Within-furrow erosion and deposition of sediment and phosphorus

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Sediment, an end product of soil erosion, hampers irrigation, pollutes rivers, and is an economic loss to farmers and a resource loss to the nations of the world. Slope, soil condition, stream-size, and the cropping system are important factors that govern both within-field erosion and sediment loss from a field.

Under present management systems, irrigation drainage streams continually load sediment into streams and rivers. Technology needs to be developed to reduce or eliminate sediments and absorbed nutrients from surface irrigation return flows. Robbins and Carter (*3*) reported that small sediment retention ponds could remove 60 to 95 percent of the suspended sediments from surface drainage water.

Soil erosion damages both the area from which the soil is eroded and the area where sediment is deposited. Large amounts of sediment may be carried from irrigation fields. Brown and associates (*1*) reported sediment concentrations in surface irrigation return flows ranging from 20 to 15,000 mg/l. Carter and associates (2) found that phosphorus (P) can be conserved by removing sediment from irrigation return flow. They found higher P concentrations on smaller particles and aggregates than on larger particles and aggregates. For example, 550, 1,150, and 1,285 mg/liter total P were attached to the sand, silt, and clay fraction, respectively.

Objectives and procedures

My study sought to determine (1) the erosion and/or deposition pattern within the furrow of various furrow-irrigated crops; (2) the total sediment

Reprinted from *Soil Erosion and Conservation*

and P losses from the furrow during each irrigation throughout the irrigation season, and (3) how effective loose straw in furrows would be as an energy dissipator to reduce erosion and increase infiltration.

The irrigation system studied—in southern Idaho—diverts water from the Snake River into large delivery canals to furrow irrigate 82,030 ha. From the large delivery canals the water is diverted into smaller canals and delivered to individual farms. Surface runoff from the farms flows back into the canal system at a lower elevation, where it is redistributed to farms. The runoff from farms at the lowest elevation returns to the Snake River via drains. Sediment contained in the runoff is deposited somewhere in the canal system or into the river. This sediment must be removed mechanically to keep the canal system clear. Or the sediment becomes a lost resource when it is carried into the river.

To retain sediments in the fields, best management practices (BMP's), such as ponding, vegetative filter strips, and buried pipe runoff control systems, have been developed and are being evaluated. However, to adequately assess the impact of these BMP's, we need an understanding of the erosion process along furrows. The more we learn about erosion and deposition within furrows, the greater will be our ability to develop soil and water conservation management practices. Therefore, my study sought to evaluate sediment and P movement dynamics as water flows down a furrow.

At the upper end of each field I measured the water entering the furrow and collected water samples to determine sediment and P concentrations. Samples also were collected in different segments along the furrow. Water flow and sediment and P concentrations were measured at the upper and lower ends of each segment.

A preliminary study was conducted on a small potato field. Plots were 18 m long in a randomized complete block design. They were fertilized with various rates of P, either banded, disked, or plowed under, repeated four times. There were six segments and seven sampling sites. The first and last sampling site was the point where water flow was measured on and off each furrow, respectively.

It is common practice in the study area for farmers to cut furrows where the tractor and implement wheels rolled during seedbed preparation, planting, and cultivating. As a result, some furrows are in compacted soil and some are not. Because of this differential compaction, I measured water flow and sediment and P losses down both compacted (wheel) and noncompacted (nonwheel) furrows. I studied two wheel and two nonwheel rows on fields of dry edible beans.

Different conditions existed on the two fields. One had a relatively uniform 0.9 percent slope—the flat-end furrow field. The second had a slope that progressively increased from 0.5 percent to 2.0 percent as it reached the drain ditch—the convex-end furrow field. The greatest slope

Table 1. Sediment and phosphorus losses from potato plots during six irrigations, 1977.

Irrigation Number	*Sediment Loss*		*P Loss*
	(t/ha)	*(%)*	*(kg/ha)*
1	3.2	23	3.1
cultivation			
2	4.9	36	-
3	3.6	26	2.7
4	1.1	8	.9
5	.7	5	1.1
6	.2	2	.1

increase occurred in the last two 32-m segments.

Convex-shaped field ends occur where a drain ditch has been constructed to transport surface runoff. As the water leaving the furrow enters the drain ditch it carries large amounts of sediment from the bottom end of the field. Each year the slope at the bottom of the field increases, which increases runoff energy. This creates a convex field end. As a result, much of the sediment lost from fields is eroded from the bottom 15 to 20 m of a field.

Loose straw was placed in irrigation furrows at the rate of 1.5 kg/100 m to evaluate the effect on sediment loss. Samples collected from these furrows were compared to furrows receiving no straw. This comparison was made using two different flow rates.

Results and discussion

During the growing season on the potato plots, six irrigations yielded 13.7 t/ha of sediment and five irrigations yielded 7.9 kg/ha of total P (Table 1). The water flow through the furrow ranged from 15.8 l/min to 6.4 l/min. During the six irrigations, 59 percent of the total sediment loss occurred during the first two irrigations, 85 percent occurred during the first three irrigations. Potato vines growing into the furrow near the end of the third irrigation slowed the water flow and reduced erosion. Erosion and deposition of sediment and P occurred at all successive segments along the furrow, except the second segment from the top where only erosion took place. The greatest erosion took place at all successive segments except the second segment during the second irrigation, which followed a cultivation.

On a bean field with flat-end furrows, the area of erosion and deposition of sediment and P changed along the furrows from irrigation to irrigation during the season. The flow rate in the furrows for eight irrigations ranged from 14.2 to 22.6 l/min. The greatest erosion and some deposition occurred in the upper half of the furrows; further erosion and the most sediment deposition occurred in the lower one-third of the furrows.

