RUNOFF CONTROL PRACTICES

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INTRODUCTION

Center pivot operators have a number of alternatives when selecting sprinkler packages for center pivots. Under the presumption of energy savings, many operators are converting systems from high pressure to some form of low pressure sprinkler. Several factors may determine whether a selection based solely upon energy cost is appropriate. Such factors as the potential for runoff may dictate the specific sprinkler selection to make. Actual energy cost savings will reflect more than the change in operating pressure. A change in water application efficiency or the operating efficiency of the pumping plant could reduce the energy savings actually realized.

Tillage practices for sprinkler irrigation must seek to control both runoff and erosion. Conservation tillage practices for control of erosion are well documented. However, many of these practices do not always result in an inkind reduction in surface runoff. In some situations, specialized tillage may be necessary to control both runoff and soil erosion. This paper will discuss matching tillage practices reported to provide runoff and erosion protection with appropriate sprinkler packages and field conditions.

The process of selecting a sprinkler package must consider the needs of the crop, capabilities of the delivery system, the field slope, the soil infiltration characteristics, the regional climatic conditions, and the management scheme of the operator. Therefore field evaluation is desirable. Based on the evaluation of the pumping plant, the soil infiltration rate, and field slope conditions, a sprinkler package can be selected which will reduce energy costs while maintaining water application efficiency.

The impact of tillage on the suitability of a sprinkler package was demonstrated quite clearly by Gilley, et al., 1981. Their research included three types of sprinklers and three tillage treatments. Table 1 is a summary of data collected during their research. Note that interaction between a specific sprinkler and the 3 tillage treatments is particularly evident for the high pressure impact and low pressure impact sprinklers. Even more revealing is the general decline in infiltration as the operating pressure of the sprinkler decreases. These data suggest that the interaction between the soil surface condition and the sprinkler type is substantial. Thus the overall tillage program prior to the irrigation season should be geared toward developing a soil surface which minimizes the impact of the sprinkler and maximize soil infiltration.

PROBLEM IDENTIFICATION

Due to system design, center pivots can be operated on undulating terrain. It is not uncommon for field slopes to be in excess of 5% somewhere in the field. Water naturally moves downslope if water is applied at rates greater than the soil infiltration rate. Water moving over the soil surface tends to pick up soil and some plant nutrients from the soil surface and transports them to another location. The best time to determine if a runoff problem exists is during the later stages of the irrigation season. If the problem is severe, surface drainage channels will be carrying water off the field during rainfall or irrigation events.

For moderate runoff cases, water will move to some other location in the field. The soil surface provides an indication that runoff has occurred. Running waters leave small channels or rills where water has been flowing. These channels have downslope outlets similar to the delta areas of a river. Thus, the best place to observe moderate runoff problems is at the base of a hill where water would normally enter a main surface drain.

Minor runoff problems must be observed in the field during an irrigation event. Minor runoff problems can be observed in areas of extreme field slope or the outside edge of the pivot. For systems with full circle water application patterns, runoff will be most noticeable on the back side of the pivot. While this problem does not generally cause soil erosion, small channels of water are noticeable during the irrigation event. Water moves over very short distances and does not always create noticeable channels where water has been flowing.

POTENTIAL CAUSES

The development of low and medium pressured sprinkler packages has compounded the potential for runoff. Increases in runoff, due to the irrigation system, occur because of two main factors: 1) system peak application rate; and 2) water droplet impact. As the operating pressure of the system is reduced the peak application rate increases and in general the water droplet size increases. Runoff amounts of 60-65% of the water applied have been recorded from fields irrigated by low pressure sprinklers (Addink, 1975). Runoff amounts of only 22% were recorded for portions of the field irrigated by high pressure sprinklers. Therefore, depending on the situation, altering tillage practices may not be necessary to control a runoff problem. Instead, an alternative sprinkler package may be required.

The impact energy supplied by water droplets causes a thin crust to be developed on the soil surface. Research conducted in South Dakota indicates that as the impact energy increased, the infiltration rate of the soil decreased (Mohammed, and Kohl, 1986). Their results show that the soil infiltration rate for an unprotected soil surface decreased from 5.3 inches per hour to 1.85 inches per hour after just one hour of water application. Soils protected by a burlap cover experienced no reduction in infiltration rate. Prior to crop canopy development, the soil infiltration rate can be reduced by water droplet impact by over 50%. During the early portion of the growing season, crop residue cover will absorb much of impact of water droplets. Thus, crop residue can play a big role in reducing runoff.

With a narrowing profit margin, the cost of applying each additional inch of water must be considered. However, it is equally important to insure that all portions of the field receive the required amount of water. One method used to reduce runoff during sprinkler irrigation has been specialized tillage conducted after planting. Three different interrow tillage practices have been field tested at two locations as a layby treatment. If weed control is not a concern, some of these practices could be implemented shortly after planting. The main drawback to earlier tillage is that the desired shattering effect on the soil profile would not take place for implements using a subsoil shank.

