff.

Loss of Suspended Solids

Suspended solid loss was evaluated in 1992 and 1993. Initial estimates indicate a difference in the amount of solids in runoff when slope equality analysis was employed comparing the NT monocrop with and without a filter strip (Figure 1A). The NT monocrop system with and without a filter strip had similar suspended solid losses in early runoff events, but without a filter strip solids continued to be lost at a greater rate later in the season. No difference was observed in slope equality of estimates of soil loss; however, there was a difference in distance between these estimates. This indicates a reduction of soil loss when a filter strip is employed on a CT monocrop system (Figure 1B). However, no differences occurred in the NT doublecrop with or without a filter strip (Figure 1C). The filter strip was established in 1991 prior to planting, and there was little differentiation between the filter and the wheat stubble. Thus little filtering of suspended solids occurred over the three year period.

The filter was able to retain suspended solids in runoff. When a filter was used on the CT monocrop system, suspended solids were reduced to levels comparable to the NT doublecrop. Thus, producers may continue to use CT and reduce suspended solids to the NT doublecrop levels.

Herbicide Loss

Metolachlor and metribuzin have high water solubilities, at 530 ppm and 1,220 ppm, respectively (Weed Science Society of America 1989). Their half-lives in soil range from 15 to 25 days for metolachlor and 7 to 60 days for metribuzin. Thus the relative short half-life and high solubility would favor higher losses early in the growing season, with rapid declines later.

NT Monocrop Soybean Production System

Regression analysis indicated no difference in concentration of metolachlor (Figure 2A) and metribuzin (Figure 3A) in runoff with or without a filter strip when evaluated by slope equality and analysis of covariance. Concentration of metribuzin was lower than metolachlor, but similar loss patterns were noted. Over 80% of the total concentration found in the runoff occurred in the first 3 runoff events for each herbicide. These data are similar to other reports (Webster and Shaw 1995; Shaw et al. 1992).

The NT monocrop soil surface lacked significant cover and was smooth and crusted over, which led to large runoff amounts. High runoff coupled with high concentration caused increased losses of metolachlor and metribuzin (Table 2 & 3). The presence of a filter strip reduced herbicide loss by at least 50%. In 1991 and 1992, total loss in runoff for metolachlor was higher than any other production system without a filter strip, with losses of approximately 2 and 4% of the amount applied, respectively (Table 4). In 1993, total loss was 1.2% of the total amount applied. Losses of metribuzin were 2 to 7% of the amount applied to the NT monocrop system. However, with a 2.8 m vegetative filter strip on the same production system, decreases in total runoff and total herbicide loss occurred. Metolachlor loss was reduced by as much as 55 to 74% for the three year period, and metribuzin had similar reductions of 50 to 76% when a filter strip was present.

CT Monocrop Soybean Production System

Initial concentrations of metolachlor and metribuzin in runoff from the CT monocrop soybean production system were similar to the previous soybean production system

(Figures 2C and 3C). No difference in concentration in runoff water was evident for metolachlor (Figure 2B) or metribuzin (Figure 3B) with or without a filter strip with the use of slope equality and analysis of covariance. As with the previous system, over 80% of the total herbicide load in runoff of both herbicides was in the first three runoff events.

In 1991 and 1992, the first rainfall/runoff event for the NT monocrop did not cause runoff from the CT, since the seedbed was rougher and rainfall amount was relatively low (Table 1). This increased infiltration of the herbicides into soil. The rainfall that caused the second runoff event from NT also produced runoff from CT. By the second rainfall event, more adsorption and microbial breakdown had occurred, rendering less available for off-site movement of the herbicide. In all three years of this study, the addition of a filter strip reduced runoff and total loss of the herbicides compared to the system without a filter strip (Table 2 & 3). Total losses of metolachlor from CT monocrop were 33 to 53% less when a filter strip was present. When a vegetative filter was present, losses were 0.2 to 1.2% of applied, compared to 0.6 to 1.8% without a vegetative filter strip (Table 4). Metribuzin loss patterns were similar.

Less metolachlor and metribuzin moved off-site from the CT monocrop with or without a filter strip compared to the NT monocrop soybean production system. Metolachlor loss from the NT monocrop without a vegetative filter strip from 1991 through 1993 were 1.9, 4.0, and 1.2% of the total applied, respectively. However, losses from the CT system without a vegetative filter strip were 1.0, 1.8, and 0.6% of the amount applied for the same three year period (Table 4). Patterns were similar for metribuzin. These losses can be attributed to the CT having a rough seedbed, slowing water movement and increasing infiltration, and thus incorporating more herbicide, making less available to move off-site.

