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ABSTRACT

EROSION and runoff from furrow irrigation of corn was measured for three conventional and three reduced tillage systems in 1981 and 1982. The plots were located on a Hastings silt loam soil having a 0.5% slope and a 366 m furrow length. Erosion was the least for slot-planting and greatest for the chisel system, ranging from 20 to 340 kg/ha, respectively, for the first 45 min of runoff during the first irrigation. Erosion from the fourth irrigation was about 75% less than from the first irrigation. Cumulative runoff after 45 min of runoff was similar for all treatments. Nutrient losses were minimal for all irrigations monitored. For most tillage treatments, no differences were measured between non-wheel and wheel track furrows for cumulative soil loss, erosion rate, sediment concentration, runoff amount and runoff rate.

INTRODUCTION

Erosion from furrow irrigated land has been recognized as a problem for many years (Israelsen et al., 1946). Mech (1959) reported soil losses of 50 t/ha during a 24-hour irrigation of corn on a fine sandy loam having a 7% slope in the Yakima Valley. About 75% of the loss occurred in the first 32 min of flow. Mech also indicated that because of cultivation and irrigation, as much as 30 cm of surface soil has been lost over a 10-year period on relatively flat fields.

Evans et al. (1982) indicated the amount of erosion in surface irrigation is influenced by slope, surface condition, soil types and structure, compaction, crop cover and residue, and furrow stream size. As shown by Torey et al. (1982), slight changes in any one or more of these factors can significantly change the erosion rate. Aarstad and Miller (1978) reported that small amounts of crop residue left in irrigation furrows effectively reduced erosion when compared to cleanly tilled furrows. Similarly, Evans et al. (1982) concluded that a combination of surge flow and the higher surface residue levels associated with reduced tillage can decrease sediment in the runoff and increase water application efficiency. Fitzsimmons et al. (1978) indicated the number of tillage operations did not greatly affect sediment losses from a furrow irrigated hop field having a 1.1% slope. Irrigating compacted furrows also resulted in greater runoff and sediment loss than irrigating non-compacted furrows.

Although some information concerning furrow irrigation, tillage and erosion interactions is available for areas of western and northwestern United States, very little information is available in Nebraska or the other midwestern states. Sediment contained in irrigation return flows and irrigation runoff has been identified as one of eleven major water quality problems in Nebraska (NNRC, 1979). In addition to impairing water quality and causing a loss of top soil, sediment derived from erosion of furrow irrigated areas has accumulated in irrigation reuse pits, drainage ditches and waterways, thus causing additional maintenance requirements.

Objectives of this project were to determine soil and nutrient losses caused by water induced soil erosion during furrow irrigation as affected by tillage systems.

PROCEDURE

Research plots were established in 1976 at the University of Nebraska South Central Station near Clay Center, Nebraska. Six tillage systems for continuous corn production were evaluated on a furrow irrigated Hastings silt loam soil. Three of the systems, chisel, disk and list, are considered conventional systems for south central Nebraska and the other systems, till-plant, rotary-till and slot-plant, are considered reduced or conservation tillage. Specific field operations, in order, within each tillage system were:

Chisel - fall shred stalks, fall disk, fall chisel plow, knife fertilize, disk, harrow, plant.

Disk - fall shred stalks, fall disk, knife fertilize, disk, harrow, plant.

List - fall shred stalks, fall disk, knife fertilize, disk, harrow, list.

Rotary-till - shred stalks, knife fertilizer, rotary-till, plant.

Till-plant - shred stalks, knife fertilize, till-plant.

Slot-plant - shred stalks, knife fertilize, plant.

After planting, all tillage plots were sprayed with herbicide and later cultivated and hilled to accommodate furrow irrigation. The photographic grid technique (Laflen et al., 1981) was used to estimate the percent of the soil surface covered by crop residue.

Irrigation furrows had an average slope of 0.5% with both the furrows and crop rows having a 76 cm spacing. Plot dimensions were 18.3 m wide and 366 m long. The experimental design was a randomized complete block with three replications.

Plots were irrigated four times in 1981 and 1982. Erosion and runoff measurements were taken on the first and fourth irrigation in 1981 and on the first and second irrigation in 1982. A wheel track or hard furrow and a non-wheel track or soft furrow were monitored in each plot. The criteria for scheduling irrigations was described by Eisenhauer et al. (1982). Water was

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metered into each furrow using a clamp-on 31.75 mm diameter orifice meter. The pressure head on the orifice was adjusted to provide a flow rate of 113.6 L/min, the maximum stream size recommended (SCS, 1983). Trapezoidal flumes having a 60° v-notch (Robinson and Chamberlain, 1960) were placed at the end of both a wheel track and a non-wheel track furrow to measure runoff. Head readings on each flume were taken one minute after runoff began and at 5 to 15 min intervals thereafter, depending on how fast the head was changing. A 0.5 L sample of the runoff was collected from the flume discharge, immediately following each head reading, for sediment and nutrient content determination. The inflow to each plot was terminated 30 min after the water in the furrow with the slowest advance time, usually the non-wheel track furrow, reached the flume.

