EVALUATION OF REDUCED APPLICATION RATES OF ACETOCHLOR TO REDUCE CONCENTRATION IN TILE DRAINAGE WATER

Semi-annual Report #6
Covering the time period of
July 1, 2010 to December 31, 2010

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Introduction

Acetochlor, a commonly used herbicide applied to the soil surface for grass control in corn, has been found in some southern Minnesota rivers. Leaching of acetochlor to tile lines in poorly drained soils has been proposed as a mechanism transporting acetochlor from the soil surface to the rivers. Thus, a study was initiated in the spring of 2008 and continued in 2009 and 2010 at the University of Minnesota Southern Research and Outreach Center at Waseca to determine if reduced application rates of acetochlor will result in reduced concentrations and losses of acetochlor and its metabolites in tile drainage water from a corn-corn-soybean rotation.

Experimental Procedures

Nine small plots in a 36-plot tile drainage research facility located on a Canisteo-Webster clay loam soil complex were used to conduct the acetochlor phase of the study. The nine plots were superimposed on a larger study examining nitrogen rate and timing practices in a corn-corn-soybean rotation study. Further details outlining the establishment of the plot and collection of the water samples were described in Semi-Annual Report #1. It should be noted that the 1.5 and 2.5 pt/A rates of Harness correspond to 1.31 and 2.19 lb acetochlor ai/A, respectively.

The experimental procedures used in the conduct of the study from July-December are shown in Table 1. Collection procedures for the water samples in July and September were similar to those described in Report #5. Leaf chlorophyll readings, a surrogate measurement relating to the N status of the plant, were taken on 30 plants per plot with a SPAD meter. Prior to harvest 1.5’ was trimmed from each end of four rows per plot. These four rows were then combined with a research-plot combine equipped with an electronic scale and a grain moisture meter. An 8-inch section of stalk between 6” and 14” above the soil surface was not taken in 2010 due to the extremely wet field conditions after physiologic maturity (PM) and the sensitivity of the test results to the timing between PM and sample collection and rainfall. Soil samples to a depth of four feet were not taken after harvest due to the 12.66” of rain in September that would have leached and denitrified residual nitrate from the profile. Prior to the soil freezing, the culverts used for collecting the acetochlor samples were covered with tarps after securely fastening the culvert tops down. This was done to prevent any overwinter wind blown soil from contaminating the instrumentation and collection equipment.

Results and Discussion

Precipitation and Tile Discharge

Available soil water in the 0-5’ soil profile was determined twice each month on a continuous corn site adjacent to the study. The data shown in Table 2 indicate soil water levels were close to field moist capacity (11.05”) for most of the year except in mid- to late-August. The high content of available soil water in April was due to the large amount of snow melt that infiltrated the profile in March. Because of record-setting September precipitation (Table 3), the soils were too wet to collect samples for determining available soil water content in September and early October. Record setting rainfall in June, June + July, September, and for the May-September growing season allowed ample opportunity for tile drainage water collection in 2010.

Tile flow data for the entire season are shown in Table 4. Drainage started on March 11 and continued through October 15. Major flow occurred in March (due to snow melt), from June 16-30, and September 23-30. Tile drainage was particularly light from April 1 – May 16 and from August 1 – September 22. Tile drainage from the 10 experimental plots occurred a total of 243 plot-days (24.3 days/plot) in the pre-acetochlor application period (3/11-5/16) and 549 plot-days (54.9 days/plot) in the post-application period (5/17-10/15). Drainage was flowing from all 10 plots on 12 days during the pre-application period and 18 days during the post-application period. This was in stark contrast to 2009 when there was not one day all year where all plots were draining. Thus, 2010 was considered a banner year to determine acetochlor losses in tile drainage, especially since flow was abundant both prior to and after acetochlor application.

