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LOW PRESSURE CENTER PIVOT IRRIGATION AND RESERVOIR TILLAGE

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In 1989 there were 4 million ha of cropland under center pivot irrigation in the 17 western states (Irrigation Journal 1990). The largest areas under center pivot are in the High Plains with soils ranging from sands to clay loams, and the Pacific Northwest with predominately silt loam soils. Most center pivot systems in the semi-arid areas are designed with gross capacities near the peak seasonal evapotranspiration rate, or approximately 10 mm/d. The length of a typical center pivot lateral is about 400 m, which evolved from standard field sizes in the western U. S. Application rates are highest near the outer end of the lateral and are determined by the system capacity, length of lateral, and the width of the water application pattern.

Low pressure center pivots are becoming more widely used as energy costs escalate. Figure 1 shows a center pivot system with spraybooms and spray heads mounted about 2 m above ground. Kincaid et al. (1986) and Kincaid et al. (1987) described low pressure application methods which are being widely used with center pivots. Table 1 lists these methods plus the conventional high pressure sprinklers, and gives average application rates near the outer end of the lateral.

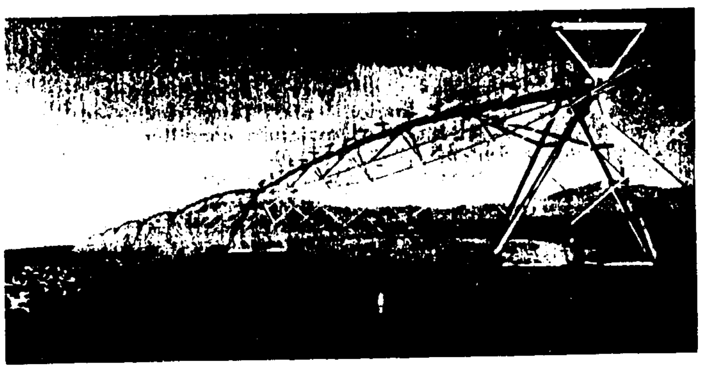

Fig. 1. Center-pivot irrigation system with low pressure sprayboom application system.

The data in Table 1 show that it is usually not possible to design low pressure center pivots to supply sufficient amounts of water to the soil without exceeding the infiltration rate of the soil. The strategy for controlling runoff has typically been to apply smaller amounts of water per rotation of the pivot (by increasing the rotation speed) and to use tillage, surface residue, and crop covers to enhance infiltration and surface storage.

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Table 1. Typical center pivot sprinkler types and application rates for a design capacity of 10 mm/d.

Sprinkler type	Pressure		Pattern width	Application rate
	kPa	psi	m	mm/h
High pressure impact	414	60	30	35
Low pressure impact	207	30	20	52
Sprayboom	138	20	20	52
Spraydrop	138	20	10	104

Basin tillage is the practice of constructing dams or dikes in furrows to create surface storage [(Lyle and Dixon 1977; Longley and Halderson 1982; Aarstad and Miller 1973)] and has been used for many years in irrigated and dryland agriculture. Reservoir tillage, a more recent development [(Longley (1984), Garvin, et al. (1986)] consists of a subsoiler or ripper shank pulled at a depth of about 0.3 m followed by a paddle wheel which penetrates to the depth of the shank, forming pits with small dikes between the pits, thus increasing infiltration rates and creating additional surface storage capacity. Figure 2 shows a reservoir tillage machine (Dammer-Diker, manufactured by Ag. Engineering and Development Co., Tri-Cities, WA**) in operation after potatoes have been planted and hilled on 0.9 m (36-in) row spacing. Figure 3 shows the tilled furrow after several irrigations with partial crop cover.

The objective of this study was to compare runoff, yield, and soil water content using the reservoir tillage method and conventional tillage (without subsoiling or diking), on a variety of soils, slopes, and crops.

