Runoff Composition of Soybean Management Systems on Leeper Clay Loam Soil[1]

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Soil erosion and runoff have traditionally belonged to the problem domain of sloping upland areas. Bottomland or flatlands were considered sediment deposition areas. With the advent of environmental concerns, especially those of nonpoint pollution sources, interest has developed in evaluating sediment production and transport on flat-and bottomland areas. This interest is heightened by concern about sediment attached agricultural chemicals, especially herbicides and insecticides that are applied to intensively cropped agricultural flat-and bottomland areas at various times during the crop growing season.

Significant soil movement from flatland areas has been reported by Murphree *et al.* (1976) on cotton cropped Sharkey silty clay in the Mississippi Delta and by Barnett *et al.* (1978) on sugarcane cropped Commerce silt loam and Sharkey silty clay soils in Louisiana. On the other hand, chemical transport on flat- and bottomland areas is less well documented. In fact, chemical movement relative to that of sediment may be more significant than that on upland areas, as sediment loads are smaller, the percentage of clay-size material is often greater, and the cropping system requiring applications of fertilizer and pesticides is more intensive. On balance, it would seem that the principles of chemical transport and sediment association of chemicals should not differ from those of upland areas. The amount of chemical movement depends on many factors, including soil and crop management systems, the amount and manner of chemical application, the incidence, frequency and characteristics of rainstorms, and antecedent conditions.

Numerous studies based on either natural storm events or simulated rainfall have shown that reduced or conservation tillage systems are effective in reducing soil erosion (McDowell and McGregor, 1979; Römkens *et al.*, 1973; McGregor, *et al.*, 1978; Laflen *et al.*, 1978). Some of these studies have indicated that a reduction in soil loss for these systems often is associated with an increase in the soluble nutrient concentration of water runoff (Römkens *et al.*, 1973; Barisas, *et al.*, 1978), even though the total nutrient removal by the sediment plus water phase may decrease. However, most of these studies were conducted on sloping land, where soil erosion and runoff are common occurrences. Less is known about the interrelationships of sediment and nutrient removal on flat- or bottomland soils, especially in the fall, winter, and spring, when runoff hazards are most prevalent. This article discusses the results of measurements of soil loss and chemical composition of runoff from various tillage management systems on bottomland during simulated rainstorms. The specific objectives are (i) to report soil erosion rates for two commonly occurring land management systems on bottomland soil in soybean production following harvest during the fall of 1977, (ii) to report on the chemical composition of runoff from these systems.

PROCEDURE

The experiments consisted of applying simulated rainstorms to plots in two tillage-management systems:

(i) Double Cropping. The soil was chiseled, disked, and springtooth-harrowed in the spring of 1977 and planted to soybeans [var. "Tracy", *Glycine Max.* (*M*)] with 91 cm row spacing. Wheat [var. "ABE" *Triticum Aestivum* (*L*)] was seeded into standing soybeans by areal simulation October 1, 1977. Soybean yield harvested on October 14, 1977, was 2360 kg/ha. Fertilizer was surface broadcast on October 14, 1977, at the rate of 224 kg/ha of 0-17-34, which is about 38 kg of phosphorus as P and 76 kg of potassium as K. Simulated rain was applied on November 14, 1977, at which time wheat plants were about 6 cm tall.

(ii) Minimum Tillage. This system was identical to the double cropping system, except that no wheat was planted.

(iii) Fallow. The soil was kept fallow since the spring of 1977. Immediately before simulation of rainfall, the plots were springtooth-harrowed up and down slope. No fertilizer was applied to the soil. Simulated rain was applied on November 1 to plots 3 and 4 and on November 23 to plots 1 and 2. The fallow system was chosen as a standard against which other systems were compared.

The experimental area was in corn during the 1976 growing season yielding 33.7 T/ha of wet silage (65% moisture content). The research area was kept clean of weeds during the 1977

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growing season. Duplicate plots were studied on the minimum tillage and double cropping system (wheat-soybean). Quadruplicate plots were examined in the fallow treatment. The experiments were part of a continuing study projected for the late spring of 1978 to assess the impact of different tillage-planting systems on soil loss and chemical composition of runoff. The double cropping and minimum tillage systems did not differ appreciably for the 1977 phase of this rainfall simulator study.

