CENTER PIVOT RUNOFF[1]

by
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Irrigation water applied uniformly to the soil surface by a center pivot sprinkler system is an important objective. However, to maintain high uniformity, the water must be infiltrated at the application point. Water movement within a field can destroy the application uniformity and any water movement out of the field represents a loss to production capability and wasted production investments.

The amount of irrigation water infiltrating into the soil at a specific location within the irrigated field is largely controlled by the irrigation system's ability to deliver water to that point. The effect of the water droplets on the soil surface and the soil's general ability to absorb water, however, plays a major role in determining whether the water is infiltrated at that point or moves to another location. Runoff has always been a design and management concern for center pivot systems. The development of low or reduced pressure sprinkler packages enhances runoff potential. The magnitude of the runoff problems will vary greatly and depend on a number of factors such as soil type, topography, crop cultural practices and sprinkler package selection.

Runoff can occur anytime the rate of application exceeds the infiltration rate of the soil as illustrated by Figure 1.

Addinke (1975) reported runoff amounts of up to 65% of the total water applied by irrigation and rainfall on field areas irrigated by low pressure spray sprinklers and up to 22% for portions of the field irrigated by high pressure sprinklers. Kincaid et al. (1969) found that, under high-pressure, center-pivot systems, up to 22% of the water applied ran off.

Aarstad and Miller (1973) recorded runoff rates of 40% on relatively flat slopes. Gilley and Mielke (1980) measured runoff of 25%, 9% and 28% for high-pressure impact, low-pressure impact and spray-nozzle systems, respectively. Plant population differences could partially account for some of the relatively high percent of runoff from the high-pressure system.

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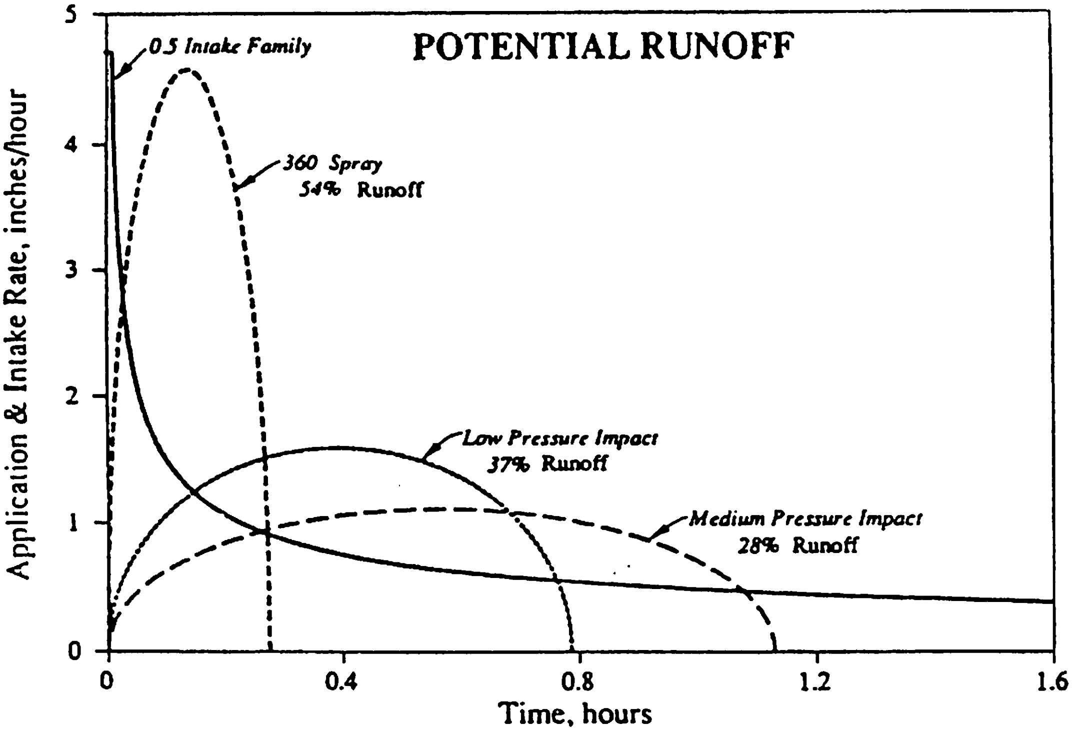

Figure 1. Potential runoff for a silt loam soil receiving a 1.1 inch water application without surface storage. (Kranz, 1988)

Management options to overcome runoff problems are 1) redesign of the irrigation system to reduce the application rate through either reduced capacity or increased coverage area, 2) increased speed of rotation, and 3) modification of cultural practices.