RESULTS AND DISCUSSION

Soil Erosion

Cumulative soil loss in the tailwater from non-wheel track furrows for 1981 and 1982 are shown in Fig. 1. The wheel track soil loss curves were similar. As previously indicated, inflow was generally terminated for each tillage plot following 30 min of runoff from the non-wheel track furrow. Approximately 15 to 20 min after inflow termination, the runoff rate began decreasing at the lower end of the furrows, thus causing a decline in the amount of soil removed. This is illustrated by a flattening or decrease in slope of the cumulative soil loss curves which generally occurred after 45 min of runoff on the non-wheel track furrows.

Generally, soil losses were greatest for the chisel system and least for slot-plant. However, comparisons of the cumulative soil loss during the first 45 min of runoff (Table 1) showed few significant differences among the conventional systems of chisel, disk and list. Similarly, there were no significant differences in the soil loss from the reduced tillage systems of till-plant, rotary-till and slot-plant. Also, with only two exceptions, there were no significant differences in the cumulative soil loss between non-wheel and wheel track furrows. Cumulative soil losses within tillage treatments for the first 45 min of runoff for the first irrigation in 1981 and the first and second irrigations in 1982 were similar and averaged 130, 137 and 111 kg/ha, respectively. The fourth irrigation in 1981 had an average soil loss of 34 kg/ha, about 75% less than the losses from any of the other three irrigations.

In 1981, the chisel and disk systems had the greatest soil losses during the first irrigation, but there was no difference at the 10% significance level among the chisel, disk, list and till-plant treatments for the non-wheel track furrows (Table 1). The average loss for these treatments was 158 kg/ha. The rotary-till and slot-plant treatments had an average loss of 29 kg/ha or 82% less than the other treatments. For the wheel track furrows, there were no significant differences among tillage treatments in the 45 min soil loss during the first irrigation in 1981 with the loss averaging 146 kg/ha. During the fourth irrigation in 1981, the non-wheel track furrows of the conventional tillage systems had an average soil loss of 43 kg/ha, while the reduced tillage systems only had a loss of 14 kg/ha. Surface sealing and smoothing caused by the three previous irrigations appeared to be a major reason for the reduction in soil loss between the first and fourth irrigations. The wheel track furrows exhibited a similar reduction in soil loss between the first and fourth irrigations, but only the disk treatment soil loss was significantly greater than the losses from the reduced tillage systems.

The cumulative soil loss after 45 min for the non-wheel track furrows was not significantly different for the chisel, disk, list and till-plant systems for the first irrigation in 1982 and averaged 194 kg/ha. Only the rotary-till and slot-plant soil losses were significantly different than the chisel system. For the wheel track furrows, chisel, disk and till-plant averaged 191 kg/ha of soil loss in the 45 min period. During the second irrigation in 1982, greater differences among tillage treatments in the cumulative soil loss were observed with the chisel system having the highest loss, 251 kg/ha. The disk and list treatments were not significantly different from each other and averaged 147 kg/ha. The reduced