Tillage management systems were laid out randomly in tracts of 7.6 x 30.5-m on Leeper clay loam soil (Alfisol) of 0.2% slope. Two rainulator plots of 1.83 x 22.13-m separated by a 30 cm bufferstrip were superimposed upon each tract.

Two 60-minute simulated rainstorms of about 7.7 cm hr^{-1} separated by a break of about one hour were applied to each plot using the rainfall simulator described by Meyer and McCune (1958). Intensities among individual storms varied from 8.8 to 7.0 cm hr^{-1}. The fallow plots were covered with black plastic between tillage and the first storm to protect the soil surface against the direct impact of raindrops from natural storms. Rainfall intensity, runoff, and soil loss were measured in the standard manner for rainulator runs (Meyer and McCune, 1958). Between 20 to 25 "grab" samples were collected per plot for each storm. The first 3 samples collected all runoff on a continuous basis, whereas the remaining samples collected runoff on an intermittent basis. The samples were collected in 1000 ml glass jars capped with a teflon lined lid. The jars were previously washed in successive order with chromic-sulphuric acid, demineralized-distilled water, acetone, and hexane to remove contaminants which would interfere with or confound the results of subsequent chemical analyses. The samples were immediately transported to the laboratory where they were kept in a refrigerator (4°C) until analysis. Sample analyses consisted of determinations of sediment concentration, dissolved solids, and the nitrogen, phosphorus, and potassium content of the water and/or sediment phase. Soluble ortho-phosphate and ammonium nitrogen were determined following filtration of the sample with the Technicon Auto Analyzer II. Nitrate-nitrogen was determined by the cadmium-copper reduction method (Wood *et al.*, 1967) as modified by Ryan[3]. Sediment nitrogen and phosphorus were also determined with the Technicon Auto Analyzer II following digestion with a mixture of 4.1 g K_2SO_4, 0.625 ml of a 0.05 M solution of HgO in 10% H_2SO_4, and 5.7 ml concentrated H_2SO_4. Potassium was determined by the atomic absorption technique.

Total chemical and soil losses were computed by integrating the chemical or sediment concentrations over the hydrograph or sedigraph.

RESULTS AND DISCUSSION

Soil Loss and Infiltration. The effect of management system on soil loss and infiltration for the two 60-minute rainstorms is summarized for each storm and plot in Table 1. Hydrographs, sedigraphs and nutrient-concentrations in the water and sediment phase for a typical plot in each system are shown in Figures 1, 2 and 3. Average soil loss for the double cropping and minimum tillage systems was about one tenth of that of the fallow plots. Infiltration was less on the fallow plots. This finding is attributed to the nearly saturated plow layer, which existed when rainfall was applied. Nearly 22.6 cm of natural rain was received in 8 storms during the 4-week study period. Table 2 summarizes the precipitation history by natural storms during the study period. In spite of the plastic cover, which protected the fallow plots from direct raindrop impact, lateral flow in the top 10 to 15 cm of the soil profile caused a near saturated condition in the surface zone of this soil. Internal drainage in this profile, especially in the massive clay subsoil was slow and appeared to take place through polygonal cracks. Therefore, the difference in

Table 1. Observed soil loss* and infiltration on Leeper clay loam soil.

Storm	Rep.	Dbl. Cropping Soil loss	Dbl. Cropping Inf.	Min. Tillage Soil loss	Min. Tillage Inf.	Fallow Soil loss	Fallow Inf.
		T/ha	cm	T/ha	cm	T/ha	cm
1	1	0.36	2.79	0.26	3.42	5.71	0.29
	2	0.39	2.68	0.27	2.15	3.65	0.25
	3					3.42	0.67
	4					2.29	1.43
	Aver.	0.37	2.74	0.27	2.79	3.77	0.66
2	1	0.46	1.58	0.44	3.05	5.19	0.12
	2	0.51	1.31	0.46	1.98	4.04	Tr.
	3					3.22	Tr.
	4					2.56	0.16
	Aver.	0.49	1.45	0.45	2.52	3.75	0.07

***Soil loss and infiltration were adjusted to the standard 60-min. rainstorm of 6.35 cm/hr intensity, using the relationship: soil loss (I = 6.35) = soil loss (I)* $(6.35/I)^2$ and the concept that infiltration is not affected by variations in rainfall intensities.**

Table 2. Precipitation by natural rain storms during the study period.