Tile discharge for each of the plots and acetochlor treatments averaged 22.1" for the March-October drainage season and 16.1" from the acetochlor post-application period (5/17-10/15) (Table 5). Flow variability among the plots, among the replications within a acetochlor treatment, and among treatments within a replication was minimal in 2010, which is considerably different than in a low-flow year such as 2009. Among the 10 plots, tile flow ranged from as high as 19.0" to as low as 11.2" during the post-application period. Low standard error of the mean indicated satisfactory variation in flow amounts among replications within all treatments. Average total post-application flow amount the three treatments ranged from 14.2" to 17.2", which is considered to be very uniform for field drainage research. This was partially due to the restricted randomization of the acetochlor treatments based on previous tile flow data. Flow variability was also considered to be excellent among the three replications (ranged from 13.5" to 18.0" for the post-application period) due to the restricted randomization technique, where rep 1> rep 2> rep 3 is expected.

Acetochlor Concentration

Concentration of acetochlor in the composite, FW water samples for each of the plots for the 2010 drainage season is shown in Table 6. Four regular samples plus one duplicate sample of the 39 tile water samples collected prior to acetochlor application contained detectable levels of acetochlor ranging from 0.03 to 0.07 µg/L. The acetochlor detects were all found in the March (snow melt) samples. The eight post-application samples that contained detectable levels of acetochlor were collected between May 20 and June 28. Although almost one-half of the total 2010 drainage occurred after July 1, no detections of acetochlor were recorded in water collected more than six weeks after acetochlor application.

A breakdown of the acetochlor detects by acetochlor rate of application is shown in Table 7 for the total 2010 drainage year and for the Post-Application period. Acetochlor was detected in 13 of the 182 water samples collected during the year and in 8 of the 143 samples collected after acetochlor application. The five detects in March may have been carryover from the acetochlor applied in 2009 - - a very dry year when only 0.7" of tile drainage occurred. During the post-application period in 2010, 1 of 47 water samples (2.1%) from the 0.0 pt/A control treatment showed a detectable level of acetochlor. For the 1.5 pt/A treatment, 3 of 59 water samples (5.1%) contained acetochlor, averaging 0.073 µg/L; whereas, 4 of 37 water samples (10.8%) contained acetochlor, averaging 0.4432 µg/L when the 2.5 pt/A rate was applied. Only 1 of the 18 duplicate water samples was different from the original sample (<0.05 vs 0.05 µg/L) - - - a very small difference. The objective of this research was met with these findings; reducing the application rate of acetochlor resulted in lower acetochlor concentrations in the water and fewer water samples at or above the minimum detection level.

Fourteen tile water grab samples were collected on seven dates (5/16, 5/30, 5/27, 6/1, 6/4, 6/18, and 6/21) from plots 1103 (1.5 pt/A) and 1506 (2.5 pt/A) to determine the presence and concentration of acetochlor degredates (ESA and OXA). Concentrations of ESA were found in all 14 samples, averaging 0.68 and 0.97 µg/L for the 1.5 and 2.5 pt/A rates, respectively (Table 8). Detectable concentrations of OXA were found in 12 of the 14 samples, averaging 0.36 and 0.53 µg/L for the 1.5 and 2.5 pt/A acetochlor rates, respectively. When comparing the ARP and MDA laboratories, the analytical results for parent concentrations of acetochlor agreed quite well between the two laboratories except for the 6/18 sample from the 1.5 pt/A treatment. The ARP laboratory showed 0.08 µg/L acetochlor while the MDA lab showed ND.

Flow-weighted concentrations of acetochlor in the drainage water after the acetochlor treatments were applied were not calculated due to the limited detections of acetochlor.

Acetochlor loss

In an effort to get a general idea of the potential amount of acetochlor lost during the post-application period during which detectable levels of acetochlor were found in 5 and 11% of the samples for the 1.5 and 2.5 pt/A acetochlor rates, respectively, we multiplied the amount of water drained during the 5/17-6/30 period (5.3 acre-inches) times the mean acetochlor concentrations for the detects (0.073 µg/L and 0.432 µg/L for the 1.5 and 2.5 pt/A rates, respectively).

