IRRIGATION WATER CONSERVING STRATEGIES FOR CORN

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INTRODUCTION

Irrigation water management has always been important to the people in southwest Nebraska. It was evident to the farmer in the area from the earliest days that the land was very productive with adequate water. Thus, over the years a large portion of the area has had irrigation systems developed. Today, due to numerous factors, water shortages and allocations have become a reality for the farmers.

Finding a way to conserve irrigation water has been an ongoing research topic since the 1920's at the University of Nebraska West Central Research and Extension Center at North Platte. The studies have found that corn yield are closely related to crop evapotranspiration (ET) and that usually yields would be lowered if ET is lowered (Payero et al., 2006a; Payero et al., 2006b; Payero et al., 2006c; Payero et al., 2006d). Additional studies have found that no significant yield reduction occurred when irrigation was delayed and corn was moderately stressed during the vegetative stage. However, significant yield reductions were found when stress occurred during the pollination and grain filling stages (Gilley et all., 1980).

The University of Nebraska-Lincoln Extension started the Republican River Basin Irrigation Management Project in 1996, funded by the US Bureau of Reclamation to help area farmers understand and adopt these water saving methods (Schneekloth and Norton, 2000) (Klocke et al., 2004). Starting in 2002, line-source irrigation based plots have been used to demonstrate three irrigation strategies on farmers= fields. The layout makes a good field day site because the three irrigation strategies are all within a few hundred feet. The line source irrigation system shows full application depth to dryland in a range of just 50 ft.

Fields days were held at each of the sites each year (except the Curtis site in 2003 because it was badly hailed). Counting these sites, and the other sites demonstrating irrigation scheduling tools, twenty-five field days have been conducted with about 760 people attending over the past five years. The scope of this paper is limited to showing the yield and water use data generated by the project and some of the keys to making these strategies work on the farm.

METHODOLOGY

The Republican River Basin Irrigation Management Project has been conducted in producer fields growing irrigated corn. The farmers have planted and cared for the crop, with the timing and quantity of water application being the main variable. The other changes that were made to the farmer=s crops were created in smaller subplots by thinning the corn stand and creating skip row areas. The population data will not be discussed in this paper.

Irrigation Management Strategies

The purpose of the plots were to demonstrate and compare three irrigation strategies for west central Nebraska. They included the traditional fully watered strategy and two that conserve water (Melvin et al., 2005). The names and descriptions of the strategies are as follows:

a. **Fully Watered**-the traditional Best Management Practice (BMP) irrigation management strategy focused on keeping soil-water at a high enough level to prevent moisture stress from being a limiting factor for yield. The goal of the strategy was to maintain the plant available soil-water (in the active root zone) between field capacity and 50% depletion from planting through maturity. Usually the soil was kept one-half to one inch below field capacity to allow for rain storage. After the hard dough stage, the soil was allowed to dry down to 60% depletion.
b. **Water Miser BMP** - the Water Miser BMP irrigation management strategy focused on saving water during the less sensitive vegetative growth stages and fully watering during the critical reproductive growth stages. Irrigation was delayed until about two weeks before tassel emergence of the corn, unless soil-water became 70% depleted (in the active root zone). Once the crop reached the reproductive growth stage, the plant available soil-water was maintained in a range between field capacity and 40% depletion. Usually the soil was kept one-half to one inch below field capacity to allow for rain storage. After the hard dough stage, the soil was allowed to dry down to 60% depletion.

c. **Deficit Irrigation**-The deficit irrigation management strategy focuses on correctly timing the application of a restricted quantity of water, both within the growing season as well as over a several year period. The intent is to stabilize yields between years by applying irrigation based on soil-water depletion. Less water will be applied during wetter years, while more will be applied through the drier years, with an average over the years equaling the available quantity of water. The management strategy is to delay the application of water until about two weeks before tassel emergence for corn, unless soil-water becomes 70% depleted. Once the crop reaches the reproductive growth stage the plant available soil-water (in the active root zone) is maintained in a range between 30 to 60% depletion. It is allowed to dry down to 70% depleted after the hard dough stage. The idea is that these depletion numbers should be changed based on the amount of water the producer has to work with. More research is needed to determine guidelines for differing water use levels.

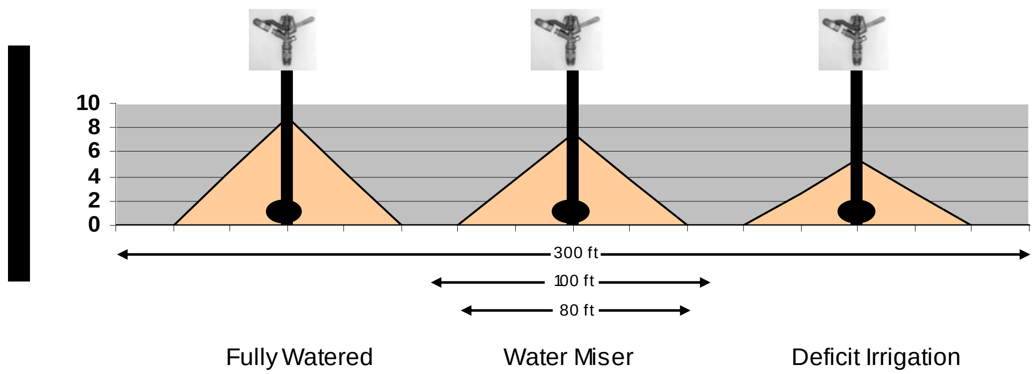
Cooperators and Site Selection

The cooperators were picked with the help of the local Extension Educators and irrigation district managers in southwest Nebraska. They were picked because of their willingness to work with the project, interest in water issues, excellent crop production skills, and location of their fields. The plots were placed on the edge of the field along a public road to facilitate viewing all season by people traveling past the field. Big signs explaining the demonstrations were placed at each site. The demonstrations were conducted at three sites each year with the exception of 2003 when only two sites were harvested because one dropped out at the last minute. The sites have included farms near the Nebraska towns of Arapahoe, Culbertson, Curtis, Holbrook, and Holdrege.