NT Doublecrop Soybean Production System

No difference was observed in concentration of metolachlor (Figure 2C) and metribuzin (Figure 3C) when a filter strip was present on the NT doublecrop soybean following wheat production system. The filter strip did not affect the amount of herbicide in runoff, indicating the filter strip did not filter suspended herbicide from the runoff water. As with the previous two systems, approximately 80% of the total amount of herbicide concentration found in runoff water was in the first three runoff events. The wheat stubble apparently did not serve as a source of herbicide contamination in later runoff events.

In 1991 and 1992, the vegetative filter strip had little effect on total runoff from the NT doublecrop system and, when coupled with herbicide concentration, the total loss of herbicide were similar (Table 2 & 3). In 1993, there was a benefit to having a filter strip present with the NT doublecrop system. Metolachlor and metribuzin losses were reduced as much as 90% with the use of a filter strip in 1993. The filter strip was established in 1991 prior to planting, and there was little differentiation between the filter strip growth density and the wheat stubble density. However, by 1993 the filter strip had developed a mat which resulted in a much more proficient filter, thus runoff was reduced, ultimately reducing total herbicide loss. The total loss of metolachlor and metribuzin without a filter strip was 120 g ha^{-1} and 46 g ha^{-1}, respectively, compared to 86 g ha^{-1} for metolachlor and 5 g ha^{-1} for metribuzin when a strip was present (Table 2 & 3). These losses were 0.5 and 1.2% of the total applied, which was approximately 85% less than the losses from the system without a filter strip (Table 4). The higher losses in 1993 are probably due to 3 years of growth for the filter strip, which allowed for more dense growth, thus reducing runoff.

CONCLUSIONS

Vegetative filter strips can effectively reduce suspended solids and also have a substantial impact on herbicide loss. The filter strips act as a natural dam or terrace and reduce the amount of runoff. By reducing runoff, the water has more time to infiltrate and incorporate the herbicide and prevent it from moving off-site. Vegetative filter strips may allow producers to be in compliance of the 1985 and 1990 Farm Bills, while at the same time continuing preferred conventional tillage practices. Further research should evaluate other species best adapted to particular regions, variation in strip widths, intervals of filter placement on slopes, other soil types, different slopes, and their impact on losses of other herbicides.

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Table 1. Total runoff from various cropping systems with and without filter strips from 1991 through 1993.

Year	DAT	Total Rainfall	NT† Monocrop		CT Monocrop		NT Doublecrop	
			W/O‡	W/	W/O	W/	W/O	W/
		(mm)	$L\ ha^{-1} \times 1000$					
1991	5	25	43.8	4.6	0.0	0.0	0.0	0.0
	12	28	215.1	107.1	72.7	57.6	51.3	51.1
	28	28	146.7	50.2	62.5	18.8	12.4	3.8
	29	41	157.8	101.0	129.5	59.6	90.2	56.9
	37	10	60.1	35.0	46.3	2.8	3.8	3.8
	52	61	237.2	18.1	194.4	112.3	137.7	187.7
	59	23	43.8	3.8	22.0	0.0	0.0	0.0
Total		216	904.5	319.8	527.4	251.1	295.4	303.3
1992	2	44	43.7	12.2	0.0	0.0	65.3	56.4
	6	47	162.7	110.0	101.3	72.7	157.0	153.0
	17	107	122.5	98.7	141.5	136.6	79.8	78.2
	22	18	19.6	3.9	0.0	0.0	6.4	5.1
	25	28	100.6	74.5	54.6	45.0	76.6	75.1
	62	27	5.5	0.2	0.3	0.5	0.0	0.0
	105	83	3.0	9.9	3.8	3.2	8.9	12.9
Total		354	457.6	309.4	301.5	258.0	394.0	380.7
1993	2	44	29.2	21.2	23.1	16.7	145.7	36.0
	17	69	166.6	83.7	167.2	39.8	171.5	57.2
	18	13	22.8	8.1	12.2	2.0	5.7	3.0
	21	15	3.0	3.0	3.0	3.0	4.3	3.0
	38	44	3.0	0.0	9.1	0.0	0.0	0.0
	49	51	61.4	10.7	36.3	9.1	15.0	17.3
	58	53	119.6	21.2	41.4	45.0	55.6	6.1
	59	43	208.8	156.6	167.2	162.4	171.5	171.1
	60	39	134.7	133.4	167.2	162.4	171.5	142.8
	85	48	12.8	3.0	8.1	4.1	11.4	4.1
Total		419	761.9	440.9	634.8	444.5	752.2	440.6

† Cropping systems: NT = No-till monocrop; CT = Conventional tillage monocrop; NT = No-till doublecrop, following wheat.