Assuming these concentrations across the total 5.3 acre-inches we calculate 40 and 235 mg acetochlor/A for the 1.5 and 2.5 pt/A treatments, respectively. Since the detects comprised only 5 and 11% of the samples, these values should be reduced accordingly, resulting in about 2 and 23 mg acetochlor/A for the 1.5 and 2.5 pt/A rates, respectively.

Corn Production

The previous crop, N rate used, tile discharge for 2010, corn yield, grain moisture content, and grain N concentration for each of the acetochlor drainage plots are shown in Table 9. Tile drainage after acetochlor application ranged between 14.1 and 17.2 acre-inches for the three acetochlor treatments. Corn grain yields were less than expected due primarily to the high amount of rainfall that led to substantial denitrification and leaching loss of fertilizer N, resulting in N deficiency. Grain moisture was significantly less when N was applied at the 140 or 160 lb/A rates. However, grain N concentration was not different among the N rates due to differences in grain yield (dilution) and to these N rates being yield limiting.

Table 1. Experimental procedures used in the acetochlor drainage study at Waseca from July 1-Dec. 31, 2010.

Procedure	Date
Take SPAD meter readings (leaf chlorophyll status)	July 19
Take stover yield from all corn plots	Sept. 13
Combine harvest corn plots	Oct. 1
Combine harvest soybean plots	Oct. 2
Combine harvest remaining corn & soybeans	Oct. 7
Chop corn stalks	Oct. 7
Chisel plow the experimental site	Nov. 2
Soil froze	Nov. 25

Table 2. Available soil water in the 0-5' profile of a Webster clay loam, continuous corn site located adjacent to the acetochlor drainage site in 2010.

Date	Avail. soil water[1/]
	inches in 0-5'
April 16	10.46
May 3	9.73
May 17	10.11
June 1	11.02
June 16	10.27
July 1	11.11
July 15	10.14
August 6	10.35
August 16	9.19
August 31	8.17
September 15	Too wet, no samples taken
October 1	Too wet, no samples taken
October 15	10.93
November 1	Too wet, no samples taken

[1/] Available water at 100% field moist capacity is 11.05".

Table 3. Precipitation amounts in 10-day periods for April-November, 2010 at the acetochlor drainage site at Waseca.

Month	Period	Precipitation	Long-term Normal
		inches	inches
January	1-31	0.68	1.39
February	1-28	1.26	0.95
March	1-10	0.63	2.49
	11-20	0.71	
	21-31	0.11	
	Total	1.45	2.49
April	1-10	0.32	
	11-20	0.44	
	21-30	0.84	
	Total	1.60	3.23
May	1-10	0.75	
	11-20	1.25	
	21-31	1.27	
	Total	3.27	3.96
June	1-10	1.57	
	11-20	5.75	
	21-30	2.32	
	Total	9.64	4.22
July	1-10	1.40	
	11-20	0.98	
	21-31	4.23	
	Total	6.61	4.47
August	1-10	0.74	
	11-20	1.11	
	21-31	0.58	
	Total	2.43	4.58
September	1-10	2.54	
	11-20	1.84	
	21-30	8.28	
	Total	12.66	3.19
October	1-10	0.00	
	11-20	0.00	
	21-31	1.02	
	Total	1.02	2.50
November	1-10	0.00	
	11-20	1.87	
	21-30	0.59	
	Total	2.46	2.32
December	1-31	3.69	1.40
Jan-Dec	Total	46.79	34.70
March-Sept. (Flow period)	Total	37.66	28.47

Table 4. Tile flow periods and the number of drainage plots flowing from the 10 plots in the acetochlor drainage study in 2010.

