Effects of Tillage on Quality of Runoff Water

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The issue of water quality is of great importance to agriculture today as agricultural land is implicated as a leading contributor of nonpoint source water pollution. In many cases, overland flow from irrigation and natural rainfall exiting cropland is rich in plant nutrients, especially nitrate and phosphate, and agricultural pesticides that are threatening the purity of our waters. The effect on man is both immediate through contaminated drinking water (Baker, 1985) and long term through degradation of aquatic bio-systems (Lee, 1973). These conditions have been reported in agricultural areas across the United States; Indiana (Romkens et al., 1973), Lake Erie (Baker, 1985), Texas (Trichell et al., 1968) are a few documented areas.

Success in reducing sediment loads in field runoff has been accomplished with conservation tillage. Harrold and Edwards (1972) reported about 0.16 Mg/ha sediment lost from no-tillage contour-row corn compared to about 51 Mg/ha with conventional tillage in Ohio. Cogo et al. (1984) found that chisel tillage with spring sweep increased rainfall infiltration and increased the length of time to runoff, resulting in decreased soil loss over no-tillage or fall moldboard plowing plus spring disk; the results were 12, 33, and 21 Mg/ha, respectively, for the three systems. In plots with continuous corn on 1.6 to 2.7% slopes, Van Doran et al. (1984) reported soil losses of 4.2 to 9.4 Mg/ha under plow-disk tillage and 0.5 to 0.8 Mg/ha under no-tillage.

These tillage systems are now being evaluated at the University of Kentucky for their effect on water quality. The data contained in this report are from the first year of a long-term field study at Lexington. The objective of the study is to compare water quality parameters of field-edge runoff under conventional tillage, chisel-plow tillage and no-tillage. In addition to total runoff volume, the water quality parameters being determined include amounts of sediments, nitrate (NO_3^-), soluble phosphorous

(P) and atrazine (2 chloro-4-ethylamino-6-isopropylamine-5-triazine) in the liquid phase of the runoff. This study does not consider actual delivery rates to a nearby stream.

MATERIALS AND METHODS

The study site is a Maury silt loam soil (fine-silty, mixed, mesic, Typic Paleudalf) with 9% slope. The site was in bluegrass sod for at least 20 years prior to establishing the experiment in 1984. Plots are 9 m wide by 30 m long. All plots were sprayed with paraquat to kill the sod. Tillage treatments were conventional tillage (CT) (moldboard plowed and disked once), chisel-plow tillage (CP) (straight shank plowed and disked once) and no-tillage (NT). There were three replications of each tillage treatment, and values reported are averages of the three replications. Following tillage and planting, fertilizers were broadcast on the soil surface at rates of 170, 60, and 135 kg/ha, N, P, and K, respectively, as ammonium nitrate (34%N), triple superphosphate (20%P), and muriate of potash (50%K). Atrazine was applied at a rate of 2.5 kg/ha active ingredient (a.i.).

Runoff samples were collected in storage tanks down-slope of the flumes positioned at the edge of each plot. Within 24 hours, usually less, after each rainfall event, a stirred, 200 ml runoff sample was collected for chemical analysis. The sediment was separated from these samples by refrigerated centrifugation for 15 minutes at 2,000 RPM, and the liquid phase was stored in a refrigerator at **3 C** until analyzed. The sediment will be analyzed at a later date. A 1 liter sample was also collected from each storage tank for determination of sediment load. Nitrate was analyzed according to the procedure of Lowe and Hamilton (1967). Soluble phosphorous was determined by the stannous chloride procedure (Jackson, 1958) and atrazine was partitioned and analyzed with high performance liquid chromatography (HPLC) as described by Lawrence (1982). The samples discussed in this report are from rainfall events from June 11 to November 4, 1984.