‡ W/O = Without or W/ = with a filter strip present.

Table 2. Metolachlor loss from plots with and without filter strips from 1991-1993.

		NT[†] Monocrop		CT Monocrop		NT Doublecrop	
Year	DAT	W/O[‡]	W/	W/O	W/	W/O	W/
		g/ha					
1991	5	35.39	2.00	NR[§]	NR	NR	NR
	12	13.19	12.77	17.06	10.21	6.39	7.69
	28	7.29	3.37	5.46	1.40	0.66	0.05
	29	6.79	5.36	8.82	3.65	2.48	1.10
	37	1.15	0.85	0.78	0.05	0.07	0.08
	52	1.30	1.14	0.91	0.90	0.59	ND[§§]
	59	0.27	0.02	0.38	NR	NR	NR
Total		65.38	25.51	33.41	16.21	10.19	8.92
1992	2	41.29	4.30	NR	NR	52.41	39.26
	6	80.08	23.24	51.38	33.95	63.07	42.43
	17	10.84	5.33	6.82	5.62	2.86	3.22
	22	1.11	0.10	NR	NR	0.14	0.09
	25	2.21	2.10	1.59	0.80	1.19	0.47
	62	0.12	0.01	0.01	0.01	NR	NR
	105	0.07	ND	0.20	ND	ND	0.10
Total		135.72	35.08	60.00	40.38	119.67	85.57
1993	2	20.47	8.01	6.3	6.28	46.28	12.34
	17	15.20	7.70	9.52	2.30	98.36	3.81
	18	1.27	0.48	0.41	0.01	0.18	0.02
	21	0.04	0.02	0.02	0.02	0.02	0.02
	38	0.07	NR	0.09	NR	NR	NR
	49	0.61	0.08	0.43	0.08	0.19	0.13
	58	0.74	0.11	0.38	0.20	0.28	ND
	59	1.14	0.99	1.53	0.89	0.71	0.54
	60	0.70	0.70	0.53	0.61	0.66	0.45
	85	0.07	0.01	0.03	0.01	ND	ND
Total		40.31	18.10	19.24	10.40	146.68	17.31

† Cropping systems: NT = No-till monocrop; CT = Conventional tillage monocrop; NT = No-till doublecrop, following wheat.

‡ W/O = Without or W/ = with a filter strip present

§ No Runoff.

§§ Not Detected.

Table 3. Metribuzin loss from plots with and without filter strips from 1991-1993.

		NT Monocrop		CT Monocrop		NT Doublecrop	
Year	DAT	W/O	W/	W/O	W/	W/O	W/
		g/ha					
1991	5	2.95	0.23	NR	NR	NR	NR
	28	1.26	0.55	1.49	0.35	0.13	0.01
	29	0.96	0.82	1.93	0.52	0.44	0.19
	37	0.19	0.12	0.16	0.01	0.02	0.02
	52	0.33	0.23	0.19	0.11	0.14	ND
	59	0.04	ND	0.09	NR	NR	NR
Total		9.63	4.68	8.47	3.97	2.56	1.70
1992	2	10.65	0.97	NR	NR	17.38	12.91
	6	14.84	3.24	6.58	1.29	13.67	11.32
	17	2.27	1.49	1.41	1.28	1.01	0.91
	22	0.24	0.03	NR	NR	0.06	0.03
	25	0.53	0.72	0.87	0.18	0.56	0.3
	62	0.03	ND	ND	ND	NR	NR
	105	0.02	0.02	0.04	ND	0.05	0.04
Total		28.58	6.47	8.90	2.76	32.73	25.51
1993	2	5.48	2.24	1.96	2.36	14.49	3.85
	17	3.21	1.67	1.72	0.43	31.45	1.03
	12	3.90	2.73	4.67	2.98	1.83	1.48
	18	0.25	0.13	0.11	ND	ND	ND
	21	ND	ND	ND	ND	ND	ND
	38	0.01	NR	0.03	NR	NR	NR
	49	0.09	0.01	0.06	0.01	0.02	0.01
	58	ND	ND	0.04	ND	ND	ND
	59	ND	ND	ND	ND	ND	ND
	60	ND	ND	ND	ND	ND	ND
	85	0.01	ND	ND	ND	ND	ND
	Total	9.05	4.05	3.92	2.80	45.96	4.89

† Cropping systems: NT = No-till monocrop; CT = Conventional tillage monocrop; NT = No-till doublecrop, following wheat.
‡ W/O = Without or W/ = with a filter strip present.
§ No Runoff.
§§ Not Detected.