LAYBY SUBSOILING

Layby subsoiling utilizes a chisel shank operated to a depth of 10 to 14 inches midway between the crop rows. Manufacturer's recommended speed of travel is approximately 5-6 mph. The idea is to partially shatter and uplift the soil profile increasing the infiltration rate and creating a rough soil surface. This practice is most effective when soil conditions are relatively dry and when controlled traffic is practiced. If the operation takes place under moist soil conditions less shattering occurs. Research in Nebraska and South Dakota, has indicated that runoff can be reduced, and in some cases, increased yields can result from the use of this practice (DeBoer and Beck, 1982 and Gilley, et al., 1981). DeBoer and Beck (1982) reported 70% less runoff from center pivot irrigated plots which were subsoiled compared to those receiving conventional tillage.

Most of the research conducted using this practice has taken place under relatively low field slope conditions (<5%). Investigations in Nebraska under steeper slopes (>9%) have indicated that under some field slope conditions the shank opening can provide a channel for water to flow in. Visual inspections have shown that on occasion water moved down into the shank opening then downslope before returning to the surface some distance away. Another observed drawback to this operation is that the shattering effect of the shank can send the plant into temporary moisture stress. A prolonged hot dry period after the tillage operation, could affect soil moisture and final yields.

BASIN TILLAGE

The basin tillage implement consists of a small paddle or set of disk blades installed behind the rear shanks of a cultivator. The paddle or disk blade drags soil for a preset distance of 3-8 feet before depositing the soil across the row. The soil deposited creates a small dam and the area upslope becomes a small water storage area or basin. Lyle and Bordovsky (1981) reported that runoff from center pivot irrigation on relatively low field slopes was reduced from 10% down to less than 1% of the water applied using basins.

A potential drawback of this tillage is that individual dams can be washed out resulting in an increasing volume of water entering the basin downslope. The worst case would involve failure of all of the basins. The resulting runoff could be similar to the untilled situation and soil erosion loss would be greater. For the research reported below, the implement appeared to have difficulty making basins where loose soil was not available on the soil surface.

IMPLANTED RESERVOIR

The implanted reservoir is essentially a combination of the basin tillage and subsoiling concepts. Like the subsoiler, the implanted reservoir implement utilizes a chisel shank operated at a depth of 10-14 inches to shatter and uplift the soil profile. Manufacturer's recommended speed of travel is approximately 5-6 mph. Somewhat analogous to the basin tiller, the implanted reservoir implement has a large paddle wheel which creates mini-reservoirs at 2 foot spacings. The main difference between the basin tiller and implanted reservoir implements is that the mini-reservoirs created by the implanted reservoir are below ground level. The benefit of this implement is that it creates a substantial amount of surface storage. Hence, the use of this type of implement would appear to adequately control runoff from sprinkler irrigated fields.

Since moisture stress is also possible with this implement, developers recommend applying 0.5-0.8 inches of water immediately after the tillage operation. The most significant drawback of this implement is that it is the most energy intensive practice of the three. Horsepower requirements range from 20-25 horsepower per row depending on the soil type and the depth of tillage.

RUNOFF CONTROL

The three practices described above were evaluated at Concord, NE and Clay Center, NE. The study took place during the 1987 growing season. Water was supplied to 5' X 36' plots using a continuous application rainfall simulator. The water droplets and application rate were similar to the last span of a center pivot equipped with low pressure spray sprinkler package. The field conditions for each location were:

	Clay Center	Concord
Crop	Sorghum	Corn
Field slope, %	1.0	10.0
Soil type	silt loam	silt loam
Tillage Time	July	June
Speed of travel, mph	5.5	5.5
Depth of shank, in.	12.0	12.0
Application rate, in/hr	4.6	4.6
Replications	4	3

Runoff amounts for Concord and Clay Center are presented in Tables 3 and 4, respectively. At Concord, the conventional tillage practice was a single disk and plant treatment. Data in Table 3 summarize some of the water application data for the Concord location. The data indicates that the basin till and implanted reservoir practices reduced runoff compared to the conventional treatment. Note that the steady-state infiltration rates do not follow the same trend as total runoff. The steady-state infiltration rate is greatest for the implanted reservoir treatment. However, the basin treatment has the lowest steady-state infiltration rate of any treatment, yet it had one of the the lowest total runoff amounts recorded at Concord. This indicates that increasing the infiltration rate will reduce runoff, but it will not account for all of the runoff control required.