Date	Amount	Date	Amount	Date	Amount
	cm		cm		cm
Oct. 25	5.33	Nov. 16	1.40	Nov. 29	1.85
Oct. 26	0.13	Nov. 17	3.23	Nov. 30	2.29
Nov. 3	2.39	Nov. 21	7.52	Dec. 1	1.27
Nov. 5	0.64	Nov. 22	1.52	Dec. 5	0.41
Nov. 9	0.38	Nov. 28	0.79	Dec. 9	0.89

infiltration between the fallow system on one hand and the double cropping and minimum tillage systems on the other hand may be explained by (i) the drainage of surface water through polygonal surface cracks, which were formed during the summer season and extended into the subsurface (tillage obliterated those surface cracks on the fallow plot), and (ii) the supply of subsurface water by lateral flow from upslope especially for the tilled fallow plots.

The difference in soil loss between the fallow and the two conservation tillage systems were very significant. The absolute amount of soil loss for the fallow plots (30.0 T/ha/yr assuming 400 erosion index units per year for the study area and assuming moisture and surface conditions throughout the year similar to those in this study) is significant relative to the widely accepted soil loss tolerance of 12 T/ha/yr. No attempt was made to derive the K-factor for this soil or the C-factor for the conservation tillage systems.

Chemical loss. The chemical removal of nitrogen, phosphorus and potassium by both water and sediment is summarized in Tables 3 and 5 respectively. Their average concentrations are given in Tables 4 and 6, respectively.

Nutrients were primarily removed by the sediment phase. Sediment accounted for 84.3% of the phosphorus loss in the double cropping system. These percentages were 87.9 and 99.3% for the minimum tillage and the fallow system, respectively. Similarly, sediment accounted for 90.8% of the nitrogen loss for the double cropping system, 90.3% for the minimum tillage system, and 94.5% for the fallow system. The percentage difference of phosphorus and nitrogen removed by the sediment phase was small among storms on each management system. This finding suggests a high degree of consistency in the

[3]Personal communication with M. E. Ryan, USDA Sedimentation Laboratory, Oxford, MS.