EXPERIMENTAL PROCEDURES

Several commercial center pivot systems were selected in the Columbia River Basin in Washington and the Snake River Plain in southern Idaho. The systems had from 8 to 10 spans, and span lengths varied from 38 m to 50 m. The soils varied from sand to silt loams, and the topography varied from nearly level to 12% slopes. The crops grown were potatoes, corn, beans and small grain. Several of the systems had more than one type of sprinkler on different spans, designed to apply the same

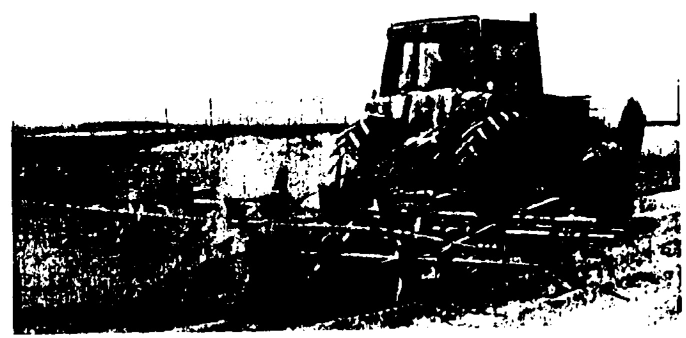

Fig. 2. Reservoir tillage machine in operation after potatoes have been planted.

** Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the USDA or the University of Idaho.

Fig. 3. Reservoir-tilled potatoes after several irrigations.

total water. Two linear traveling laterals were also used to simulate center pivots. The linear systems were designed to discharge approximately the same flow per unit length as the outer portions of a center-pivot system. Table 2 lists the systems, type of sprinklers, pressures, system capacities, soils, slopes and crops grown.

Runoff plots were established in May or June at about 20 to 30% crop cover, and the tillage was done by the farmer or by research personnel. There were usually one or two irrigations (20-30 mm) applied before tillage. The depth of tillage was 250-300 mm in most cases. Plot areas with uniform soil and slope were selected in the outer 2 to 4 spans where application rates were highest. Plots were sized to fit within one span of a pivot to eliminate wheeltrack effects. Plot length varied from 10 m to 50 m depending upon the area of uniform soil and slope available. Plot width varied from about 5 m to 10 m depending upon the crop row spacing. The upslope ends of the plots were dammed to prevent surface runoff from upslope areas.

Soil water, and water application and runoff were measured throughout the growing season; crop yield and quality were also measured. Additional details for individual systems are given by Garvin and Busch (1985), Kincaid et al. (1986), Nabil (1987), Kincaid et al. (1987), and Hasheminia (1990).

RESULTS

Runoff

The primary purpose of reservoir tillage is to prevent runoff, and thus provide more water for crop use. Table 2 gives percent runoff, crop yield, and average percent volume increase in soil water for reservoir as compared with conventional tillage. In some cases, runoff was measured for only a portion of the season so runoff comparisons between systems are not meaningful. It is the runoff reduction within each system due to reservoir tillage that is most important. In many cases, runoff was eliminated by the use of reservoir tillage. The difference in runoff produced by different sprinkler types was not significant in most cases, so the data were combined for purposes of comparing tillage treatments.

Table 2. Center-pivot system, crop, soil, slope, runoff, yield and soil water from conventional and reservoir tilled plots.