Surface runoff at Clay Center shows that all three interrow tillage treatments provided excellent runoff control. The conventional treatment at Clay Center was fall disk, spring harrow, plant and a single cultivator for weed control. While surface runoff would be expected to be lower under 1% slope, if a channel is supplied for water to flow in, runoff can still be a problem. The data presented in Table 4 indicate that runoff amounts were not consistently reduced by the higher infiltration rates.

SOIL EROSION LOSS

Soil losses recorded for Concord and Clay Center are presented in Tables 3 and 4 respectively. Significantly greater soil loss was recorded for the subsoil treatment at Concord compared to the other treatments. At the time of the rainfall simulations, the soil surface was loose and granular for all treatments. Upon visual inspection, the opening left by the subsoil shank provided a channel for water to move down slope. Most of the soil loss originated from the side slopes of the channel. These data indicate that producers must be aware that shank openings from a subsoiler or anhydrous applicator will provide excellent water conveyance channels on steep slope areas. These channels may increase soil loss and should be avoided. If 4"-6" deep basins are formed by the basin tiller, or implanted reservoir implement, adequate control of soil loss is possible on up to 10% slopes.

Erosion at Clay Center was two orders of magnitude lower than recorded at Concord. Due to lower field slope conditions, runoff water contained less energy and thus did not scour away soil from the water flow pathways. The conventional treatment recorded greater soil loss than the implanted reservoir and subsoil treatments. These data indicate that runoff will not normally be a concern on 1% field slopes. Many tillage practices will be capable of controlling runoff and soil loss effectively.

ADDITIONAL CONSIDERATIONS

This type of runoff control does not come about without cost. The major drawback of the implanted reservoir and subsoiler is that they require about 20-25 horsepower per row. The purchase cost of the subsoiler or implanted reservoir ranges from $5,000-$6,500 for a 5 row unit. Cost for the basin tillage equipment is approximately $300 per row with minimal extra horsepower requirements.

Installation costs must be offset by higher yields, less water application or the need to control runoff from the field due to state and/or federal legislation. All Nebraska evaluations have indicated no yield advantage to using these practices. However, soil moisture samples taken after harvest have indicated that more water is stored in the soil profile at the end of the year. Consequently, the only potential advantage to using these implements appears to be in the water conservation area.

In this part of the country, the implanted reservoirs and basins have remained largely intact if the implement is operated according to the manufacturer's recommendations. Small combines tend to drop into the depressions. The main problem is with the narrow rear wheels. This problem can be remedied by not placing reservoirs or basins in the rows to be travelled by the combine or the combine could be retrofitted with wider wheels on the rear of the machine.

Years with above normal precipitation in the fall can delay harvest due to wet soil conditions. Generally this condition would be most severe in low lying field areas. If soil moisture is a problem at harvest time the use of these practices may compound the problem.

SUMMARY

A sprinkler package selection should be made after careful consideration of the operating efficiency of the system. Surface runoff can affect the cost of irrigation substantially. Under low slope conditions several tillage practices are available which can reduce runoff. Under steep slope conditions, fields with low intake rate soil may need to create additional surface storage in order to control runoff.

Interrow tillage practices have been used to provide soil surface storage and increase soil infiltration rate. Clear identification of severe runoff is recommended prior to use of energy intensive alternatives. Careful timing of the tillage practice and controlled traffic will increase the effectiveness of the practice and extend the effective lifetime of the tillage practice.

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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

Table 2. Soil surface storage estimates based upon field slope.

Field Slope (%)	Soil Surface Storage (inches)
> 5	0.0
3-5	0.1
1-3	0.3
< 1	0.5

taken from Dillon, et al., 1972.

Table 3. Average runoff, erosion, and steady-state infiltration rates for various interrow tillage practices following 2 inches of water application practices at Concord, NE under 10% slopes.

Treatment	Water Applied (inches)	Runoff (inches)	Steady-State Infiltration Rate (in/hr)	Soil Loss (lb/ac)
Subsoil	2.0	0.8c *	1.6a	3,752b
Implanted Reservoir	2.0	0.2b	2.7a	127a
Basin Tiller	2.0	0.2ab	1.5a	137a
Reduced Tillage	2.0	0.5a	2.2a	1,658a

- all data the average of 4 replications
* data in the same column followed by the same letter are not significantly different at the 0.05 level

Table 4. Average runoff, erosion, and steady-state infiltration rates for various interrow tillage treatments following 2 inches of water application at Clay Center, NE under 1% slopes.

Treatment	Water Applied (inches)	Runoff (inches)	Steady-State Infiltration Rate (in/hr)	Soil Loss (lb/ac.)
Subsoil	2.0	0.1a *	2.1ab	12a
Implanted Reservoir	2.0	0.1a	3.0b	11a
Basin Tiller	2.9	0.2	1.7ab	116ab
Conventional	2.0	0.1a	1.4a	43b

- all data the average of three replications
* data in the same column followed by the same letter are not significantly different at the 0.05 level.