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Conservation tillage effects on sediment and phosphorus losses from a furrow irrigated field.

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Abstract.

Dry beans are often grown after alfalfa in southern Idaho, which conventionally involves four or more tillage operations before planting. The objective of this three year study (1998-2000) was to determine the effects of conservation tillage on runoff, soil erosion and phosphorus loss from dry beans following small grain under furrow irrigation. Tillage treatments were direct seed, spring disk, fall disk and fall chisel plow. Polyacrylamide (PAM) was applied to half of the furrows during the last two years of the study. Direct seeding increased residue in furrows, which tended to reduce runoff volume and soil loss but increased soluble P loss. Applying PAM significantly reduced soil loss for only 4 of 11 irrigations, but significantly decreased total annual soil loss 63% in 2000. Direct seeding did not significantly reduce dry bean stand, but weed competition and other factors reduced bean yields from direct seed by 39% and 47% the last two years of this study. The three tilled treatments had similar crop yields, residue amounts and phosphorus losses.

Keywords. Dry beans, polyacrylamide, phosphorus, conservation tillage, direct seed.

Introduction

Dry beans are often grown after alfalfa in southern Idaho, which conventionally involves four or more tillage operations before planting. Altering the crop rotation so small grain or corn are grown after alfalfa allows farmers to use less tillage while better utilizing nitrogen from the previous alfalfa crop. Growing small grain or corn after alfalfa decreases soil nitrate content, reduces fertilizer costs, and decreases nitrate leaching below the root zone (Meek et al., 1994; Meek et al., 1995). Corn and small grain can be directly seeded into alfalfa which was shown to be more profitable with less soil erosion than growing dry beans with conventional tillage (Carter and Berg, 1991). Altering the crop rotation, however, requires dry beans to be grown after a high residue crop like small grain.

Dry beans have been grown in small grain residue on non-irrigated land in the northern Great Plains (Deibert, 1995). Carter and Berg (1991) successfully produced furrow irrigated dry beans following small grain using conservation tillage (spring disk, roller harrow, plant). While residue can hamper water flow in irrigation furrows, grain straw can also benefit furrow irrigation. Brown and Kemper (1987) showed that dry bean yield increased and sediment loss decreased when a straw mulch was added to irrigation furrows. It is more efficient to lightly incorporate straw or leave it on the soil surface rather than adding straw to furrows in a separate operation. Straw incorporated in the top 15 cm of soil by rototilling significantly increased cumulative infiltration and visibly decreased soil erosion under furrow irrigation in Washington (Miller and Aarstad, 1971). Incorporating straw with conservation tillage may be a good way to control erosion from dry beans. The objective of this study was to measure the effect of conservation tillage on runoff, soil erosion and phosphorus loss from dry beans following small grain under furrow irrigation.

Materials and Methods

This study contained four tillage treatments (direct seed–DS, spring disk–SD, fall disk–FD and fall chisel plow–FC) and two crops (dry bean and spring wheat) in a split-plot design with crop as the main plot and tillage as the subplot. Treatments were replicated three times. Both crops were grown each year, however, sediment and phosphorus losses were only measured on dry bean plots ('Viva Pink' *Phaseolus vulgaris* L.). Spring wheat (*Triticum aestivum* L.) was grown primarily to provide residue for the following dry bean crop.

The field was Portneuf silt loam (coarse silty mixed superactive mesic durinodic Xeric Haplocalcids) with 1% slope. Field length was 150 m. This field was planted to corn in 1995 and 1996 using conservation tillage. Tillage treatments were applied on dry bean and spring wheat plots in 1997 with runoff measurements starting in 1998.

FD and FC plots were disked two to four weeks after wheat or bean harvest. FC plots were chisel plowed in October or early November. All plots except DS were roller harrowed in the spring before planting wheat with a conventional grain drill with double disk openers, because the soil was too wet to disk before planting wheat in late March or early April. Before planting dry beans, all plots except DS were disked and then roller harrowed to incorporate herbicide. Dry edible beans were planted in late May with a standard Monosem[1] planter with 0.56 m row spacing. Each plot was 12 rows wide (6.7 m) with a furrow spacing of 1.12 m.