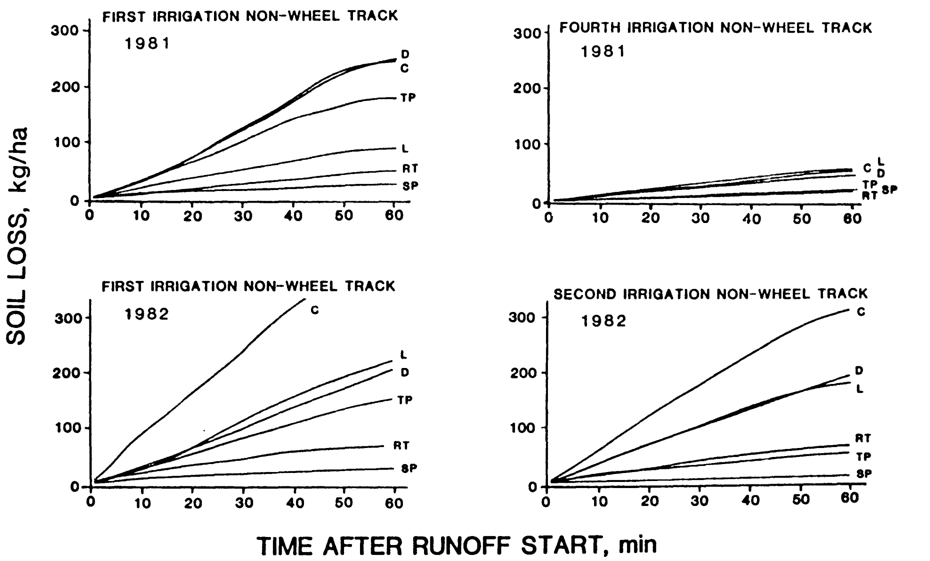

Fig. 1—Cumulative soil loss from furrow irrigation of different tillage treatments. C is chisel; D is disk; L is list; TP is till-plant; RT is rotary-till; an SP is slot-plant. Curves from wheel track furrows were similar.

TABLE 1. CUMULATIVE SOIL LOSS AND EROSION RATE FROM FURROW IRRIGATION OF VARIOUS TILLAGE SYSTEMS USED FOR CONTINUOUS CORN PRODUCTION.

Irrigation Tillage System	Cumulative soil loss* Non-wheel track furrow		Cumulative soil loss* Wheel track furrow	Erosion rate† Non-wheel track furrow	Erosion rate† Wheel track furrow
	kg/ha			kg/(ha·h)	
1st irrigation 81					
Chisel	206 [a]		177 [a]	330 [a]	480 [a]
Disk	200 [a]		195 [a]	230 [ab]	450 [ab]
List	75 [ab]		170 [a]	98 [b]	200 [c]
Till-plant	152 [ab]		188 [a]	130 [b]	220 [bc]
Rotary-till	38 [b]		95 [a]	65 [b]	94 [c]
Slot-plant	20 [b]		52 [a]	25 [b]	75 [c]
4th irrigation 81					
Chisel	43 [a]		44 [b]	68 [a]	98 [ab]
Disk	37 [a]	‡	75 [a]	80 [a]	110 [a]
List	48 [a]		37 [bc]	56 [ab]	54 [ab]
Till-plant	16 [b]	‡	38 [bc]	28 [b]	48 [ab]
Rotary-till	13 [b]		21 [bc]	25 [b]	42 [ab]
Slot-plant	13 [b]		18 [c]	25 [b]	35 [b]
1st irrigation 82					
Chisel	341 [a]		269 [a]	380 [a]	300 [a]
Disk	149 [ab]		156 [ab]	210 [a]	180 [a]
List	169 [ab]		113 [b]	290 [a]	180 [a]
Till-plant	118 [ab]		150 [ab]	170 [a]	280 [a]
Rotary-till	57 [b]		75 [b]	64 [a]	99 [a]
Slot-plant	21 [b]		30 [b]	22 [a]	36 [a]
2nd irrigation 82					
Chisel	259 [a]		243 [a]	310 [a]	300 [a]
Disk	148 [b]		135 [bc]	200 [b]	170 [bc]
List	152 [b]		151 [b]	200 [b]	220 [ab]
Till-plant	41 [c]		66 [cd]	46 [c]	83 [cd]
Rotary-till	55 [c]		62 [cd]	52 [c]	65 [cd]
Slot-plant	7 [c]		13 [d]	10 [c]	18 [d]

* Soil loss for first 45 min of furrow irrigation runoff.
† Erosion rate after furrow irrigation runoff reached equilibrium conditions. No significant differences in erosion rates observed at the 10% level between non-wheel and wheel track furrows for each tillage system each irrigation.
‡ Cumulative soil loss was significantly different at the 10% level between non-wheel and wheel track furrows for only these treatments.
[a] Numbers with the same superscript were not significantly different (Duncan's multiple range test, 10% level) within each irrigation and wheel track for each column.

tillage systems were also not significantly different from each other and had an average soil loss of 41 kg/ha, an 84% reduction in the soil loss from the chisel system.

For a more complete evaluation of the soil loss from the different tillage systems, the erosion rate following equilibrium conditions should also be compared. These rates can be used to estimate the soil loss for runoff periods other than 45 min. Equilibrium conditions were generally reached after 15 to 20 min of runoff had occurred and continued until recession began.

Erosion rates, closely paralleling the cumulative soil loss information, were similar within tillage systems for the first irrigation in 1981 and the first and second irrigations in 1982 (Table 1). During the fourth irrigation in 1981, erosion rates were approximately 75% lower for the conventional systems. However, erosion rates for the reduced tillage systems were similar for all irrigations. With the exception of the fourth irrigation in 1981, the erosion rates were always highest for the chisel system and lowest for the slot-plant treatment averaging 350 and 31 kg/(ha·h) respectively. In the fourth irrigation in 1981, the disk system had the highest erosion rate averaging 95 kg/(ha·h). Without exception, there were no significant differences between non-wheel and wheel track erosion rates.