Period	No. Days	Drainage[1/]	Avg. No. of Plots[2/] draining/day	Tile Flow Recorded
		plot-days	plots/day	days all plots flowing
<3/11	--	No flow	--	--
3/11-3/31	21	175	8.3	12
4/1-4/30	30	52	1.7	0
5/1-5/16	16	16	1.0	0
pre-application flow total				
3/11-5/16	**67**	**243**	**3.6**	**12**
5/17-5/31	15	83	5.5	0
6/1-6/15	15	82	5.5	0
6/16-6/30	15	138	9.2	10
7/1-7/15	15	55	3.7	0
7/16-7/31	16	46	2.9	0
8/1-9/22	53	17	0.3	0
9/23-9/30	8	80	10.0	8
10/1-10/15	15	48	3.2	0
>10/16	--	0	--	0
post-application flow total				
5/17-10/15	**152**	**549**	**3.6**	**18**

[1/] Includes all acetochlor plots where ≥3 gal/plot/day of flow was recorded. This equals 220 gal/A/d or 0.008 acre-inch/day.

[2/] Potential maximum of 10.0.

Table 5. Monthly tile flow during the post-application period (May 17-Oct. 15, 2010) from the acetochlor treated plots at Waseca.

Acetochlor Trt. No.	Acetochlor Rate	Rep 1	Rep 2	Rep 2 Ex	Rep 3	Avg.	SE[1/]
		plots					
		1503 1103 1506	2109 2307 2309	2507	3510 3513 3512		
	pt./acre	Tile flow (acre – inch)					
		May 17-31					
1	0	1.0	0.1		0.3	0.5	0.3
2	1.5	0.8	0.0	1.3	0.0	0.5	0.3
3	2.5	0.6	0.0		0.1	0.3	0.2
						0.4	
		June 1-15					
1	0	1.4	0.6		0.6	0.9	0.3
2	1.5	1.1	0.4	1.5	0.4	0.8	0.2
3	2.5	1.1	0.1		0.6	0.6	0.3
						0.7	
		June 16-30					
1	0	4.2	4.7		2.4	3.8	0.7
2	1.5	5.3	4.7	4.9	2.9	4.3	0.7
3	2.5	5.7	4.4		3.4	4.5	0.6
						4.2	
		July 1-31					
1	0	1.36	0.63		0.30	0.76	0.31
2	1.5	1.36	0.04	1.38	0.03	0.70	0.39
3	2.5	0.40	0.15		0.00	0.18	0.12
	Avg.					0.55	
		Aug. 1-31					
1	0	0.00	0.00		0.00	0.0	0.00
2	1.5	0.01	0.00	0.04	0.00	0.01	0.01
3	2.5	0.01	0.01		0.00	0.01	0.00
	Avg.					0.01	
		Sept. 1-30					
1	0	7.4	9.0		7.3	8.0	0.5
2	1.5	10.1	11.2	9.3	10.3	10.2	0.4
3	2.5	10.7	12.1		11.6	11.5	0.4
	Avg.					9.9	
		Oct. 1-15					
1	0	0.57	0.01		0.04	0.21	0.18
2	1.5	0.28	000	0.86	0.01	0.29	0.20
3	2.5	0.25	0.00		0.05	0.10	0.08
	Avg.					0.20	
		May 17-Oct. 31 Total					
1	0	16.0	15.0		11.2	14.1	1.5
2	1.5	19.0	16.3	19.6	13.6	17.2	1.4
3	2.5	18.9	16.8		15.8	17.2	0.9
		18.0	16.0		13.5	16.1	

[1/] SE = standard error of the mean.

Table 6. Acetochlor concentrations in the FW tile drainage samples collected on the following dates at Waseca in 2010.