Flow rates in wheel rows ranged from 14.2 to 18.4 l/min; rates in the nonwheel rows ranged from 15.2 to 22.6 l/min. Water reached the end of furrows in wheel rows 45 to 90 minutes quicker than in nonwheel rows; nonwheel rows received 11 percent more water. When the farmer rechecks his irrigation set and finds some rows moving slower, he increases the flow to get the water through the furrows. Such was the case on this flat-end field, accounting for the increased water to the nonwheel rows. Also, there was 15 percent less runoff water and 23 percent more infiltration in the nonwheel rows. Sediment and P losses were about twice as great in the wheel rows as a result of wheel compaction and increased water flow velocities (Table 2). The wheel rows were eroded wider, while the nonwheel rows were eroded narrower and deeper.

During the first two irrigations on the flat-end bean field, 49 percent of the total sediment eroded left the furrows. This loss increased to 62 percent by the end of the third irrigation and 77 percent by the fourth irrigation. Only 23 percent of the total eroded sediment was lost during the last four irrigations. This decrease in the last four irrigations resulted from several factors. Bean leaves and other organic materials dropping and hanging in the furrows slowed the water. This reduced the energy of the flow, increased infiltration, and decreased runoff. Thus, improved water and soil management practices during the first four irrigations should have the greatest positive impact on the amount of sediment and P lost from furrow-irrigated fields.

On the bean field with convex-end furrows, erosion was greatest in the bottom one-third of the furrows. Erosion in the upper two-thirds of the furrows was similar to the upper two-thirds of the flat-end field. Sediment loss increased almost tenfold on the field with convex-end furrows,

Table 2. Average flow, runoff, sediment, and phosphorus losses per irrigation from bean field with flat furrow ends and convex furrow ends.

Furrow Type	*Furrow Length (m)*	*Flow (liters/min) On*	*Off*	*Runoff (%)*	*Sediment Loss (kg)*	*(kg/ha)*	*P Loss (gm)*	*(gm/ha)*
Flat furrow ends (1980)								
Wheel row	286.5	16.6	5.2	32	12	375	14	428
Non-wheel row	286.5	18.1	4.5	25	6	184	7	228
Convex furrow ends (1981)								
Wheel row	196.9	20.0	7.7	39	94	4,264	53	2,400
Non-wheel row	196.9	21.4	5.7	26	57	2,586	32	1,473

Table 3. Average flow, total sediment generated, and sediment lost on bean fields from furrows receiving straw and no straw at two different rates.

	Average Flow (liters/min)		*Total Sediment*		
Treatment	*On*	*Off*	*Generated (kg)*	*Lost (kg)*	*Lost (kg/ha)*
Straw	13.2	4.5	192	69	3,968
	15.8	7.5	225	73	4,198
No straw	10.3	5.6	668	98	5,635
	15.0	8.6	1,013	225	12,938

compared to the flat-end-furrow field (Table 2). This occurred even though the flat-end field received more irrigations, had longer furrows, and had more sediment deposition within the furrows. Compared to the wheel-row furrows, the nonwheel rows received 4 percent more water. Also, there was 33 percent less runoff water and 26 percent more infiltration in the nonwheel row. Sediment and P loss was 1.6 times greater from the wheel rows than the nonwheel rows.

Loose straw in the furrows reduced the sediment generated from erosion by 71 percent, where the entering stream size was 13.2 and 10.3 l/min for the straw and no-straw furrows, respectively (Table 3). Also, 30 percent less sediment was lost from the straw furrows than from the no-straw furrows. Straw applied when the flow rate was 15.8 and 15.0 l/min for the straw and no-straw furrows, respectively, reduced generated sediment by 78 percent and sediment loss by 68 percent.

Straw also affected infiltration; at the lower flow rates the straw furrows received 24 percent more water and had 23 percent less runoff and 82 percent more infiltration than the no-straw furrows. Infiltration on the straw furrows at the higher flow rates increased only 20 percent over the no-straw furrows. At the higher flow also, straw furrows received 5 percent more water and had 6 percent less runoff than the no-straw furrows. Table 3 also shows that increased flow rate on the no-straw furrows increased the sediment generated by 1.5 times and the sediment lost by 2.3 times. Flow rates had little effect on the sediment generated and lost on the straw-treated furrows.

Where straw was applied, lateral wetting extended beyond the bean rows in 6 hours, compared to 12 hours with no straw. At the end of 12 hours of irrigation the bean rows with straw were over-watered.

Conclusions

Sediment and P data collected along different length segments of irrigation furrows during the growing season showed that 85 percent of the sediment was lost during the first three irrigations on potato plots. The remainder was lost during the second three irrigations. The potato vines laying in the furrows after the third irrigation slowed the water flow and reduced erosion.

On the bean plots the points of erosion and/or deposition were continually changing from irrigation to irrigation. On a bean field with flat-end furrows most of the sediment generated down each furrow was deposited in the lower one-third of the field. Water not only moved faster down compacted wheel rows but sediment and P losses doubled in the wheel rows compared to the nonwheel rows.

On a bean field with convex-end furrows, erosion was greatest in the bottom one-third of the furrows and sediment loss increased almost tenfold compared to the field having flat-end furrows.

Straw placed in furrows within a bean field under two different flow rates reduced erosion and increased infiltration. Therefore, proper use of organic matter and better water management in the early part of the growing season could effectively increase infiltration and reduce soil and nutrient losses.

REFERENCES

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