RESULTS AND DISCUSSION

Although results are preliminary, statistical analyses incomplete, and interpretations and conclusions tentative, there are important trends suggested by the data. During the first four rains, either the NT or the CP produced the lowest runoff volumes. However, from mid-season, runoff amounts were about the same for all three tillage systems during most of the rains. This suggests greater infiltration with the conservation tillage methods during the first half of the season, but little difference after mid-season. Total runoff volume measured during the season was two times greater with CT than with CP or NT.

Except for one rainfall event, June 22, the CP treatment appeared to produce the greatest amount of sediment in the runoff and NT the least (Table 1). The total amount of sediment measured during the season was slightly more with CT, mainly because of the much higher amount on June 22.

From this, it appeared that the sod cover of the NT was more effective in protecting the soil from erosion. We have no explanation for the tendency for more sediments from CP than from CT.

Table 1. Total rainfall, runoff volume, and sediment load, 1984.

Date of event	Rainfall	Runoff volume			Sediment load		
		CT†	CP	NT	CT	CP	NT
	cm	---------liters/ha--------			--------kg/ha-------		
6-11‡	1.2	560	4,763	512	--‡	--	--
6-18	4.5	39,409	21,229	16,903	--	--	--
6-22	2.6	11,622	3	3,335	46	13	7
7-4	4.8	16,729	7,271	12,134	31	33	21
7-11	0.4	3	227	256	2	2	1
7-26	1.6	911	1,005	1,127	1	8	4
8-1	1.3	13,618	1,481	1,625	2	3	2
10-21	5.3	3,160	3,532	3,623	2	5	2
10-28	2.9	1,861	2,328	2,076	2	4	1
11-1	2.4	1,319	1,855	1,510	1	2	<1
11-4	1.5	741	740	774	<1	3	<1
Season total	28.5	89,933	44,434	43,875	87	74	38

† CT = Conventional tillage, CP = Chisel-plow tillage, NT = No-tillage.
‡ Delay in installation of equipment delayed start of sampling.

The concentration of NO_3^- in the liquid phase of the runoff tended to be highest with NT and lowest with CP (Table 2). Total NO_3^- per event (runoff volume times NO_3^- concentration in runoff) was not greatly different among tillage treatmeits, except for three events (June 22, July 4, and August 1) when runoff was much greater from CT and one (June 11) when CP resulted in the greatest NO_3^-. Overall total NO_3^- from CP plots tended to be somewhat less than from CT. Total NO_3^- removal during the season (average NO_3^- concentration in Table 2 times total runoff in Table 1) for CT, CP, and NT were 171, 53, and 145 g/ha N, respectively.

Water-soluble P concentration in the runoff liquid phase are shown in Table 3. One of the notable trends in the water-soluble P concentration was what appeared to be a substantial increase in concentration at the end of the season, specifically the October 28, November 1, and November 4 sampling dates. We have not determined the cause of this, but intend to study it more thoroughly in the future.

Total water-soluble P in runoff, i.e., total runoff values in Table 1 times average P concentration values in Table 3, were 90, 67, and 22 g/ha P, respectively, for CT, CP, and NT.

Table 2. Nitrate in runoff liquid phase as affected by tillage, 1984.

Date	Concentration of nitrate CT[‡]	CP	NT	Total nitrate[†] CT	CP	NT
	mg/liter N			g/ha N		
6-11	0.2	3.1	9.8	<1	15	5
6-22	2.2	0.8	2.7	26	<1	9
7-4	1.6	0.8	0.5	27	6	6
7-11	3.1	1.8	3.0	<1	<1	<1
7-26	2.1	0.4	2.9	2	<1	3
8-1	0.9	0.5	2.5	12	1	4
10-28	2.2	0.9	3.0	4	2	6
11-1	1.3	1.2	2.5	2	2	4
11-4	3.5	2.2	2.5	3	2	2
Avg	1.9	1.2	3.3			

† Runoff volume times NO_3^- concentration in runoff.
‡ CT = Conventional tillage; CP = Chisel-plow tillage; NT = No-tillage.