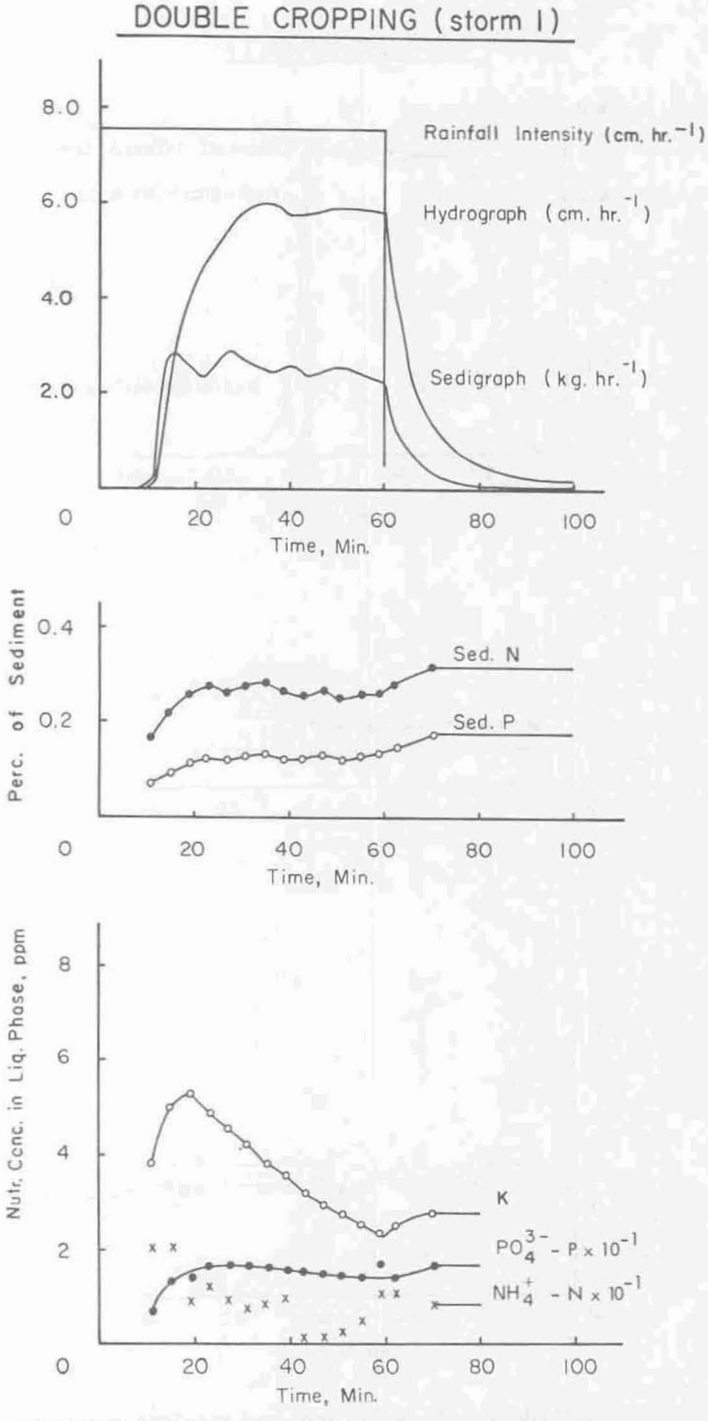

Fig. 1. Hydrograph, sedigraph, and nutrient concentration for the first 60-minute simulated rainstorm on a plot in the double cropping system.

contribution to chemical loss by the sediment phase. Potassium content of the sediment was not determined.

Sediment nitrogen and sediment phosphorus concentrations expressed as percentage of sediment were very constant during a run (Figs. 1 through 3). There was a tendency for those samples collected at the recession end of the hydrographs to have appreciably larger concentrations of sediment nitrogen and phosphorus than the samples collected during rainstorms. This increase is attributed to the relative increase of colloidal material, mostly clay, in the runoff. The absence of rainfall led not only to reduced sediment loads in the recession end of the hydrograph (Figs. 1 through 6) but also to a shift in the sediment size distribution toward the fines. Similarly, the increase in nitrogen and phosphorus concentrations of sediment from the minimum tillage and the double cropping as compared with that of the fallow system (Table 6) can only be explained by a relatively larger clay content in sediment runoff from these conservation tillage systems. Assuming that the native soil nitrogen and soil phosphorus were the same for all plots, then the clay content of sediment from the conservation tillage was about 1.8 times as large as that of the fallow plots.

Nutrient removal by water was relatively minor. Differences in nutrient removal among storms were generally small, but concentrations tended to decrease for the second storm due to (i) decreased infiltration (Table 1) and (ii) reduced residual amounts of added fertilizer - at least for the fertilized treatments. The most nutrients lost for the various management systems were potassium for the double cropping and minimum tillage systems and nitrate-nitrogen for the fallow system.

Nitrogen loss from the double cropping and minimum tillage systems was negligible but was appreciable from the fallow plots (Table 3). No definitive explanation can be given for the removal of nitrate-nitrogen from the fallow plots except that the aerobic condition created following tillage before rain simulation enhanced activity of nitrifying bacteria. The nitrate-nitrogen thus produced would be present in soil water within the inter- and intra-aggregates soil pores of detached aggregates and surface soil and thus could account for the increased concentrations in runoff water. Ammonium-nitrogen was not detected in the water phase of runoff samples from the fallow plots. Double cropping and minimum tillage had detectable but erratic levels of ammonium-nitrogen. Differences in concentrations may be explained by a combination of factors such as variations in sediment concentrations, sample storage effects, crop residue

Table 3. Observed nutrient removal* by water runoff on Leeper clay loam soil.

