Brown, M.J., and R.E. Sojka. 1991. Reducing erosion and sediment loss from furrow irrigated slopes. In:Erosion Control:A global perspective. pp. 316-323. Proc. Intl Erosion Control Assoc., Orlando, FL, Feb 20-22. Publ. Intl Erosion Control Assoc., P.O. Box 4904, Steamboat Springs, CO 80477.

REDUCING EROSION AND SEDIMENT LOSS FROM FURROW IRRIGATED SLOPES

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EROSION CONTROL: "A Global Perspective"

Proceedings of Conference XXII
INTERNATIONAL EROSION CONTROL ASSOCIATION
February 20-22, 1991
Orlando, Florida, USA

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ABSTRACT

Furrow-irrigated fields often have different slopes along a furrow, which tend to cause different water intakes and erosion rates. Irrigated furrows on the steeper slopes develop deep, narrow channels that reduce the wetted perimeter in the furrows. This results in increased erosion, lower infiltration, and crops growing on the steep slopes do not receive adequate water for the highest crop yield. Loose grain straw placed by hand in furrows, on several different sloping plot studies, slowed the water that in turn reduced erosion and sediments by as high as 71% while at the same time infiltration increased by 50% which resulted in increased dry bean yields as high as 62%. Machines have now been commercially developed to mechanically place straw in furrows at desired rates. Seasonal furrow-irrigation erosion patterns, plotted from nine years of data for various crops, will also be presented and discussed. The erosion pattern in the absence of cultivation and a growing crop is compared to the erosion pattern in the presence of cultivation and growing crops. The maximum peak erosion for sugarbeets, corn, and beans occurred during the same three-week period of the irrigation season in southern Idaho.

INTRODUCTION

Crop residue is an effective tool for reducing erosion (Larson et al., 1978). For example, corn residue in irrigation furrows reduced erosion and runoff turbidity and increased infiltration (Aarstad et al., 1978). Researchers found that small amounts of straw reduced erosion in furrows having 3% slope (Miller, 1969). Erosion was severe in the untreated clean furrows and negligible in the straw furrows.

Furrow flow rate and cultivation are important factors affecting soil erosion. Miller and Aarstad (1978) found that cultivating the furrow bottom on Warden fine sand loam (coarse-silty, mixed, *Mesic Xerollic Canborthids*) with a 3% slope caused serious erosion when the furrow inflow rate was 6 $\ell\ min^{-1}$ or more. When 6.7 t/ha and 13.4 t/ha of straw were applied in the furrows, erosion was eliminated at all inflow rates up to 8 $\ell\ min^{-1}$. Berg and Carter (1980) found that erosion increased sharply on row-cropped fields when slopes exceeded 1%.

Farmers, in some areas of southern Idaho, furrow-irrigate fields having slopes that vary across the field from less than 1% to 5% or more. Erosion is most severe when slopes are convex, i.e., have steeper footslopes than headslopes. When erosion is severe enough it makes management more difficult and often results in yield reduction.

Flow velocity and furrow slope are two factors that affect severity of furrow erosion. Different combinations of slope and flow velocity have differing erosive effects. For example, a furrow having a 1% slope, irrigated at 15.1 $\ell\ min^{-1}$, will yield very little sediment because the flow velocity is low. On the other hand, a furrow having a 4% slope, irrigated at the same flow rate of 15.1 $\ell\ min^{-1}$, will yield a higher amount of sediment because the steep slope increases the flow velocity. Since the water moves at a higher velocity in the 4% sloping furrow more shear is exerted on the soil causing greater soil detachment and higher sediment loss. As a result of this increased velocity, narrow deep channels develop on the steeper slopes that decreases the wetted perimeter and infiltration rate (Figure 1). Therefore, any crop growing on these steep slopes will probably receive inadequate water for maximum yields.

Field observations indicate that when furrow slope exceeded 1%, headcuts often developed (Figure 2). These miniature waterfalls drop one to 10 cm from the existing furrow bed elevation to a lower level, which may be the original furrow bottom before cultivation, or a cultivation pan, where the soil cohesion is high. Kinetic energy, gained by this dropping water, breaks aggregates loose from the impact zone. This undermines the overlying soil which then breaks loose and is quickly disintegrated into small aggregates by the turbulent water in and near the impact zone.