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[1] Mention of trademarks, proprietary products, or vendors does not constitute a guarantee or warranty of the product by the USDA-ARS and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

In 1998, runoff and sediment were measured for three of five irrigations. All irrigations were monitored in 1999 (5) and 2000 (6). Runoff was measured from two furrows in each dry bean plot in 1998. Dry bean plots were split in 1999 and 2000 so half of the furrows could be treated with polyacrylamide (PAM) to compare its effectiveness under high residue conditions. Runoff was measured from only one furrow in each subplot to limit the number of monitored furrows to 24. Approximately 30 g of anionic, water soluble, high molecular weight, granular PAM were applied to the first 1 to 2 m of each treated furrow before every irrigation (Lentz et al., 1992). This method of applying PAM is commonly used by farmers in the area.

Small trapezoidal flumes were installed at the end of the furrows for measuring water flow rate. Sediment concentration was measured by pouring a 1-L runoff sample into an Imhoff cone and reading the settled volume after 30 min (Sojka et al., 1992). Water samples for total and dissolved phosphorus (P) analysis were also collected during three irrigations in both 1999 and 2000. Samples were collected from the first two irrigations and the last irrigation both years. Two, 50-mL water samples were collected from flume outflow. Unfiltered samples were collected for total P analysis (persulfate digestion; American Public Health Association, 1992). The second sample was filtered (0.45 mm) in the field within 15 minutes of collection, stabilized with 0.5 mL of saturated H_3BO_3, and analyzed for dissolved reactive P (DRP) (Murphy and Riley, 1962).

The irrigation water source was the Snake River (typical chemical analysis: pH = 8.2, electrical conductivity = 0.5 dS m^{-1}, sodium adsorption ratio = 0.7, sediment < 10 mg L^{-1}, total P < 0.10 mg L^{-1}, DRP < 0.01 mg L^{-1}). Furrow inflow rate was controlled by spigot valves on gated pipe. Inflow rates were measured by the time required to fill a known volume.

Plant stands were measured in June each year by counting the number of plants in a 2-m long section of two adjacent bean rows. Plant stand was counted in three locations in each plot. Crop residue cover was measured in furrows after planting and before the first irrigation. Percent cover was measured with the line transect method, using a 30-m long string with 100 equal-spaced marks (USDA NRCS, 2002). Measurements were taken in three locations per plot in 1998 and 1999 and four locations per plot in 2000.

Dry bean yield was measured at locations in the center four rows of each plot, which were harvested with a plot combine. Two, 30-m long windrows were harvested from each plot, approximately 15 m from the inflow end and 15 m from the runoff end of the field. Sub-samples, collected from the plot combine, were cleaned to determine the weight of soil and foreign material in each sample. In 1999 and 2000, hand samples were collected to identify if PAM affected dry bean yield. Two adjacent bean rows, 2-m long, were collected by hand before the rest of the field was cut and windrowed. These samples were threshed with the same plot combine that was used in the field.

Runoff data from dry bean plots were analyzed as a split-plot experimental design with tillage treatments as the main plots and PAM treatment as the sub plot all three years. Only the main plot effects (tillage) were used in 1998 since PAM was not applied during this first year. Each irrigation was analyzed separately. Dry bean yield and surface residue were analyzed as a randomized complete block. Differences among tillage treatment means were separated by least significant difference tests ($P<0.05$).

Results and Discussion

Tilling wheat stubble greatly reduced surface residue as expected. Irrigation furrows in DS plots had significantly more residue than furrows in the other treatments (Table 1). Although furrows in DS plots were reformed before the first irrigation, about 70% of the surface was covered with crop residue. There were no significant differences in surface residue among the three tilled treatments in any year.

Direct seeding dry beans did not significantly affect plant stand in any year (data not shown). Plant stand varied from 190,000 to 200,000 plants ha^{-1}. FC, FD and SD tillage treatments had satisfactory yields that approached or exceeded the Twin Falls County, ID average of 2500 kg ha^{-1} (Table 2). Dry bean yield, however, was significantly less in DS than the other treatments in 1999 and 2000 (Table 2). Yields were not significantly different in the first year of the study (P=0.12). Weed control became a problem in the DS plots with time. DS plots had noticeably more grass and broadleaf weeds than the tilled plots, which had herbicide incorporated before planting. Glyphosate was applied to DS plots immediately after beans were planted, but no post-emergence herbicide was applied, primarily because few are labeled for use on dry beans in southern Idaho. Applying PAM to furrows did not affect dry bean yield (data not shown).

Furrow inflow rates were set equal among all treatments, with two exceptions. Inflow volume was not significantly different between PAM treated and control furrows. Inflow volume was significantly different among tillage treatments for two irrigations. FC had less inflow (about 15%) than the other three treatments for irrigation 1 in 1998, and DS had greater inflow (about 16%) than the other treatments for irrigation 3 in 2000, in an effort to advance water across the field faster.