		Tillage System											
Storm	Rep.	Dbl. Cropping				Min. Tillage				Fallow			
		P-PO_4^{3-}	N-NO_3^-	N-NH_4^+	K	P-PO_4^{3-}	N-NO_3^-	N-NH_4^+	K	P-PO_4^{3-}	N-NO_3^-	N-NH_4^+	K
		kg/ha											
1	1	0.11	Tr	Tr	1.26	0.06	0.03	0.06	0.90	0.02	0.08	Tr	0.32
	2	0.07	Tr	0.04	1.72	0.05	0.07	0.08	0.90	0.02	0.27	Tr	0.25
	3									0.03	0.29	Tr	Tr
	4									0.02	1.16	Tr	Tr
	Aver.	0.09	Tr	0.02	1.49	0.06	0.05	0.07	0.90	0.02	0.45	Tr	0.29
2	1	0.12	Tr	0.09	1.60	0.06	Tr	0.04	1.30	0.02	0.04	0.02	0.08
	2	0.08	Tr	0.29	1.89	0.06	0.05	0.03	1.34	0.02	0.07	Tr	0.19
	3									0.03	0.16	Tr	Tr
	4									0.02	0.49	Tr	Tr
	Aver.	0.10	Tr	0.19	1.75	0.06	0.02	0.04	1.32	0.02	0.19	0.00	0.13

*Nutrient removal has been adjusted for nutrient content in rain water and adjusted to the standard 60 min. rain storm of 6.35 cm/hr intensity.

Table 4. Average nutrient concentration* in water runoff on Leeper clay loam soil.

		Tillage System											
Storm	Rep.	Dbl. Cropping				Min. Tillage				Fallow			
		P-PO_4^{3-}	N-NO_3^-	N-NH_4^+	K	P-PO_4^{3-}	N-NO_3^-	N-NH_4^+	K	P-PO_4^{3-}	N-NO_3^-	N-NH_4^+	K
		ppm											
1	1	0.31	Tr	Tr	3.54	0.21	0.12	0.21	3.06	0.03	0.13	Tr	0.52
	2	0.20	Tr	0.10	4.69	0.15	0.20	0.24	2.73	0.03	0.43	Tr	0.40
	3									0.05	0.52	Tr	Tr
	4									0.04	2.35	Tr	Tr
	Aver.	0.26	Tr	0.05	4.12	0.18	0.16	0.23	2.90	0.04	0.86	Tr	0.23
2	1	0.24	Tr	0.02	3.35	0.15	Tr	0.09	3.10	0.03	0.04	0.07	0.13
	2	0.16	Tr	0.06	3.74	0.13	0.11	0.07	3.07	0.03	0.10	Tr	0.29
	3									0.05	0.24	Tr	Tr
	4									0.03	0.80	Tr	Tr
	Aver.	0.20	Tr	0.04	3.55	0.14	0.06	0.08	3.09	0.04	0.30	0.02	0.10

*Concentration has been adjusted for nutrient content in rain water and adjusted to the standard 60 min. rainstorm of 6.35 cm/hr intensity.

Table 5. Observed nutrient removal in sediment from Leeper clay loam soil.

Storm	Rep.	Dbl. Cropping Sed. N	Dbl. Cropping Sed. P	Min Tillage Sed. N	Min Tillage Sed. P	Fallow Sed. N	Fallow Sed. P
		kg/ha					
1	1	0.96	0.45	0.64	0.33	8.28	4.73
	2	1.00	0.47	1.01	0.44	7.15	3.78
	3					4.80	2.81
	4					3.16	1.71
	Aver.	0.98	0.46	0.82	0.39	5.85	3.26
2	1	1.00	0.51	0.64	0.33	5.09	2.88
	2	1.19	0.63	1.07	0.49	5.45	2.87
	3					6.61	3.84
	4					3.67	1.99
	Aver.	1.09	0.57	0.86	0.41	5.20	2.90

Table 6. Average nutrient concentration in sediment from Leeper clay loam soil.