Irrigation System Design

A large variety of sprinkler types and configurations are available to irrigators selecting a center pivot system. As previously illustrated in Figure 1, the sprinkler package selected greatly influences the potential for runoff. Much of the differences in peak application rates is due to the wetted area. However, in general low pressure systems also have an increased size of water droplet since droplet size increases with a decrease in pressure and with an increase in nozzle size. Larger nozzle sizes are needed to supply the required discharge for low pressure systems. Larger droplet sizes have more kinetic energy and therefore have more impact on the soil surface resulting in more surface crusting and reduced infiltration capability of the soil. This effect of sprinkler package type (and the impact of tillage) on soil water infiltration capacity is shown in Table 1.

Peak application rates can be reduced by reducing the irrigation system capacity. However, reducing capacity increases the risk of reducing crop yield due to deficit soil water levels.

Table 1. Infiltration rates for a Sharpsburg silty clay loam after one hour of water application by various types of sprinklers (Gilley et al., 1981).

	Tillage Treatment		
Sprinkler Type	Till Plant	Disk	Chisel
High Pressure Impact	8.3	6.3	15.4
Low Pressure Impact	3.0	2.6	7.5
Low Pressure Spray	4.5	3.0	2.6

Rotational Speed

Increasing the speed of rotation will reduce the depth of water applied per irrigation. This means less water is applied at a rate greater than the soil intake rate. Surface storage of the applied water may then be sufficient to retain the water until infiltration occurs. Peak application rate of the system does not change with a change in rotational speed (See Figure 2). However, while increasing speed of rotation may solve runoff problems, reduced application depths may also result in reduced yields due to other factors. Dorn (1983) reported 12% corn yield reduction for corn water with one-half inch irrigation verses one inch applications.

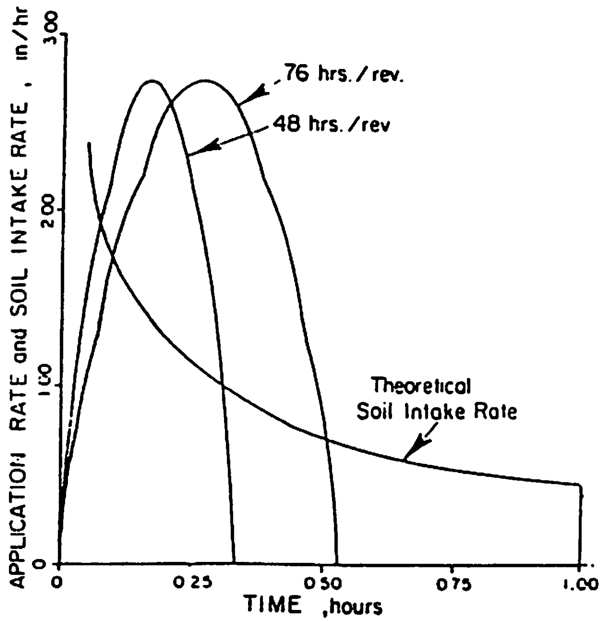

Figure 2. Application Rates for Low-Pressure Impact Center Pivot Irrigation Systems at Two Speeds of Rotation at 1,200 ft. from Center of Rotation of 130 acre System and 750 gpm. (Gilley and Mielke, 1980).

Cultural Practices

Tillage practices influence water management by affecting the infiltration capability of the soil and affecting the roughness of the soil surface. Conservation tillage practices tend to result in higher water intake rates and a rougher soil surface then conventional tillage. Conservation tillage affects infiltration rates by maintaining crop residues on the surface that absorb impact energy of either rainfall or irrigation droplets, thus reducing surface crusting. A rougher soil surface generally results in increased surface storage giving water more time to infiltrate into the soil without running off. Residue management and tillage practices such as subsoiling, furrow diking or implanted reservoirs can be important management options to the irrigator wishing to control sprinkler irrigation runoff.