Residue Cover and Erosion

The percentage of soil surface covered with residue prior to the first irrigations in 1981 and 1982 for the various tillage treatments is shown in Table 2. In both years, the conventional systems had less residue than the

TABLE 2. RESIDUE COVER AFTER TILLAGE, PLANTING AND CULTIVATION FOR VARIOUS TILLAGE SYSTEMS.

Tillage System	Residue Cover 1981*	Residue Cover 1982†
	Percent	
Chisel	7.9 [a]	1.4 [a]
Disk	7.7 [a]	0.5 [a]
List	10.3 [a]	2.7 [a]
Till-plant	23.8 [bc]	13.9 [b]
Rotary-till	14.3 [ab]	12.5 [b]
Slot-plant	28.3 [c]	20.3 [c]

* Measurements taken between cultivation and hilling.
† Measurements taken between hilling and first irrigation.
[a] Numbers with the same superscript were not significantly different (Duncan's multiple range test, 10% level) within each year.

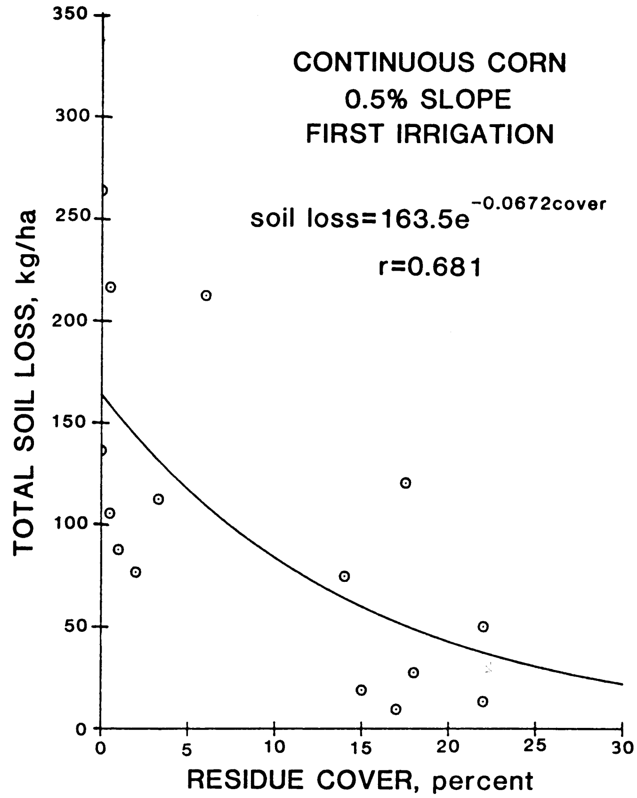

Fig. 2—Total soil loss after 45 minutes of runoff in 1982 vs. percent of soil surface covered with residue.

reduced tillage systems, 13.8 percentage points on the average. Slot planting had the highest residue level and averaged 24.3% for the 2 years.

The data on cumulative soil loss after 45 min of runoff and crop residue were analyzed using non-linear curve fitting techniques. The equation

$$\text{erosion} = Ae^{B \cdot RC} \quad [1]$$

where A and B are constants and RC is the percent residue cover, was fitted to the 1982 data. The 1981 residue information was not used to develop the equation since the hilling operation used to form the irrigation furrows occurred after the residue cover measurements were made.

The equation developed relating residue cover and soil loss had a correlation coefficient of 0.68 (Fig. 2). The value of B for this study on a 0.5% slope was −0.0672 and is within the range of −0.03 to −0.07 reported for row cropped land having steeper slopes and using rainfall simulation techniques to measure the soil loss (Laflen and Colvin, 1981; Dickey et al., 1983). The value A, which is the soil loss when no residue is present, was 163 kg/ha.

Runoff

Fig. 3 illustrates the cumulative runoff from the non-wheel track furrows for the various tillage treatments. The wheel track runoff curves were similar. In 1981, the amount of runoff during the first 45 min of runoff was significantly less for the till-plant and rotary-till non-wheel track furrows than for the wheel track furrows for both the first and fourth irrigations (Table 3). Otherwise, there were generally no significant differences in the cumulative runoff between the non-wheel and wheel track furrows. The amount of runoff in the 45 min period tended to be greater in 1982, possibly because the soil was more compact due to unusually heavy spring rains (Eisenhauer et al., 1982).