This paper combines results from several soil erosion studies on steep slopes in southern Idaho. Data from some of these soil erosion studies were used to plot a long term seasonal erosion pattern (Brown et al., 1991). The crops grown on the plots in these study areas were sugarbeets, dry beans and corn (*Beta vulgaris* L., *Phaseolus vulgaris* L., *Zea mays* L.).

STUDY METHODS

The studies reported in this paper were conducted on Portneuf silt loam (*Durixerollic Calciorthid*) planted to dry beans. The 1982 study was conducted on plots having slopes ranging from 0.4 to 0.7%. Water-sediment samples were collected at 30.4 m intervals as water moved down each furrow. There were two straw and two no-straw furrows at two flow rates. Loose straw was placed by hand in the bottom of the straw-treated furrows at the rate of 1.5 kg/100 m (which for this row spacing = 195.3 kg ha^{-1}). Flow rates varied from irrigation to irrigation but were held constant during each irrigation. Low flow rates for the season averaged 10.3 $\ell\ min^{-1}$ and 13.2 $\ell\ min^{-1}$ for the no-straw and straw-treated furrows, respectively. High flow rates for the season averaged 15.1 $\ell\ min^{-1}$ and 15.8 $\ell\ min^{-1}$ for the no-straw and straw-treated furrows, respectively.

There were six 10-hour irrigations during the growing season. Water flow was measured as water entered and left each furrow, and 1-liter samples were collected to determine sediment concentrations and yield at each sampling site. All samples were transported to the laboratory immediately after collection where they were vacuum filtered through preweighed Whatman 50 hardened filter papers. Filters containing sediment were dried, weighed, and sediment concentrations and yields calculated.

The 1984 plot area had a 2.4% slope in the upper 40-m section A of the furrow and a 3.9% slope in the middle 40-m section B and a 1.9% slope in the lower 40-m section C. The 1985 plot area slopes were 2.4%, 4.4%, and 2.4% for the upper, middle and lower 35-m furrow sections A, B, and C, respectively.

Straw-treated furrows received straw at the rate of 4.5 kg/100 m and 3 kg/100 m in 1984 and 1985, respectively. Water was applied at the upper furrow section at the rate of 15.1 $\ell\ min^{-1}$. Four 8-hour irrigations in 1984 and three 12-hour irrigations in 1985 were monitored. Soil erosion was calculated from small trapezoidal flume measurements of infiltration, water runoff and sediment concentration taken at the end of each furrow section. The dry beans were harvested and threshed at the end of the 1984 growing season to determine yield.

RESULTS AND DISCUSSION

Comparing no-straw furrows at two flow rates in 1982, 55% of applied water ran off at the low flow rate (Table 1). At the high flow rate 57% ran off. When straw was applied 34% and 48% ran off at the high and low rates respectively. There was 34% more runoff and 56% more erosion in no-straw furrows at high flow than at low flow. The straw-treated furrows significantly increased infiltration and high flow significantly increased runoff (α = .01 level).

Although infiltration on the straw-treated furrows was about the same at both flow rates, runoff was almost twice as high at the high flow rate (42%). Soil

Figure 1. Narrow deep channel that developed on the 3.0% slope.