Table 4. Percentage of metolachlor and metribuzin lost in runoff as compared to the amount applied with and without filter strips from 1991-1993.

	NT† Monocrop		CT Monocrop		NT Doublecrop	
Year	W/O‡	W/	W/O	W/	W/O	W/
			Metolachlor			
1991	1.9	0.8	1.0	0.5	0.3	0.3
1992	4.0	1.0	1.8	1.2	3.5	2.5
1993	1.2	0.5	0.6	0.3	4.3	0.5
			Metribuzin			
1991	2.3	1.0	1.8	0.8	0.5	0.4
1992	6.8	1.5	1.1	0.6	7.8	6.1
1993	2.1	0.9	0.9	0.7	11.9	1.2

† Cropping systems: NT = No-till monocrop; CT = Conventional tillage monocrop; NT = No-till doublecrop, following wheat.

‡ W/O = Without or W/ = with a filter strip present.

§ No Runoff.

§§ Not Detected.

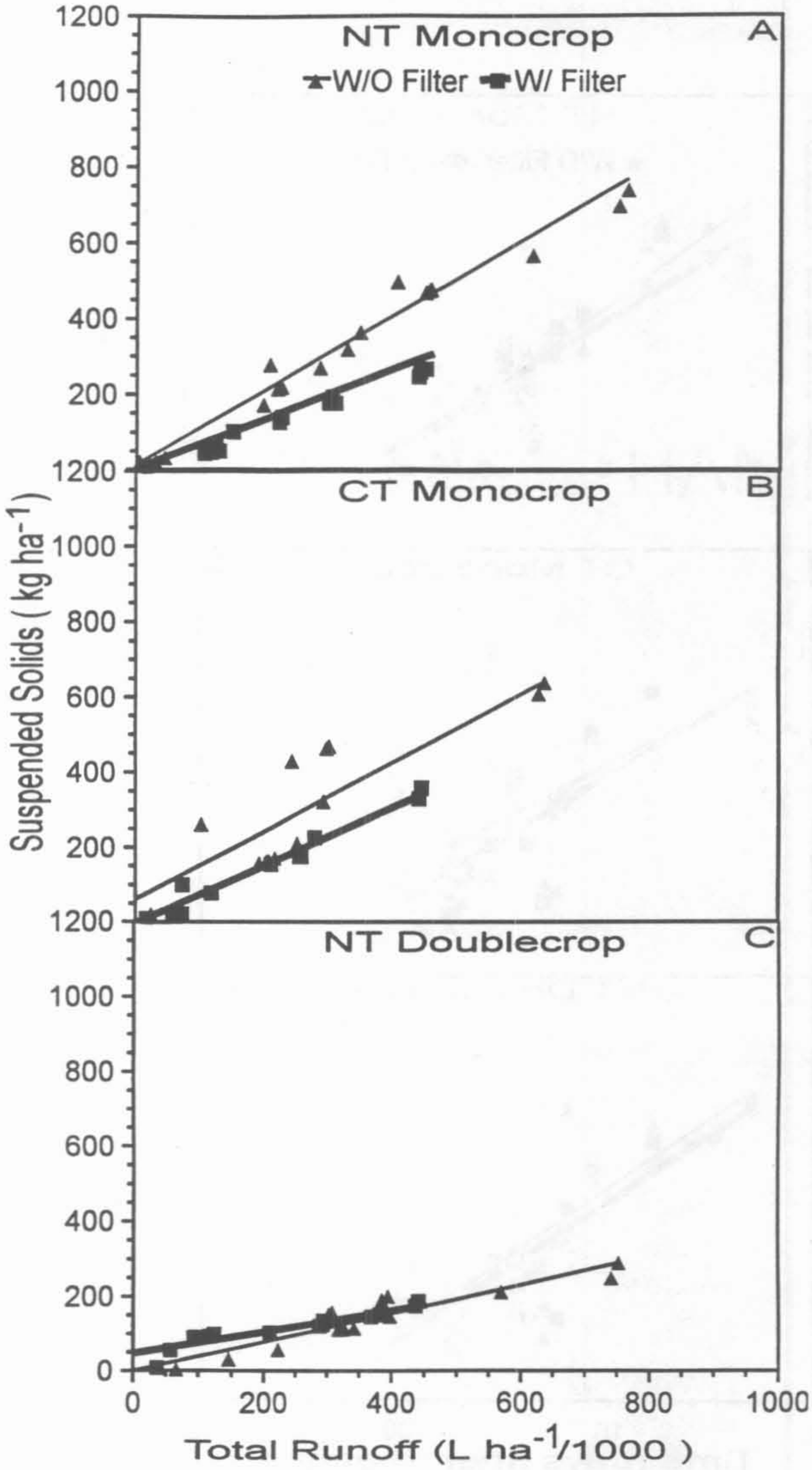

Figure 1. Influence of vegetative filter strips on losses of suspended solids in runoff from different soybean production systems.

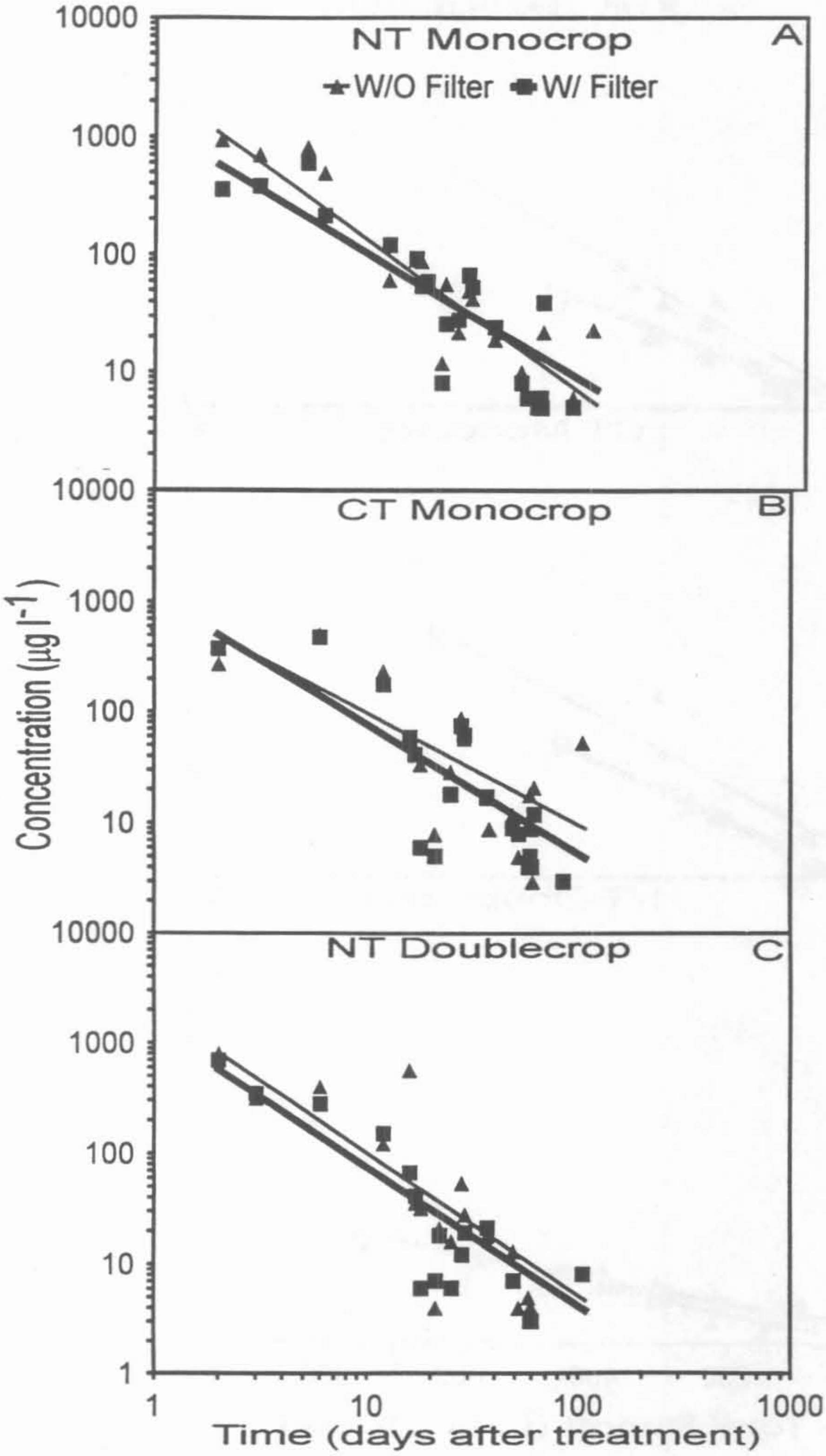

Figure 2. Influence of vegetative filter strips on metolachlor concentration in runoff water from different soybean production systems.