During the first irrigation in 1981, runoff for the three conventional systems averaged 7.9 mm for 45 min in the non-wheel track furrows, whereas the reduced tillage systems averaged only 4.5 mm or 43% less. This difference between the conventional and the reduced tillage treatments was significant at the 10% level. For the fourth irrigation in 1981, only rotary-till was significantly different than the three conventional systems of chisel, disk and list for the non-wheel track furrow.

In 1982, for the first irrigation, there were no significant differences among any of the tillage treatments or between the furrows in the amount of runoff for the 45 min time period. On the average, 9.9

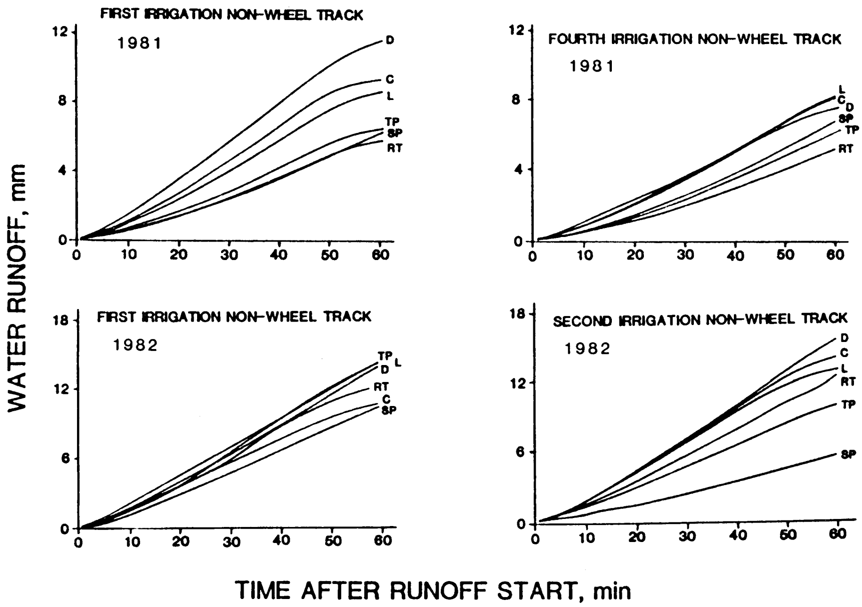

Fig. 3—Cumulative runoff from furrow irrigation of different tillage systems. C is chisel; D is disk; L is list; TP is till-plant; RT is rotary-till; and SP is slot-plant. Curves from wheel track furrows were similar.

TABLE 3. CUMULATIVE RUNOFF AND RUNOFF RATE FROM FURROW IRRIGATION OF VARIOUS TILLAGE SYSTEMS USED FOR CONTINUOUS CORN PRODUCTION.

Irrigation Tillage System	Runoff* Non-wheel track furrow		Runoff* Wheel track furrow	Runoff Rate† Non-wheel track furrow		Runoff Rate† Wheel track furrow
	mm			mm/h		
1st Irrigation 81						
Chisel	7.8 [ab]		7.5 [a]	12.4 [a]		14.4 [a]
Disk	9.2 [a]		9.4 [a]	12.2 [a]		17.5 [a]
List	6.8 [b]		8.2 [a]	11.1 [a]	§	15.4 [a]
Till-plant	5.0 [c]	‡	8.5 [a]	8.6 [b]	§	13.8 [a]
Rotary-till	4.3 [c]	‡	7.1 [a]	7.8 [b]	§	12.2 [a]
Slot-plant	4.3 [c]		8.7 [a]	8.4 [b]		15.0 [a]
4th Irrigation 81						
Chisel	6.2 [a]		6.9 [ab]	11.2 [a]		12.2 [b]
Disk	6.1 [a]		8.4 [a]	11.6 [a]	§	16.1 [a]
List	6.2 [a]		8.2 [a]	11.0 [a]		14.4 [ab]
Till-plant	4.3 [ab]		7.6 [a]	8.8 [ab]	§	13.6 [ab]
Rotary-till	3.7 [b]	‡	5.6 [b]	7.5 [b]	§	12.0 [b]
Slot-plant	4.7 [ab]	‡	5.0 [b]	9.9 [ab]		11.8 [b]
1st Irrigation 82						
Chisel	8.5 [a]		10.7 [a]	11.7 [a]		14.3 [a]
Disk	10.0 [a]		10.3 [a]	15.9 [a]		15.4 [a]
List	10.7 [a]		9.8 [a]	19.2 [a]		16.2 [a]
Till-plant	10.6 [a]		10.4 [a]	15.3 [a]		16.2 [a]
Rotary-till	9.4 [a]		11.7 [a]	14.9 [a]		18.9 [a]
Slot-plant	7.6 [a]		8.6 [a]	11.8 [a]		16.6 [a]
2nd Irrigation 82						
Chisel	11.6 [a]	‡	13.4 [a]	17.6 [a]		20.8 [a]
Disk	11.9 [a]		9.4 [b]	19.0 [a]		14.0 [b]
List	11.1 [a]		11.7 [ab]	16.8 [a]		18.6 [ab]
Till-plant	7.8 [ab]		11.0 [ab]	12.2 [ab]		17.9 [ab]
Rotary-till	9.5 [a]		10.7 [ab]	15.4 [a]		16.8 [ab]
Slot-plant	4.1 [b]	‡	9.8 [b]	7.3 [b]	§	16.8 [ab]