Runoff was not typically affected by PAM (Table 3). Applying PAM reduced runoff for all tillage treatments during irrigation 1 in 2000. Runoff was reduced because infiltration increased about 20% with PAM application during this irrigation, similar to previous studies (Trout et al., 1995; Sojka et al., 1998). Oddly, runoff was significantly greater from PAM treated furrows during irrigation 5 in 1999. There was also a significant PAM x tillage interaction for this irrigation. Infiltration was 15 to 25% less with PAM application on the three tilled treatments, but PAM did not affect infiltration on DS plots.

The mass of soil lost during irrigation was significantly less with PAM treatment for only one of the five irrigations in 1999 and three of the six irrigations in 2000 (Table 3). Although PAM treatment significantly reduced soil loss for only 4 of 11 irrigations, total annual soil loss was 33% less (P=0.06) from PAM-treated furrows in 1999 and 63% less (P=0.02) in 2000. Previous studies on research plots have shown that PAM can reduce erosion by more than 90% (Lentz et al., 1992; Sojka and Lentz, 1997). Part of the reason that PAM was not as effective in this study may have been that our application procedure was not as meticulous as in other research trials (i.e. weighing exact amounts of PAM for each furrow and carefully applying it to furrow soil), but similar to procedures used by growers on commercial fields. Another factor was the presence of headcuts in furrows, 5 to 10 m from the gated pipe. Applying PAM stabilizes the soil surface to sediment detachment, but does not stop bedload from moving along the bottom of the furrow.

PAM application significantly reduced total P loss when soil loss was reduced (Table 3). Reducing erosion typically reduces total P loss because most phosphorus in runoff from furrow irrigated row crops is usually associated with sediment (Berg and Carter, 1980). DRP did not follow the same trend as soil loss (Table 3).

Significant interactions between PAM and tillage resulted in smaller relative differences among tillage treatments. Therefore, values in Tables 4 and 5 are averages for main plots, in order to simplify presentation of results. Tillage treatment had little effect on runoff or soil erosion during the first two years of the study (Table 4). By the third year (2000), the increased residue in the DS furrows significantly reduced runoff for 4 of the 6 irrigations. Less runoff, however, did not correlate with decreased soil loss for 3 of the 4 irrigations, probably because soil loss was low from all treatments (Table 4). Average sediment loss was less than 0.7 Mg ha^{-1} for each irrigation in 2000 and 63% of the water samples had sediment concentrations < 0.10 mg L^{-1}, which is the minimum concentration measured with the Imhoff cones. Less than 2% of the samples had sediment concentrations <0.10 mg L^{-1} in 1998 and 22% in 1999.

Tillage had the greatest effect on soluble P loss in irrigation runoff. DRP loss was significantly greater from DS than other treatments in the first and last irrigations in both 1999 and 2000 (Table 6). DRP loss tended to be greater for the second irrigation, but was not significant in 1999 (P=0.07) or 2000 (P=0.06). Residue in furrows on DS plots slowed water flow, allowing greater time for P to desorb from soil and residue.

Typically less than 10% of the total P is soluble in runoff from furrow irrigated row crops (Berg and Carter,1980). DRP averaged 9% (median=3%) of the total P for tilled plots and 32% (median=18%) for DS plots in 1999. The percentage in 2000 increased to 39% (median=33%) for tilled plots and 83% (median=82%) for DS plots. DRP was greater than 80% of the total P in 30% of the water samples from DS plots and only 2% of the samples from tilled plots.

Conclusion

Direct seeding increased residue in furrows compared to tilled treatments, which tended to reduce runoff volume and soil loss but increased soluble P loss. Runoff from direct seeded dry beans had significantly greater DRP losses for 4 of the 6 irrigations when P samples were collected. Applying PAM significantly reduced soil loss for only 4 of 11 irrigations. However, PAM significantly reduced total annual soil loss in 2000 by 63%. Direct seeding resulted in no significant differences in the stand of dry beans, but weed competition reduced bean yields the last two years of this study. The three tilled treatments had similar crop yields, residue amounts, and sediment and phosphorus losses. Based on this three year study, we would not recommend direct seeding dry beans following small grain in a furrow irrigated field.

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Table 1. Surface residue in furrows measured by 30 m long string. Three measurements were made in each plot in 1998 and 1999 and four measurements were made in each plot in 2000. Values in a column with different letters are significantly different (P<0.05)

	Surface Residue (%)		
Tillage	1998	1999	2000
FC*	16 b	7 b	44 b
FD	33 b	15 b	44 b
SD	32 b	27 b	43 b
DS	74 a	69 a	73 a

* FC–Fall Chisel plow, FD–Fall Disk, SD–Spring Disk, DS–Direct Seed.