Storm	Rep.	Dbl. Cropping Sed. N	Dbl. Cropping Sed. P	Min. Tillage Sed. N	Min. Tillage Sed. P	Fallow Sed. N	Fallow Sed. P
		ppm					
1	1	2657	1251	2506	1290	1450	829
	2	2604	1229	2284	1004	1350	711
	3					1403	822
	4					1384	748
	Aver.	2632	1240	2395	1147	1397	778
2	1	2513	1272	2413	1237	1395	790
	2	2342	1240	2305	1060	1377	728
	3					1424	828
	4					1433	777
	Aver.	2428	1256	2359	1149	1407	781

effects, etc. However, no single factor can be indicated as the chief cause of the observed variations.

Orthophosphate removal was largest for the double cropping system followed by the minimum tillage and the fallow systems. However, orthophosphate concentrations were small for all systems (Table 4). Apparently, orthophosphate in runoff water from the double cropping and minimum tillage mostly originated from the residual applied fertilizer. The unfertilized fallow system yielded mostly phosphorus that was released from the soil adsorption complex.

The relatively large potassium loss from the double cropping and minimum tillage system is primarily attributed to the removal of surface applied fertilizer. However, no attempt was made to determine the straw mulch contribution to potassium loss. During the initial phase of runoff, concentrations were large but decreased as runoff continued (Fig. 1). The fallow plots showed relatively constant potassium concentrations in runoff.

SUMMARY

Soil, water, and nutrient losses from soybean management systems were studied on bottomland areas during the wet fall of 1977. Soil loss from systems in conservation or minimum tillage was substantially less than that from fallow systems but appreciable in relation to the generally accepted permissible soil loss levels. Nutrient removal was appreciable for the double cropping and minimum tillage systems. Nutrient removal from fallow conditions was almost exclusively associated with sediment. Sediment nitrogen and phosphorus removal when expressed as percent of sediment, indicated that the clay content of sediment increased as sediment yield decreased.