* Cumulative runoff after 45 min of furrow irrigation runoff.
† Runoff rate after furrow irrigation runoff reached equilibrium conditions.
‡ Furrow irrigation runoff was significantly different at the 10% level between non-wheel and wheel track furrows for only these treatments.
§ Furrow irrigation runoff rate was significantly different at the 10% level between non-wheel and wheel track furrows for only these treatments.
[a] Numbers with the same superscript were not significantly different (Duncan's multiple range test, 10% level) within each irrigation and wheel track for each column.

mm of runoff occurred during the 45 min time period. For the second irrigation of the non-wheel track furrows in 1982, the slot-plant treatment had significantly less runoff than all other treatments except till-plant. However, for the wheel track furrow, slot-plant runoff was only significantly less than that of the chisel system, by about 27%.

Runoff rates after reaching equilibrium conditions in the furrow irrigation runoff are shown in Table 3. The statistical results closely parallel information pertaining to the cumulative runoff data. Unlike the soil loss results, there was little difference between the first and fourth irrigations in 1981. The runoff rates also tended to be greater in 1982 than in 1981. The average runoff rate was 12.4 and 11.7 mm/h for the 1981 first and fourth irrigations and 15.5 and 16.1 mm/h for the 1982 first and second irrigations, respectively. For the non-wheel track furrows, there was a difference in the runoff rate between the conventional and reduced tillage systems, averaging 14.1 and 10.8 mm/h, respectively. This trend was not observed for the wheel track furrow.

Sediment Concentration

Sediment concentration changes in the irrigation runoff from the non-wheel track furrows are shown in Fig. 4. The concentrations were generally highest as the runoff began and decreased with time, becoming relatively constant after 10 to 15 min of flow. The concentration within tillage treatments for the first irrigation in 1981 and the first and second irrigations in 1982 were similar. Sediment concentrations for the fourth irrigation in 1981 were about 75% less than any of the other irrigations. With only one exception, there were no significant differences between non-wheel and wheel track furrows.

As with the erosion information, the sediment concentration tended to be highest for the chisel treatment and lowest for slot planting (Table 4). In general, the significant differences in sediment concentration were between chisel and slot-plant. The conventional systems tended to have higher concentrations than the reduced tillage systems.

Nutrient Loss

During the 1981 irrigations, runoff samples were also analyzed for nitrogen and phosphorus to assess the magnitude of nutrient loss during irrigation runoff. The losses after 45 min of runoff are shown in Table 5. In general, the losses were very low, less than 1.65 kg/ha of nitrogen and 0.03 kg/ha of phosphorus. The disk system had the greatest losses for both the first and fourth irrigations with slot-plant and rotary-till having the least. The average nitrogen loss across tillage treatments for the first irrigation was 0.62 kg/ha, whereas the average