Yr	System	SPR type	PR kPa	CAP mm/d	Crop	Soil	Slope %	Runoff CT %	Runoff RT %	Yield CT t/ha	Yield RT t/ha	Volumetric soil water increase %
85	KUNAU	SB	140	9.2	PTO	SL	1.0	16	3	37.5	39.7	4.3
							8.0	19	24	41.5	40.4	-2.2
		SD	140	9.9	PTO	SL	1.0	11	3	41.7	33.9	2.7
							8.0	23	11	41.7	42.9	2.9
	UI103	SB	100	10.3	PTO	SA	2.0	7	0	38.8	48.7	2.4
	EOF	SD	70	10.1	PTO	SA	7.7	26	0	65.5	66.9	1.3
	LPC	SD	140	10.1	PTO	SA	4.5	6	0	49.4	52.9	1.9
	SRCLIN	SD&SB	100	a	BEAN	SL	0.5	7	0	3.07	3.01	0.4
	LARSON	IM	410	7.0	BEAN	SL	4.0	8	0	2.06	1.75	0.8
	SM106	SB	100	10.3	CORN	SA	5.7	26	5	11.9	11.9	1.4
	UI237	SB	100	9.9	CORN	SAL	6.4	14	3	9.9	10.3	1.5
	UI235	IM	350	10.1	CORN	SAL	5.0	n	n	7.6	8.8	2.4
	DC41	SB	100	6.2	BARL	SL	2.0	n	n	8.5	8.1	n
	SUNHVN	TS	140	9.9	WIWH	SL	5.5	33	9	5.2	6.2	n
86	KUNAU	SD&SB	140	9.2	PTO	SL	1.5	13	1	35.2	40.4	2.8
	SRCLIN	SD&SB	100	a	PTO	SL	0.5	1	0	48.7	51.4	0.7
	UI216	SB	100	9.9	PTO	SA	1.0	4	0	47.3	49.8	0.0
							4.0	43	3	47.8	52.3	2.7
	EOF64	SD	100	10.1	PTO	SA	1.0	9	2	74.0	58.1	2.0
							12.0	22	6	69.3	73.4	0.8
	ABLIN	SD	100	a	PTO	SL	0.2	0	0	27.8	28.7	0.3
	SM106	SB	100	10.3	CORN	SA	1.0	3	0	11.7	12.1	n
							6.0	37	16	11.4	12.1	1.2
	UI237	SB	100	9.9	CORN	SA	1.0	2	0	12.1	12.6	n
							4.0	14	6	11.7	12.1	2.2
	GLEN	IM&SB	100	7.8	BEAN	SL	4.0	8	0	2.24	n	2.1
87	KUNAU	SD&SB	140	9.2	PTO	SL	0.8	15	2	26.7	36.3	3.7
	SRCLIN	SD&SB	140	a	PTO	SL	0.5	7	2	28.3	29.4	3.3
	RIRIE	SB	140	9.0	PTO	SL	3.8	n	n	40.9	38.8	1.1
	HAMER	IM	345	9.0	PTO	SL	1.9	n	n	44.2	45.5	0.7
	SRCLIN	SD&SB	140	a	BEAN	SL	0.5	8	0	3.1	3.19	0.8
88	KUNAU	SD&SB	140	9.2	PTO	SL	3.0	25	19	32.5	39.5	3.7
	SRCLIN	SD&SB	140	a	PTO	SL	0.5	20	0	22.2	25.6	0.5
	SRCLIN	SD&SB	140	a	WIWH	SL	0.5	n	n	7.9	7.9	-1.0
89	KUNAU	SD&SB	140	9.2	PTO	SL	0.7	11	1	54.5	62.1	2.1
	SRCLIN	SD&SB	140	a	PTO	SL	0.5	14	0	32.1	35.2	2.0
	SRCLIN	SD&SB	140	a	WIWH	SL	0.5	12	0	9.3	9.3	-0.9

INDEX

SD	Spray drop	RT	Reservoir tillage
SB	Spray boom	a	Linear system
TS	Top spray	n	Not measured
IM	Impact sprinkler	PTO	Potato
SL	Silt loam	WIWH	Winter wheat
SA	Sandy	BARL	Barley
SAL	Sandy loam	CAP	System capacity
CT	Conventional tillage	PR	Nozzle pressure

Where runoff was not eliminated, it was primarily due to overtopping and washout of the dikes; this usually occurred on the steeper slopes. In the corn fields, the crop was planted (0.8 m rows) on a nearly flat surface and the tillage was done when the corn was about 0.3 m high. Runoff from the tilled corn plots was largely due to stemflow to the base of the plants and runoff down the crop row. Ridge planting of corn may reduce this tendency. For example, on ridge-planted potatoes, most runoff was eliminated, with the following exceptions. On the 1985 Kunau plots the tillage was done immediately after planting and the soil was too dry to form stable aggregates. As a result, many of the furrows began to produce runoff by mid season on the steeper slopes on this erodible silt soil. As a result of this experience, tillage for subsequent trials was done when the soil water was higher (60 to 80% of field capacity). Row washout in the 1988 Kunau plots was due to an intense rainfall which occurred after an early season irrigation which overfilled the pits, eroded the dikes and caused runoff from subsequent irrigations.

The sandy soils exhibited some surface sealing and, as a result, runoff was as high on the sandy soils as on silt loams. Therefore, runoff for all soils was averaged for each crop in Table 3. Runoff for potatoes and corn averaged about 15% with conventional tillage (CT) and less than 5% with reservoir tillage (RT). Beans, with closer row spacing (and more reservoirs per unit area) had less runoff. Only two grain fields had measured runoff.