Acetochlor Trt No.	Acetochlor Rate	Rep 1	Rep 2	Rep 2 Ex	Rep 3	Avg.
		plots				
		1503, 1103, 1506	2109, 2307, 2309	2507	3510, 3513, 3512	
	pt./acre	Acetochlor concentration (µg/L)				
			March 13			
1	0	ND	ND		ND	<0.03
2	1.5	**0.07**	ND	ND	ND	<0.05
3	2.5	ND	**ND[3/]**		ND	<0.03
			March 17			
1	0	ND	ND		ND	<0.03
2	1.5	ND	ND	**0.03**	ND[2/]	<0.03
3	2.5	ND	ND		ND	<0.03
			March 24			
1	0	ND[2/]	ND		ND	<0.03
2	1.5	ND	ND	ND	**0.03**	<0.03
3	2.5	**0.03**	ND		ND	<0.03
			May 16			
1	0	ND[2/]	--		ND	<0.03
2	1.5	ND	--	ND	--	<0.03
3	2.5	ND	--		--	<0.03
			Post-Application Period			
			May 20			
1	0	ND[2/]	--		--	<0.03
2	1.5	ND	--	ND	--	<0.03
3	2.5	ND	**1.29**		--	<0.66
			May 24			
1	0	ND	--		--	<0.03
2	1.5	ND	--	ND[2/]	--	<0.03
3	2.5	ND	--		--	<0.03
			May 27			
1	0	<0.05	--		--	<0.05
2	1.5	<0.05[2/]	--	<0.05	--	<0.05
3	2.5	<0.05	--		--	<0.05
			June 1			
1	0	<0.05	**0.10**		--	<0.05
2	1.5	<0.05[2/]	--	<0.05	--	<0.05
3	2.5	<0.05	--		--	<0.05
			June 4			
1	0	<0.05	--		<0.05	<0.05
2	1.5	<0.05[2/]	<0.05	<0.05[2/]	--	<0.05
3	2.5	<0.05	--		--	<0.05
			June 8			
1	0	<0.05[2/]	--		--	<0.05
2	1.5	<0.05	--	<0.05	--	<0.05
3	2.5	--	--		--	--

			June 12			
1	0	<0.05	<0.05		<0.05[2/]	<0.05
2	1.5	<0.05	<0.05	<0.05	**0.09**	<0.06
3	2.5	<0.05	**0.27**		<0.05	<0.12
			June 16			
1	0	<0.05	<0.05		<0.05	<0.05
2	1.5	<0.05	<0.05[2/]	<0.05	<0.05	<0.05
3	2.5	<0.05	<0.05	<0.05	<0.05	<0.05
			June 18			
1	0	<0.05	<0.05		<0.05	<0.05
2	1.5	**0.08**	<0.05	<0.05	<0.05	<0.06
3	2.5	<0.05	**0.12**		**<0.05[4/]**	<0.07
			June 21			
1	0	<0.05	<0.05[2/]		<0.05	
2	1.5	<0.05	<0.05	<0.05	<0.05	
3	2.5	<0.05	<0.05		<0.05	
			June 25			
1	0	<0.05	<0.05[2/]		<0.05	
2	1.5	<0.05	<0.05	<0.05	--	
3	2.5	<0.05	<0.05		<0.05	
			June 28			
1	0	<0.05	<0.05		<0.05[2/]	
2	1.5	<0.05	<0.05	<0.05	**0.05**	
3	2.5	<0.05	<0.05		<0.05	
			July 2			
1	0	<0.05	<0.05		<0.05	
2	1.5	<0.05	<0.05[2/]	<0.05	--	
3	2.5	<0.05	<0.05		<0.05	
			July 6			
1	0	<0.05[2/]	--		--	
2	1.5	<0.05	--	<0.05	--	
3	2.5	<0.05	--		--	
			July 26			
1	0	<0.05	<0.05		<0.05	
2	1.5	<0.05[2/]	--	<0.05	--	
3	2.5	<0.05	<0.05		--	
			Sept. 24			
1	0	<0.05[2/]	<0.05		<0.05	
2	1.5	<0.05	<0.05	<0.05	<0.05	
3	2.5	<0.05	<0.05		<0.05	
			Sept. 30			
1	0	<0.05	<0.05		<0.05	
2	1.5	<0.05	<0.05	<0.05	<0.05[2/]	
3	2.5	<0.05	<0.05		<0.05	

[1/] ND = <0.03 ppb (0.03 µg/L).
[2/] Duplicate sample also = ND or < 0.05
[3/] Duplicate sample = 0.03
[4/] Duplicate sample = 0.05

Table 7. Acetochlor concentrations in tile drainage samples collected at Waseca in 2010.