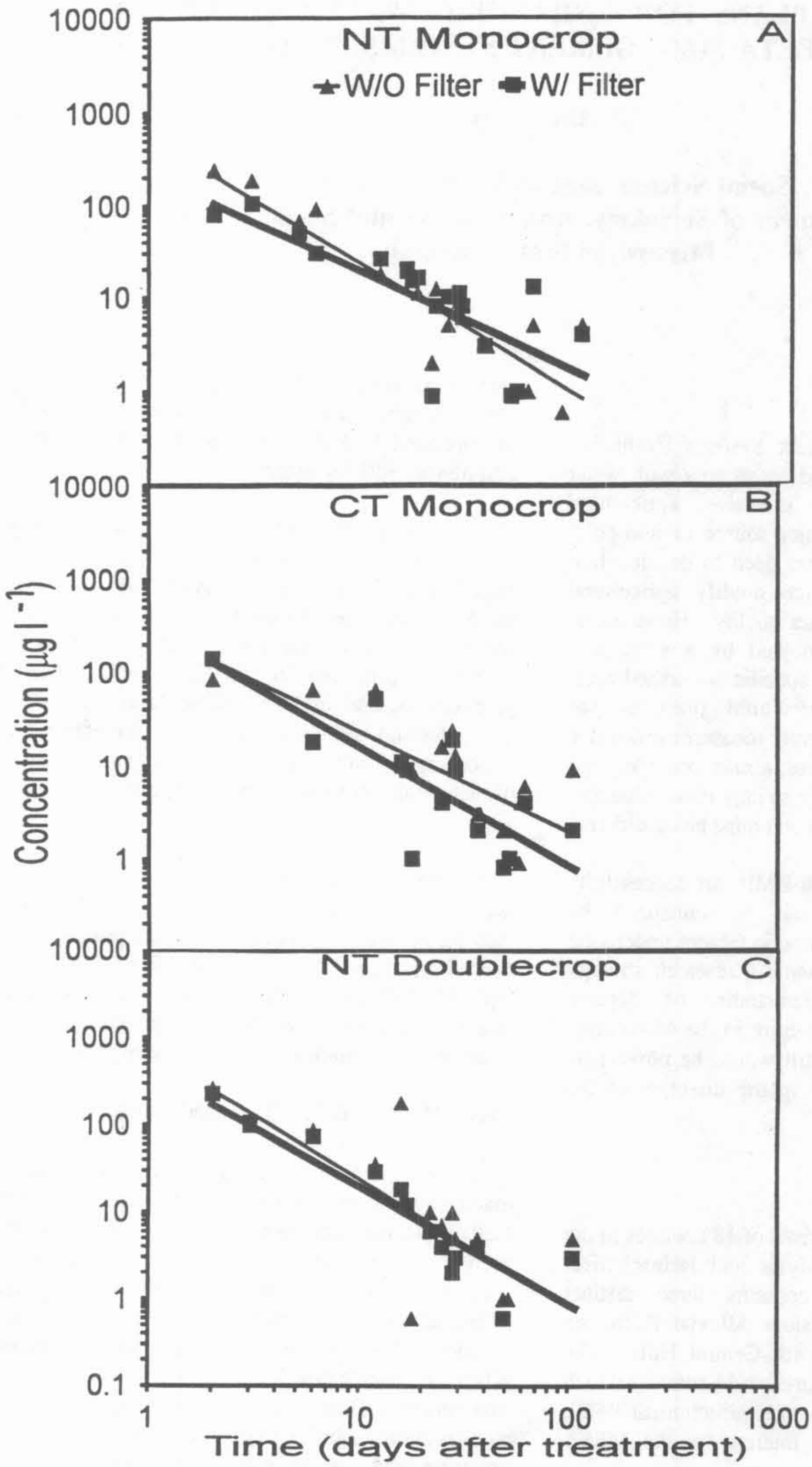

Figure 3. Influence of vegetative filter strips on metribuzin concentration in runoff water from different soybean production systems.