Table 3. Average percent runoff and yield for different crops.

CROP	Runoff % CT	Runoff % RT	Yield, t/ha CT	Yield, t/ha RT
PTO	13.9	3.7	43.1	45.1
CORN	16.0	5.0	12.7	13.3
BEANS	7.8	0	2.74	2.65
GRAIN	23	4.5	7.73	7.88

Runoff is averaged for three ranges of slope in Table 4. On slopes less than 5%, the reservoir dikes generally remained intact and nearly eliminated runoff. On the steeper slopes, where dike failure was more common, reservoir tillage considerably reduced runoff. When runoff began on the steeper slopes there was a tendency to erode a deep channel to the subsoiler depth.

Table 4. Average percent runoff and soil water for three slope ranges.

Slope percent	No. fields	Runoff % CT	Runoff % RT	Soil water increase % by vol (RT-CT)
0-1	16	9	1	1.4
1-5	8	16	4	2.0
>5	8	25	9	1.0

Soil Water

Soil water was usually higher in reservoir-tilled plots than in the conventional plots due to reduced runoff (Table 2). The average difference in measured soil water for the June-August period is given. Although the average differences were small, they were consistent (Table 4). In some cases, soil water was measured in the upslope and downslope quarters of the plots so that within-plot surface water movement could be evaluated. Soil water in the conventional plots in the latter part of the season was usually highest in the lower quarter, indicating surface movement. These measurements showed that in most cases, soil water distribution was more uniform in the reservoir tilled plots than in the conventional plots.

Crop Yield and Quality

The effect of reservoir tillage on crop yield was variable depending on the crop and the amount of runoff from the check plots. Where runoff from conventionally-tilled plots was less than 10%, there was usually little affect on yield. Over the five year period on the Kunau farm potato yields were increased an average of 15% and average percent number one tubers was increased from 63% for conventional plots to 65% for reservoir-tilled plots.

Grain is usually planted into a flat soil surface and can produce significant runoff. Reservoir tillage can be done after flat-planting grain to reduce runoff. However, better results were obtained when the grain was planted using 150 mm (6-in) row spacing on ridged soil [0.9 m (36-in) ridge spacing]. Ridges between the dikes similar to the row crops directed any surface water into the reservoirs. The tillage operation can reduce the plant stand, but this effect is minimized by tilling prior to germination. Stand counts were reduced by reservoir tillage, but final yields were not significantly different.

Beans were planted in 560 mm (22-in) rows and were tilled when there was about 30% plant cover. Although runoff was eliminated, yields were slightly reduced, indicating possible plant damage due to tillage. Narrow-spaced row crops such as beans and sugar beets should be reservoir tilled shortly after planting to prevent plant damage.

Reservoir tillage should be the last field operation before harvest. Herbicide can be sprayed behind the tillage implement. Where mechanical weed control is used the tillage can be done after the last cultivation. The increased surface roughness can cause a problem for harvesting some crops. The use of dual wheels reduces the effective roughness, and a furrow smoothing device can be pulled ahead of the wheels.

Sprinkler Type

In most of these tests, the sprinkler type did not have a significant effect on crop yield, but there was a consistent tendency toward lower runoff under the sprayboom systems. The two main reasons for this are the lower application rates as compared to sprayheads on drops, and small drop sizes which have less erosive effect on the soil as compared to low pressure impact sprinklers. Thus, the infiltration rates and effective surface storage tended to remain higher through the season with spraybooms. Further research is being conducted on infiltration rates and surface storage.

SUMMARY AND CONCLUSIONS

Reservoir tillage was compared to conventional tillage as a means of controlling runoff under center-pivot irrigation. In most cases, soil water content was higher in the reservoir-tilled plots later in the season. Yields were usually slightly higher with reservoir tillage, and potato quality was improved. Reservoir tillage prevented most runoff, which was as high as 43% on conventional tilled plots. Some washout of the reservoirs occurred on the steeper slopes or when heavy rains occurred. Reservoir tillage is an effective method of controlling runoff and allows the use of low pressure center-pivot systems on medium textured soils and variable topography.

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