Table 3. Concentration of water-soluble P in runoff liquid phase as affected by tillage, 1984.

Date	Concentration of P CT	CP	NT	Total P CT	CP	NT
	mg/liter			g/ha		
6-11	0.35	0.04	0.09	<1	<1	<1
6-22	0.56	0.50	0.24	7	<1	1
7-4	0.67	0.45	0.68	11	3	8
7-11	0.49	0.35	0.14	<1	<1	<1
7-26	1.03	1.71	0.12	1	2	<1
8-1	0.42	0.64	0.19	6	1	<1
10-28	0.89	1.10	1.13	2	3	2
11-1	2.27	2.13	1.09	3	4	2
11-4	2.12	6.61	0.80	2	5	1
Avg	1.00	1.50	0.50			

The atrazine concentration tended to be highest from the conservation tillage plots, especially CP, during the earlier part of the season (Table 4); however, by the July 4 sampling date, this difference had disappeared. This may be attributed to less contact of the atrazine with soil under conservation tillage because of the killed sod mulch.

A gradual decrease in atrazine concentration was apparent as the season progressed, although there remained measurable quantities even in the November 4 runoff. Expressed as a sum for all dates (average concentrations in Table 4 times total runoff volumes in Table 11, atrazine amounts in

Table 4. Concentration of atrazine in runoff liquid phase as affected by tillage, 1984.

Tillage	Atrazine, mg/liter						
	6-11	6-27	7-4	7-11†	7-26	11-4	Avg
CT	0.03	0.02	0.03	0.07	0.02	0.01	0.03
CP	0.11	0.25	0.01	0.01	0.02	0.01	0.07
NT	0.10	0.02	0.04	0.01	0.01	0.01	0.03

† Only 1 replicate plot analyzed

relation to tillage systems were 27, 31, and 13 g/ha atrazine (a.i.) for CT, CP, and NT, respectively. Thus, because of the greater runoff from CT, the amount of atrazine removal appeared to be about the same as from the CP. Atrazine removal was apparently lower with NT than CP due to its lower concentration in the runoff and lower than CT due to less runoff.

Generally, the runoff from CP plots had the highest pH, NT runoff was slightly lower, and CT was lowest (Table 5). There was no apparent explanation for the relationship between pH and tillage system. The pH is considered to be a very important property of runoff due to its possible influence on the rate of atrazine degradation (Best and Weber, 1974).

Table 5. pH of runoff as affected by tillage system, 1984.

Tillage	6-27	7-4	7-11	7-26	8-1	10-28	11-1	11-4	Avg
	pH								
CT	7.16	5.78	6.17	6.48	6.17	6.12	6.16	5.86	6.24
CP	7.19	6.57	6.42	6.69	6.40	6.18	6.74	6.30	6.56
NT	7.30	6.19	7.25	6.37	6.23	5.86	6.35	5.45	6.38

SUMMARY

Generally, the first year's data from this study showed little statistically significant difference in water quality parameters due to tillage. At least part of this can be attributed to the homogeneity of these plots in their first year of tillage following many years in bluegrass sod. The data does indicate certain trends. Runoff from NT tended to be highest in NO_3^- concentrations throughout much of the season, but the total amount of NO_3^- was greatest in runoff from CT. Total runoff volume and sediment load for the season were also greatest from CT. Runoff from CP was most often highest in concentrations of both water-soluble P and atrazine and often carried higher total amounts of atrazine. Because of the higher volume of runoff, the greatest total amount of water-soluble P was removed from the CT plots. The pH values generally were highest for CP and lowest for CT runoff.

Our NO- and P results were similar to those reported by Romkens et al. (1973) ahd angle et al. (1984), although significant differences between tillage treatments were few. With subsequent cropping years, these plots are expected to become much more characteristic of their respective tillage systems in regard to surface condition, soil structure, organic matter and surface pH, all of which have been indicated as influencing runoff volume and its composition and sediment delivery.

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