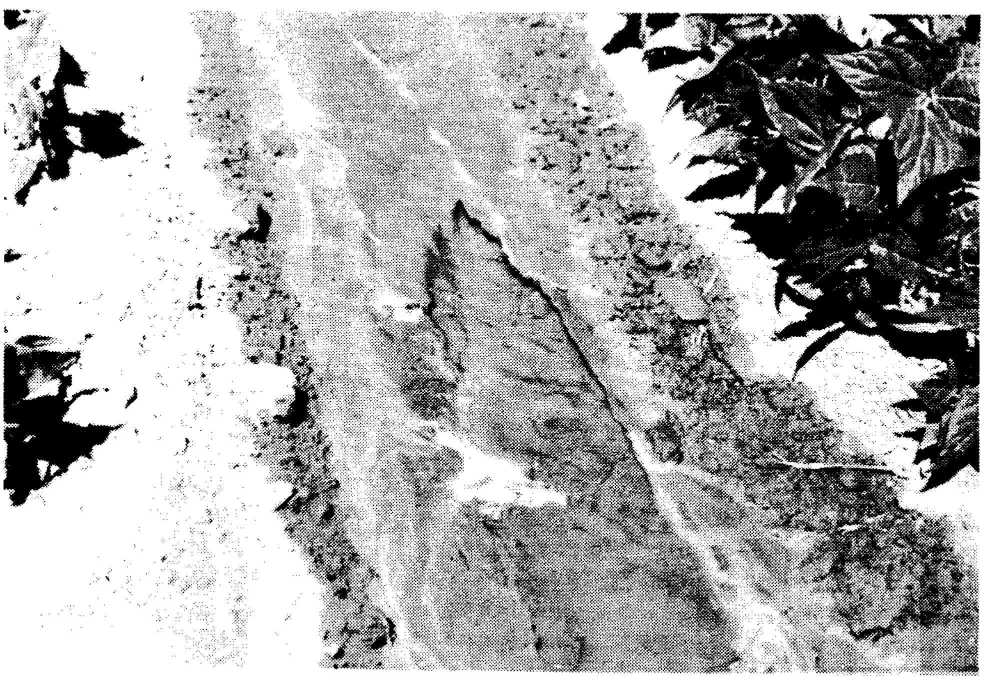

Figure 2. Headcut that developed on the 2.4% slope which is eroding upstream.

loss at the high flow rate was 29% greater. Net sediment yield from the no-straw and straw-treated furrows was 98 and 47 kg, respectively, at the low flow rates. At the higher flow rates net sediment yield was 224 and 66 kg from the no-straw and straw-treated furrows, respectively. Straw reduced net sediment yield 52% and 71% during the irrigation season at the low and high flow rates, respectively.

During 1984, with four 8-hour irrigations, 89% of the total water applied infiltrated in the straw-treated furrows compared to 56% in the untreated furrows (Table 2). Only 11% of the applied water ran off straw-treated furrows compared to 44% runoff from untreated furrows. During 1985 (Table 3) runoff from the straw-treated and untreated furrows was 23% and 44%, respectively while the infiltration was 77% and 56%, respectively. In 1984, infiltration in section B (3.9% slope) averaged 923 liters in the untreated furrows and 1,971 liters in the straw-treated furrows (Table 2). As a result, plants adjacent to the straw-treated furrows received more than twice as much water as plants adjacent to untreated furrows.

Straw effectively reduced erosion and sediment loss and increased infiltration at all slopes during 1984 and 1985 (Tables 2 and 3). The flow rates entering all furrows, with each treatment, in Section A, were equal. However, the flow rates leaving each furrow section varied. Because less water infiltrated into the untreated furrow sections, compared to treated furrow sections, flow rates were higher in the untreated furrow sections. These higher flow rates contributed to increased sediment loss in all untreated furrow sections compared to straw-treated furrow sections.

Straw increased dry bean yields, reduced sediment loss, and increased infiltration in all furrow sections (Tables 2 and 4). Straw in section A (2.4% slope) furrows during 1984 increased bean yields 667 kg/ha (24%) and reduced sediment yield 83% compared to untreated furrows. The largest increase in bean yield resulting from straw treatment occurred in the sections with a 3.9% slope. In the straw-treated section B furrows, bean yield increased 1,306 kg/ha (62%) and sediment yield decreased 86% compared to untreated furrows. In the straw-treated section C (1.9% slope) furrows, bean yield increased 614 kg/ha (21%) while sediment decreased 96% compared to untreated furrows. The greater yields in the straw-treated, steep furrow B sections resulted in part from increased moisture and to fertilizer accumulated in the steep sections due to inadequate water and low extraction by prior crops.

The general perception has been that furrow erosion was highest during the first irrigation of dry, disturbed soil following furrowing or cultivating. However, while conducting these and earlier studies it was observed that runoff sediment concentrations, used to calculate erosion, varied for different crops. For example, dry bean irrigations started the last of June at which time sediment concentrations were high. On the other hand, sugarbeet irrigations started the last of April at which time sediment concentrations were low. The highest sediment concentrations didn't accompany the earliest sugarbeet irrigations like it did with dry beans. To determine when maximum peak erosion occurs, data from several furrow erosion studies in southern Idaho were used to plot seasonal soil erosion patterns (Figure 3).

Erosion from sugarbeets and corn was low compared to beans, as the irrigation season began. Irrigation was started during April for sugarbeets, May for corn and June for beans. Even though irrigations for the different crops began at different times, the maximum erosion for all three crops occurred during the same three-week period, from June 24 to July 10. As the irrigation season progressed, erosion decreased. This decrease in erosion can be partly attributed to increased crop maturity and aggregate stability. For example, the large sugarbeet leaves often hang into the furrows. This slows the water, increasing both the wetted perimeter and infiltration, thus reducing runoff and lessening erosion (Brown, 1985). This decrease in erosion also occurs to a lesser extent with the lower, older corn and bean leaves dying and falling into the furrow. The continued increase in aggregate stability or cohesion from a low in the spring to a maximum in the fall (Lehrsch et al., 1988) would result in less aggregate breakdown with fewer relatively small aggregates subsequently entrained in the furrow stream.