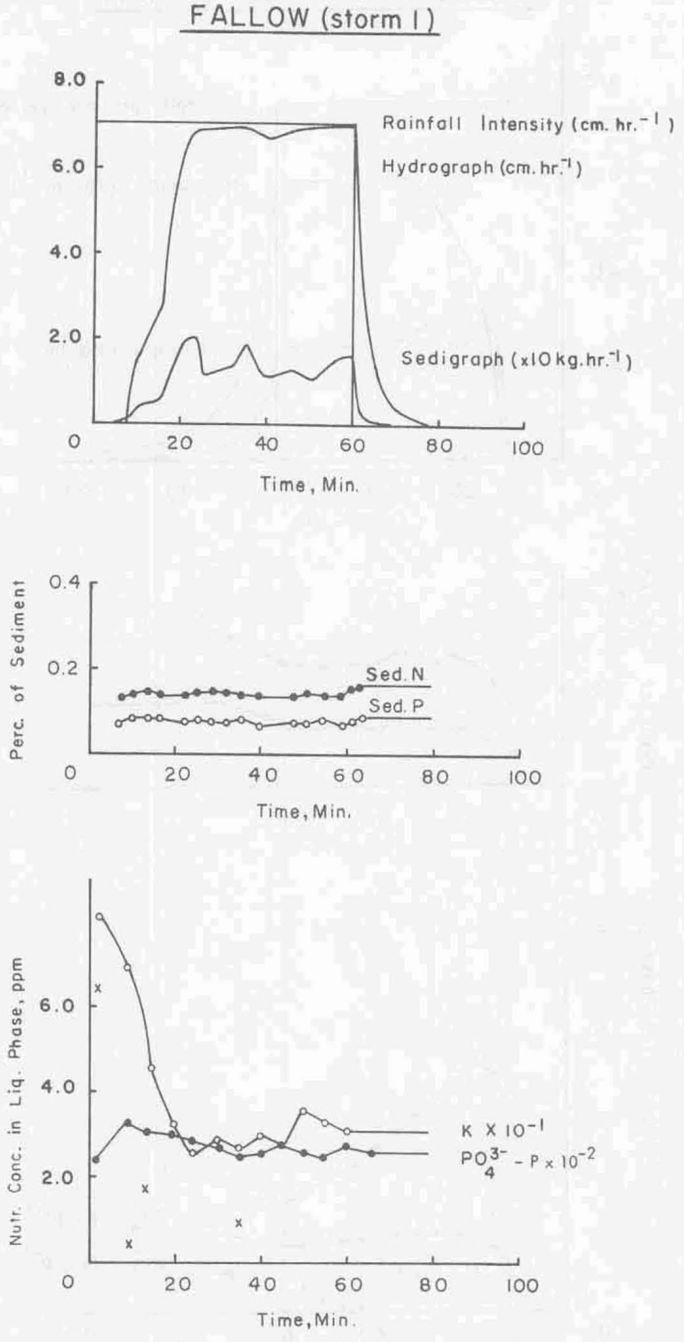

Fig. 2. Hydrograph, sedigraph, and nutrient concentration relationships for the first 60-minute simulated rainstorm on a plot in the fallow system.

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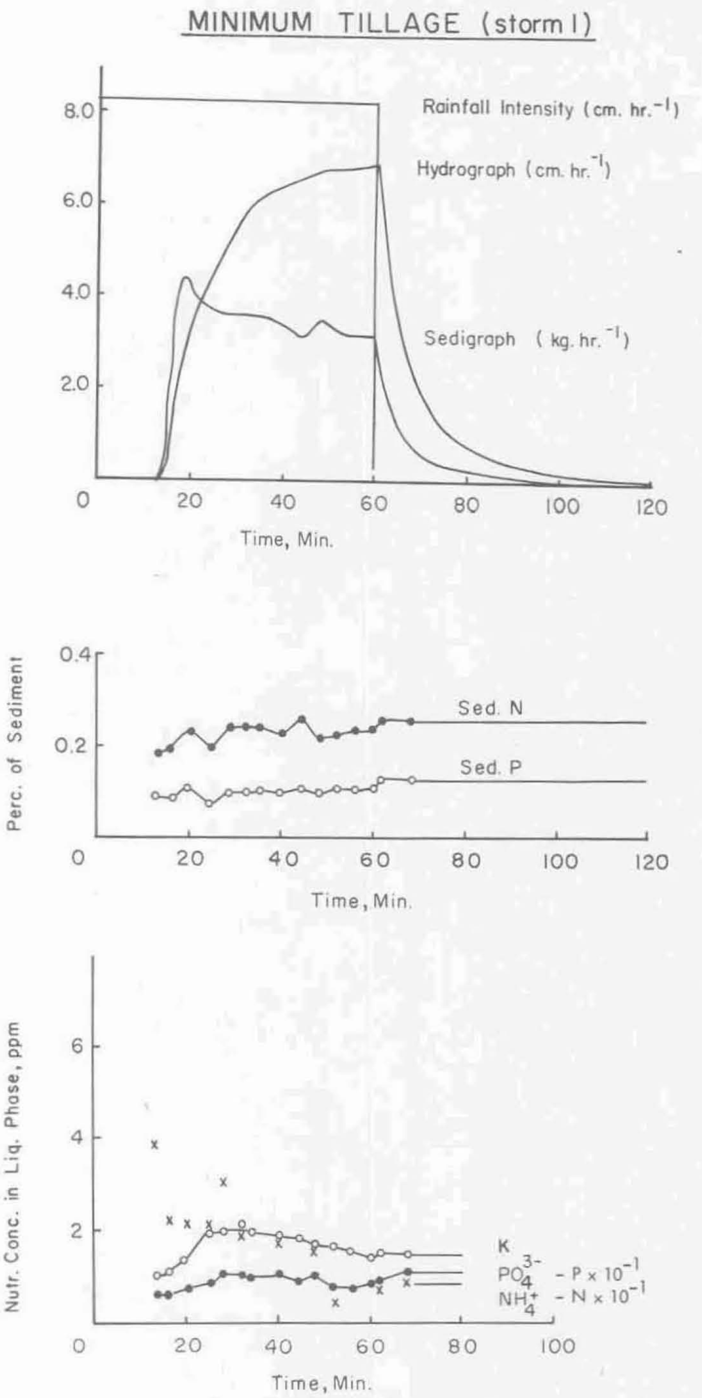

Fig. 3. Hydrograph, sedigraph, and nutrient concentration relationships for the first 60-minute simulated rainstorm on a plot in the minimum tillage system.

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