Research Results

Lamm (1987a) reported the results of a four year study that compared impact sprinkler and spray nozzle performance on four different tillage systems. Results are shown in Table 2. The conventional tillage treatment was fall disk, spring disk with spring tooth cultivator prior to planting. The corrugation treatment included conventional treatment with the corrugations (furrows) installed at the 6-8 leaf stage. The furrow dams were also installed at the 6-8 leaf stage. Water use as used in Table 2 would inadvertently include runoff as it is defined as irrigation plus rain plus soil water depletion. In most years, the furrow damming treatment resulted in less water use and higher yields due to better runoff control. Furrow damming has increased yields by an average of 3 to 12 bu/ac for the impact and spray systems, respectively. The no-tillage treatment performed well later in the study as surface residues increased over time. Lamm concluded that controlling runoff is critical in maintaining high crop yields under spray systems. If runoff is not controlled, the yield reduction from decreased available soil water could easily cost the irrigator more than the energy savings from switching to spray nozzles.

Table 2. Corn yield, water use and water use efficiency data for a sprinkler irrigation study, KSU, 1983-86. (Lamm 1987)

Irrigation System	Tillage System	Grain Yield ave. bu/ac	Water Use inches	WUE lb/ac-in
Impact	Conventional	169.2	30.5	310
	Corrugation	159.8	29.9	300
	Furrow Dam	172.2	29.5	328
	No Tillage	164.8	30.3	302
Spray	Conventional	163.8	31.0	298
	Corrugation	173.0	30.9	314
	Furrow Dam	175.9	28.6	347
	No Tillage	174.5	29.1	332

Lamm (1987b) also reported results of comparison of diking methods under a low pressure spray on soybeans (Table 3). Two treatments are an above ground dike (basin) in a furrow and a below ground basin (implanted reservoir). The results indicate both diking methods did control runoff better than the control and resulted in better yield. No direct measurement of runoff was made for either study.

Table 3. Soybean yields and water use data in a furrow damming study, KSU, 1984-1986. (Lamm 1987b).

Damming Treatments	Grain yields	Water Use	WUE
Control (none)	44.5	20.8	135
Basin	46.0	20.3	140
Implanted Reservoir	49.4	19.9	156

Either method of diking can be effective in controlling runoff from high application rate sprinklers or rainfall events. The basin dike is relatively inexpensive to purchase and operate, but does require a defined furrow. The machine to make implanted reservoirs does not require a furrow and is generally more expensive to purchase and requires more power to operate.

Kranz (1989) reported the results of a center pivot runoff control study conducted at two sites in Nebraska using four tillage treatments. Table 4 shows a summary of results. The three interrow tillage treatments all reduced runoff compared to the conventional treatment. Data is also presented on soil loss. At the Concord site, the subsoil treatment had significantly greater soil loss than other treatments. Kranz cautioned producers that on steep slopes the shank openings from a subsoiler or anhydrous application makes an excellent water conveyance channel that may increase soil loss. Subsoiling should not be used on steep slopes to avoid excessive soil loss. Jasa and Dickey (1989) also reported that while subsoiling did reduce water runoff rate, it did not significantly reduce the soil erosion rate. This data was collected for the first simulated rainfall event after tillage on 5% slopes.

Table 4. Recorded water application rates, soil infiltration rates, surface runoff and soil erosion for simulation runs at Concord, NE (10% slopes) and Clay Center, Ne. (1% slopes) during 1987. (Kranz, 1989).

Treatment	Application Rate	Steady State Infiltration Rate	Accumulated Runoff	Accumulated Soil Loss
		Concord		
	in/hr	in/hr	inches	lb/ac
Conventional	4.88a	2.20a	.49a	1317a
Basin Till	4.76a	1.49a	.23ab	109a
Implanted Reservoir	4.61a	2.71a	.15b	101a
Subsoil	4.45a	1.55a	.80c	2979b
Average	4.69	1.99	.42	1126
		Clay Center		
Conventional	5.87b	1.41a	.10a	34.1a
Implanted Reservoir	5.31b	3.00a	.11a	8.8b
Subsoil	5.24b	2.12ab	.11a	9.2b
Average	5.47	2.18	.11	17.4

- data for each location followed by the same letter are not statistically significant at $P<0.05$ level.

Summary

Runoff from center pivot irrigation systems can be a significant portion of the total application amount. Runoff represents a decrease in productivity and a waste of production investments. The move to low pressure spray nozzles and impact sprinklers increase the runoff potential due to increases in peak application rates and the possibility of reduced soil infiltration rates due to increased soil disturbance from larger droplets. However, management options exist that could reduce or eliminate runoff and include 1) redesign of the irrigation system, 2) increased speed of rotation, and 3) modification of cultural practices. Tillage practices to leave more residue on the soil surface and interrow tillage practices such as furrow diking and subsoiling have been utilized as a means of reducing runoff through either increasing surface storage of water or increasing soil infiltration rate.

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