Table 2. Dry bean yield. Values in a column with different letters are significantly different (P<0.05)

	Dry Bean Yield (kg ha^{-1})		
Tillage	1998	1999	2000
FC*	2807 a	2370 b	2627 b
FD	2796 a	2480 b	2627 b
SD	2678 a	2279 b	2410 b
DS	2150 a	1446 a	1345 a

* FC–Fall Chisel plow, FD–Fall Disk, SD–Spring Disk, DS–Direct Seed.

Table 3. Statistical significance (P<0.05) of polyacrylamide treatment on runoff volume and soil, total P and DRP mass losses in furrow irrigation runoff. Phosphorus samples were only collected during the three irrigations in 1999 and 2000 so annual totals were not calculated for total P and DRP.

Irrigation	Runoff	Soil	Total P	DRP
		1999		
1	ns*	ns	ns	ns
2	ns	ns	ns	control>PAM
3	ns	ns	-	-
4	ns	ns	-	-
5	PAM>control	control>PAM	control>PAM	control>PAM
total	ns	ns	-	-
		2000		
1	control>PAM	control>PAM	control>PAM	control>PAM
2	ns	ns	ns	ns
3	ns	control>PAM	-	-
4	ns	ns	-	-
5	ns	ns	-	-
6	ns	control>PAM	control>PAM	ns
total	ns	control>PAM	-	-

* ns denotes that PAM treatment did not have a significant effect.

Table 4. Runoff and soil loss from furrow irrigation. Only three irrigations were monitored during 1998 so season totals are not calculated. Parameter values in a row with different letters are significantly different ($P<0.05$) for that irrigation. Letters are not shown when tillage treatment means were not significantly different.

	Runoff (mm)				Soil Loss ($Mg\ ha^{-1}$)			
Irrigation	FC*	FD	SD	DS	FC	FD	SD	DS
				1998				
1	31	17	12	16	1.0	0.1	0.5	0.3
2	39 a	31 ab	25 bc	17 c	2.1	0.4	0.2	0.1
3	79	90	53	65	7.0	6.9	2.5	2.1
				1999				
1	47	45	47	37	2.9	1.8	1.7	0.5
2	51	52	44	45	6.9	4.7	5.3	2.3
3	90	94	71	66	5.5	8.5	2.4	0.7
4	37	39	34	32	1.3	0.8	0.3	0.0
5	23	21	22	16	0.2	0.2	0.1	0.0
total	249	251	217	195	16.7	15.9	9.8	3.6
				2000				
1	16	12	14	9	0.1	0.1	0.0	0.0
2	29 a	25 a	23 a	3 b	0.0	0.0	0.0	0.0
3	36	35	30	24	0.6 a	0.3 ab	0.1 b	0.0 b
4	42 a	40 a	42 a	22 b	0.7 a	0.4 b	0.1 c	0.0 c
5	59 a	59 a	59 a	22 b	0.2	0.2	0.1	0.0
6	22 a	26 a	27 a	12 b	0.0	0.0	0.0	0.0
total	204 a	197 a	196 a	92 b	1.7 a	1.0 ab	0.3 bc	0.1 c

* FC–Fall Chisel plow, FD–Fall Disk, SD–Spring Disk, DS–Direct Seed.

Table 5. Total and dissolved reactive P (DRP) losses with furrow irrigation runoff. Phosphorus samples were not collected in 1998 and were collected for only 3 irrigations in both 1999 and 2000. Parameter values in a row with different letters are significantly different ($P<0.05$) for that irrigation. Letters are not shown when tillage treatment means were not significantly different.

	Total P Loss (g ha^{-1})				DRP Loss (g ha^{-1})			
Irrigation	FC*	FD	SD	DS	FC	FD	SD	DS
				1999				
1	2597	1475	1360	444	55 b	36 b	73 b	198 a
2	5390	4030	4106	2289	51	59	60	98
5	279 a	159 ab	84 b	61 b	5 b	4 b	3 b	9 a
				2000				
1	136	63	80	187	22 b	15 b	17 b	112 a
2	62	51	30	59	14	14	11	51
6	63	67	44	37	9 b	10 b	9 b	26 a

* FC–Fall Chisel plow, FD–Fall Disk, SD–Spring Disk, DS–Direct Seed.