SUMMARY

The studies reported in this paper show that loose wheat straw placed in steep irrigation furrows can reduce soil loss, increase water infiltration and crop yields. This also can result in conservation of water and plant nutrients. Even though irrigation generally starts in late April for sugarbeets, May for corn and late June for beans, in southern Idaho, the seasonal soil erosion patterns are similar. Peak erosion for sugarbeets, corn and beans occurred during the same three-week period of the irrigation season.

Table 1. Average total flow, runoff, and infiltration for six irrigations at two flow rates in furrows with and without straw, planted to dry beans, 1982.

	No-Straw		Straw	
	Low flow (10.3 ℓ/min)	High flow (15.1 ℓ/min)	Low flow (13.2 ℓ/min)	High flow (15.8 ℓ/min)
Flow On (ℓ)	36,841	53,954	45,667	56,750
Runoff (ℓ)	20,322	30,682	15,669	27,250
%	55	57	34	48
Infiltration (ℓ)	16,519	23,272	29,998	29,500
%	45	43	66	52
Sediment yield (kg)	98	224	47	66

Table 2. Average flow rate, infiltration and sediment yield at different slopes in 1984 (8-hour irrigations) with and without wheat straw.

		Straw				No straw			
Furrow section	Slope (%)	Flow off (ℓ/min)	Sed. (t/ha)	Infiltration (ℓ)	(%)	Flow off (ℓ/min)	Sed. (t/ha)	Infiltration (ℓ)	(%)
A (Top)	2.4	10.8	13.5	2,488	34	12.4	79.9	1,683	23
B (Middle)	3.9	7.0	18.2	1,971	27	10.8	125.7	923	13
C (Bottom)	1.9	2.8	0.5	2,009	28	8.0	68.3	1,457	20
Percent Infiltrated					89				56
Percent Runoff					11				44

Table 3. Average flow rate and sediment yield at different slopes in 1985 (12-hour irrigations) with and without wheat straw.

		Straw				No straw			
Furrow section	Slope (%)	Flow off (ℓ/min)	Sed. (t/ha)	Infiltration (ℓ)	(%)	Flow off (ℓ/min)	Sed. (t/ha)	Infiltration (ℓ)	(%)
A (Top)	2.4	11.2	29.6	3,292	30	12.4	121.9	2,412	22
B (Middle)	4.4	8.2	57.5	2,250	21	10.3	226.1	1,690	15
C (Bottom)	2.4	4.2	4.3	2,874	26	7.6	53.2	2,044	19
Percent Infiltrated					77				56
Percent Runoff					23				44