Parameter	Acetochlor Treatment (pt/A)		
	0.0	1.5	2.5
Total number of water samples	60	74	48
No. of acetochlor detects	1	6	6
% Detects	1.7	8.1	12.5
Avg. acetochlor conc. in detects (µg/L)	0.10	0.059	0.298
Acetochlor detects conc. range (µg/L)	--	0.03-0.09	0.03-1.29
Std error of the mean (µg/L)	--	0.011	0.202
No. Regular samples	51	67	46
No. Duplicate samples	9	7	2
No. samples where duplicate differed from regular sample	0	0	1 (<0.05 vs. 0.05)
	Post-Application Period		
No. of samples collected in post-application period	47	59	37
No. of acetochlor detects	1	3	4
% Detects	2.1	5.1	10.8
Avg. acetochlor conc. in detects (µg/L)	0.10	0.073	0.432
Acetochlor detects conc. range (µg/L)	--	0.05-0.09	0.05-1.29

Table 8. Acetochlor concentrations in tile water grab samples collected at Waseca in 2010.

Plot	Acetochlor Rate	Collection Date	ARP Parent Conc.	MDA Parent Conc.	Acetochlor Degredates ESA Conc.	Acetochlor Degredates OXA Conc.
	pt/A		- - - - - - - - - - - - -	µg/L	- - - - - - - - - - - - -	
1103	1.5	5/16	ND[1/]	ND	0.47	0.07
	1.5	5/20	ND	ND	0.33	0.05
	1.5	5/27	--	ND	0.29	0.05
	1.5	6/1	--	ND	0.80	0.20
	1.5	6/4	--	<0.05	0.23	ND
	1.5	6/18	0.08	ND	1.17	0.77
	1.5	6/21	<0.05	ND	1.50	0.99
			Detect avg. =		**0.68**	**0.36**
1506	2.5	5/16	ND	ND	0.96	0.49
	2.5	5/20	ND	ND	0.89	0.47
	2.5	5/27	--	ND	0.73	0.21
	2.5	6/1	--	ND	0.24	ND
	2.5	6/4	--	ND	0.82	0.17
	2.5	6/18	<0.05	<0.05	1.66	1.18
	2.5	6/21	<0.05	ND	1.46	0.64
			Detect avg. =		**0.97**	**0.53**

[1/] ND = assumed to be <0.05 µg/L.

Table 9. Tile discharge and corn production parameters for the plots receiving acetochlor in 2010.

Acetochlor		Plot	Prev.	2010	2010 Tile[1/]	Corn	Grain	Grain N
Trt. No	Rate	No.	Crop	N rate	discharge	yield	moisture	concentration
	pt./A			lb N/A	acre-inches	bu/A	%	%
1	0	1503	Corn	0	16.2	50.3	25.7	1.16
		2109	"	0	14.9	60.9	26.2	1.14
		3510	"	0	11.3	61.5	28.3	1.05
				Average	14.1	57.6	26.7	1.12
2	1.5	1103	"	160	19.0	151.9	19.8	1.15
		2307	"	160	16.3	150.4	21.6	1.07
		2507	Soyb	0	19.7	109.6	20.8	1.02
		3513	Corn	160	13.7	171.8	20.9	1.11
				Average	17.2	145.9	20.8	1.09
3	2.5	1506	"	60+80	18.9	169.2	22.0	1.10
		2309	"	60+80	16.8	168.2	21.0	1.09
		3512	"	60+80	15.8	171.7	21.3	1.13
				Average	17.2	169.7	21.4	1.11

[1/] May through October.