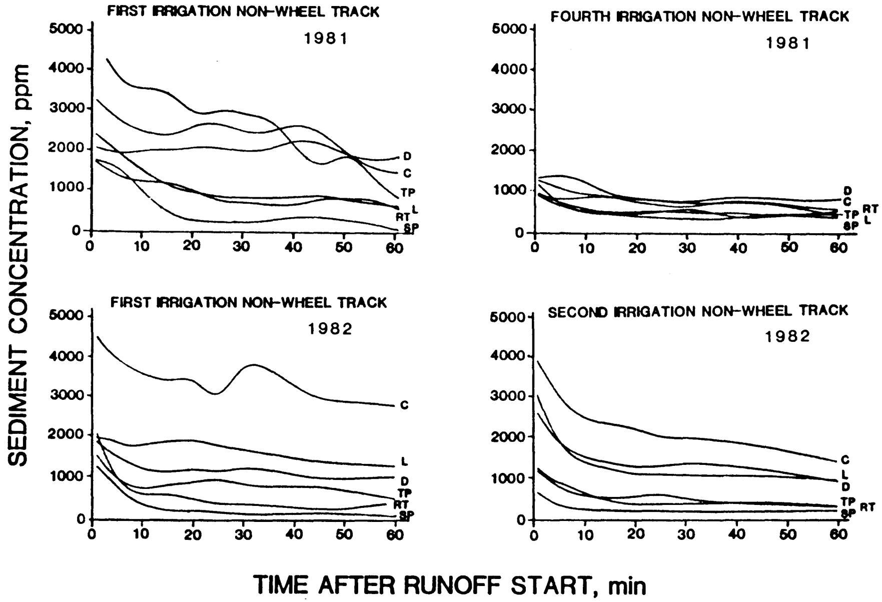

Fig. 4—Sediment concentration in furrow irrigation runoff from different tillage treatment. C is chisel; D is disk; L is list; TP is till-plant; RT is rotary-till; and SP is slot-plant. Curves from wheel track furrows were similar.

phosphorus loss was 0.02 kg/ha. Similar to the erosion data, the nitrogen loss during the fourth irrigation was more than 80% less than the loss during the first irrigation and averaged 0.11 kg/ha.

SUMMARY AND CONCLUSIONS

Soil loss and runoff from furrow irrigation on a 0.5% slope were measured for six tillage treatments from both non-wheel and wheel track furrows during four irrigations. Soil loss tended to be greater from the conventional tillage systems of chisel, disk and list than from the reduced tillage systems of till-plant, rotary-till and slot-plant. The chisel system had the greatest soil loss, averaging almost 200 kg/ha across the four irrigations, and slot-plant had the least, averaging 22 kg/ha, an 89% reduction.

Cumulative soil losses within tillage treatments for the 45 min sampling period for the first irrigation in 1981 and the first and second irrigations in 1982 were similar, averaging 126 kg/ha. The fourth irrigation in 1981 had an average soil loss of 34 kg/ha, about 75% less than losses from any of the other three irrigations. The

TABLE 4. AVERAGE SEDIMENT CONCENTRATION IN THE RUNOFF FROM FURROW IRRIGATION OF VARIOUS TILLAGE SYSTEMS USED FOR CONTINUOUS CORN PRODUCTION.

Irrigation Tillage System	Concentration* Non-wheel track furrow		Wheel track furrow
		ppm	
1st irrigation 81			
Chisel	2627 ab		2371 a
Disk	2098 abc		2018 ab
List	1058 bc		2046 ab
Till-plant	2931 a		2156 ab
Rotary-till	876 bc		1348 ab
Slot-plant	458 c		591 b
4th irrigation 81			
Chisel	675 ab		652 ab
Disk	724 ab		884 a
List	764 a	†	458 b
Till-plant	366 bc		495 b
Rotary-till	389 bc		356 b
Slot-plant	272 c		362 b
1st irrigation 82			
Chisel	3769 a		2884 a
Disk	1236 b		1913 ab
List	1676 ab		1201 b
Till-plant	880 b		1294 ab
Rotary-till	534 b		653 b
Slot-plant	226 b		329 b
2nd irrigation 82			
Chisel	2262 a		1846 a
Disk	1234 b		1495 a
List	1431 b		1324 a
Till-plant	471 c		528 b
Rotary-till	517 c		591 b
Slot-plant	174 c		134 b

* Concentrations were determined by dividing the total soil removed by the total runoff which occurred during the first 45 min of furrow irrigation runoff.

† Average sediment concentration was significantly different at the 10% level between the non-wheel and wheel track furrow for this treatment only.

[a]Numbers with the same superscript were not significantly different (Duncan's multiple range test, 10% level) within each irrigation and wheel track.

TABLE 5. PHOSPHORUS AND TOTAL NITROGEN LOSS FOR THE FIRST 45 MIN OF FURROW IRRIGATION RUNOFF DURING THE FIRST AND FOURTH IRRIGATIONS IN 1981.

Tillage System	Nitrogen loss* First irrigation	Nitrogen loss* Fourth irrigation	Phosphorus loss† First irrigation	Phosphorus loss† Fourth irrigation
		kg/ha		
Chisel	0.92	0.16	0.02	0.01
Disk	1.15	0.19	0.02	Trace
List	0.38	0.12	0.01	0.01
Till-plant	0.82	0.13	0.02	0.01
Rotary-till	0.23	0.02	0.01	Trace
Slot-plant	0.22	0.02	0.01	0.01

*Includes NO_3-N and NH_4-N in runoff and total Kjeldahl (primarily organic nitrogen) in sediment.