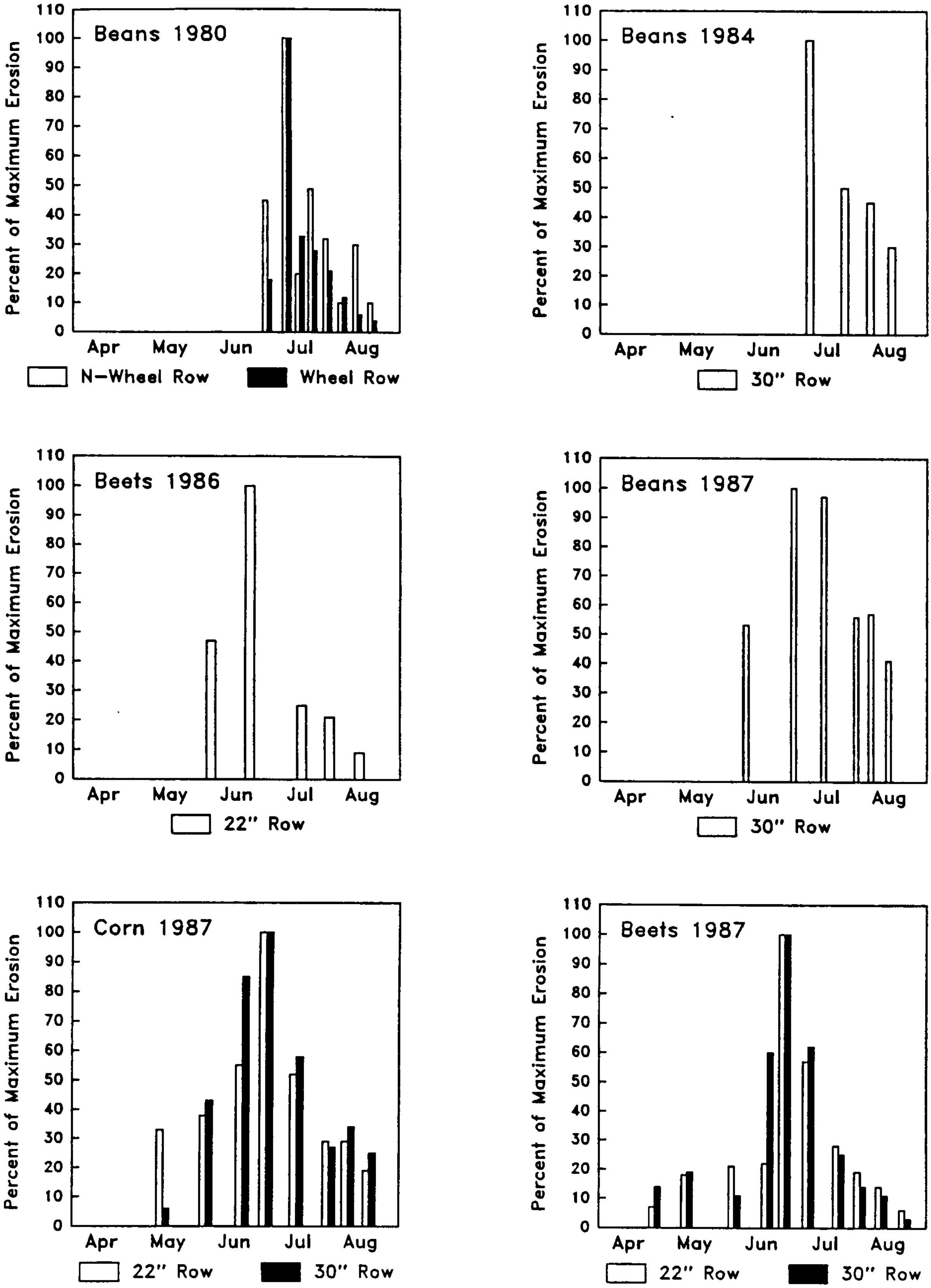

Figure 3. Seasonal soil erosion patterns for sugarbeets, corn and dry beans.

Table 4. Dry bean yields from straw treated and untreated furrows for the 1984 irrigation season.

Furrow section	Slope (%)	Straw (kg/ha)	No straw (kg/ha)	Yield Increase (%)
A (Top)	2.4	3,440	2,773	24
B (Middle)	3.9	3,413	2,107	62
C (Bottom)	1.9	3,600	2,986	21

ACKNOWLEDGMENT

The authors thank E.C. Kennedy-Ketcheson for preparing the computer bar graphs in Figure 3.

REFERENCES CITED

Aarstad, J.S., and D.E. Miller. 1978. Corn residue management to reduce erosion in irrigation furrows. J. Soil Water Cons. 33:289-291.

Berg, R.D., and D.L. Carter. 1980. Furrow erosion and sediment losses on irrigated crop land. J. Soil Water Cons. 35:267-270.

Brown, M.J. 1985. Effect of grain straw and furrow stream size on soil erosion and infiltration. J. Soil Water Cons. 40:389-391.

Brown, M.J., D.L. Carter, G.A. Lehrsch, and R.E. Sojka. 1991. Seasonal trends in furrow irrigation erosion in southern Idaho. Submitted to J. Soil Water Cons. for publication.

Larson, W.E., R.F. Holt, and C.W. Carlson. 1978. Residues for soil conservation. In: W.R. Oswald (ed.) p. 1-15. Crop Residue Management Systems. Special Publ. 31. Am. Soc. Agron., Madison, WI.

Lehrsch, G.A., M.J. Brown, and P.M. Jolley. 1988. Furrow erosion as affected by aggregate stability changes in a Portneuf silt loam. p. 280. In: Agronom. Abst., ASA, Madison, WI.

Miller, D.E. 1969. Residues improve furrow irrigation infiltration rates. Crops and Soils (Aug-Sept):23-24.

Miller, D.E., and J.S. Aarstad. 1971. Furrow infiltration rates as affected by incorporation of straw or cultivation. Soil Sci. Soc. Am. Proc. 35:492-495.