† Includes soluble P in runoff and sodium bicarbonate extractable P in the sediment.

magnitude of soil loss from furrow irrigation of these plots was low when compared to the Soil Conservation Service tolerable soil loss of 11.2 t/ha.

The erosion rates after reaching equilibrium conditions in the runoff were generally highest for the chisel system and lowest for slot planting, averaging 350 and 31 kg/(ha·h), respectively. Similar to the cumulative soil loss information, erosion rates within tillage treatments from the 1981 first irrigation and 1982 first and second irrigations were about the same. Erosion rates from the 1981 fourth irrigation were about 75% lower.

The cumulative soil loss was related to the percentage of soil surface covered with residue. The greater the residue cover, the lower the soil loss. Slot planting had the greatest amount of residue, averaging about 24.3% after cultivation. The chisel and disk systems had the least residue cover, averaging 4.4%, and tended to have the greatest amount of erosion.

During the first irrigation in 1981, cumulative runoff in the non-wheel track furrow from the three conventional systems for the 45 min period averaged 7.9 mm, whereas the reduced tillage systems averaged only 4.5 mm or 43% less. In 1982, there were few significant differences among the runoff amounts for the non-wheel and wheel track furrows. The runoff rate averaged 14 mm/h for the conventional systems, while the average rate for the reduced tillage systems was 10.7 mm/h. The difference in rate was not observed in wheel track furrows.

Sediment concentrations tended to be highest near the start of runoff, then decreased to a relatively constant value. As with the cumulative soil loss and erosion rate information, slot planting had the lowest concentration and the chisel system tended to have the highest.

Very few differences were measured between the non-wheel and wheel track furrows for cumulative soil loss, erosion rates, runoff, runoff rates and sediment concentration.

Nutrient losses from furrow irrigation was very low, averaging 0.62 kg/ha nitrogen and 0.02 kg/ha phosphorus for the first irrigation. The greatest loss of 1.15 kg/ha nitrogen and 0.02 kg/ha phosphorus was from the disk system. The rotary-till and slot-plant treatments had the least nutrient losses.

References

1. Aarstad, J. S. and D. E. Miller. 1978. Corn residue management to reduce erosion in irrigation furrows. J. Soil and Water Conservation 33(4):289-291.
2. Dickey, E. C., D. P. Shelton, P. J. Jasa and T. R. Peterson 1984. Tillage, residue and erosion on moderately sloping soils. TRANSACTIONS of the ASAE 24(4):1093-1099.
3. Eisenhauer, Dean E., Elbert C. Dickey, Paul E. Fischbach and Kenneth D. Frank. 1982. Influence of reduced tillage on furrow irrigation infiltration. ASAE Paper 82-2587, ASAE, St. Joseph, MI 49085.
4. Evans, R. G., J. S. Aarstad and D. E. Miller. 1982. Integrating furrow irrigation with trash tillage techniques. ASAE Paper 82-2578, ASAE, St. Joseph, MI 49085.
5. Fitzsimmons, D. W., J. R. Busch, G. W. Lewis and C. W. Berg. 1978. Controlling irrigation runoff losses with proper management. ASAE Paper 78-2090, ASAE, St. Joseph, MI 49085.
6. Israelsen, O. W., G. D. Clyde and C. W. Lauritzen. 1946. Soil erosion in small irrigation furrows. Utah Agr. Exp. Sta. Bull. No. 320, 39 p.
7. Laflen, J. M., M. Amemiya, and E. A. Hinz. 1981. Measuring crop residue cover. J. Soil and Water Conservation 36(6):341-343.
8. Laflen, J. M. and T. S. Colvin. 1981. Effect of crop residue on soil loss from continuous row cropping. TRANSACTIONS of the ASAE 24(3):605-609.
9. Mech, S. J. 1959. Soil erosion and its control under furrow irrigation in the arid west. USDA, ARS. Agr. Int. Bull. No. 184, 6 p.
10. Nebraska Natural Resources Commission. 1979. Section 208 Water Quality Management Plan for the State of Nebraska, 57 p.
11. Robinson, A. R. and A. R. Chamberlain. 1960. Trapezoidal flumes for open-channel flow measurement. TRANSACTIONS of the ASAE 3(1):120-128.
12. Soil Conservation Service. 1983. Nebraska Irrigation Guide. USDA-SCS, Lincoln, NE.
13. Torey, R., V. I. Myers and J. W. Martin. 1982. Furrow irrigation on steep irrigated land. U. of Idaho Agr. Res. Bull. No. 53, 20 p.