Plot Layout and Management

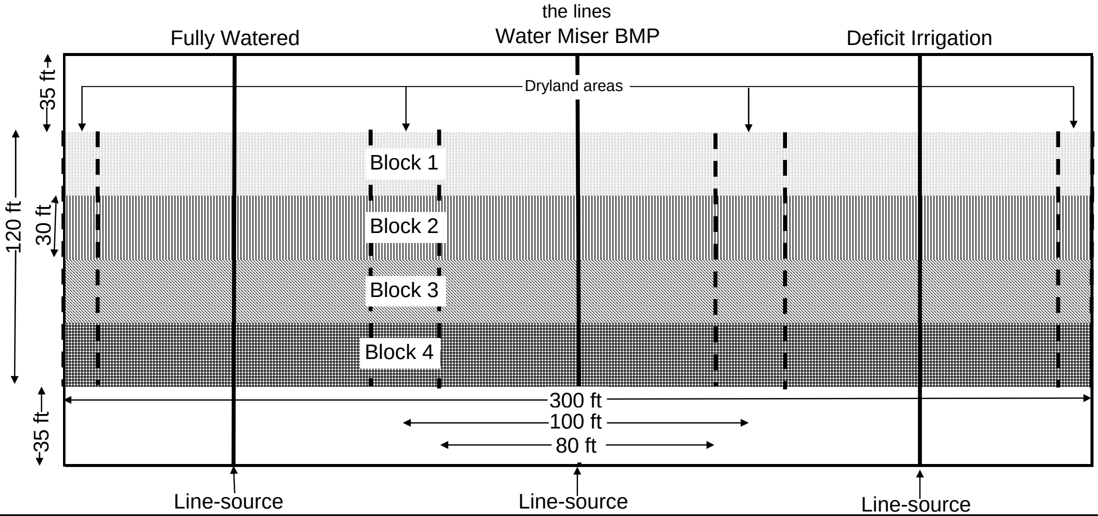
The irrigation demonstration sites used three line-source sprinkler laterals to show the Fully Watered, Water Miser BMP or Deficit Irrigation strategies. A line-source irrigation system refers to a set of sprinklers that are placed in the field and left in the same location for the season (Figure 1). The sprinkler spacing within the line was 10 ft and the spacing between the lines was 100 ft (Figure 2). The sprinkler used had a wetted diameter of 80 ft, creating a 20 ft strip between the lines that does not receive any irrigation to represent dryland conditions. This configuration creates a watering pattern of the planed application depth next to the sprinkler line and a gradual decrease in the depth of application until about 40 ft from the line where no water is

Figure 1. Front view of the demonstration plot showing the three line-source sprinkler system.



applied. The advantage of the setup is that it gives the planed depth of irrigation plus a gradient from the planed depth to dryland. The sprinkler lines extended 35 ft past each end of the treatment area to create the correct overlap of the sprinkler pattern. The plot size including the overall sprinkler line length was 300 ft by 190 ft.

Figure 2. Top view of the demonstration plot showing the three line-source sprinkler system and 4 block for treatments along the lines



The tillage and cropping methods were the normal practices for that farmer and were primarily conventionally tilled furrow irrigated fields. The timing and the amount of water applied were the only management variables. The irrigation scheduling and water application was done by the project manager. Soil moisture data was gathered every two weeks by the neutron attenuation method. ET data from the High Plains Regional Climate Center was used to predict irrigation needs in-between. An irrigation scheduling spreadsheet was used to manage the data and calculate the application depth for each week. The soil types were all silt loam and ranged in water holding capacity from about 1.9-2.5 in/ft. The water application rate was limited to a net application of 2 inches per week (about the same as a 750 GPM center pivot on 125 acres) to simulate a typical system for the area.

RESULTS AND DISCUSSION

The plot yields have been measured each year by either hand harvesting or with a plot combine. The data has been collected and summarized across the 100 ft width of each of the line-source sprinkler systems. This represents ten yields points that range from the planed irrigation depth to dryland, eight that received irrigation and two that were dryland. Table 1 shows the yields and the amount of water that was applied to the three strategies at the farmer=s

Table 1. 2003-2006 Average of Corn Yields and Water Use by Management Strategy and Site

	Management Strategy		
	Fully Wate	Water Mise	Def.
Site	Average Yields (bu/acre)		
Holbrook	193	197	
Culbertson	150	165	117
Holdrege	239	244	233
Curtis	219	223	177
Arapahoe	192	185	171
All Sites[1]	198	203	174
Percent of **Fully Watered** Yield	100	102	88
Site	Applied Water (acre-inches/acre)		
Holbrook	10.0	6.6	
Culbertson	10.1	9.0	5.6
Holdrege	6.0	4.7	3.4
Curtis	9.5	9.5	7.0
Arapahoe	8.9	8.1	6.9
All Sites[1]	8.9	7.6	5.5
Percent of **Fully Watered** Applied Water	100	85	62

[1] Yield and applied water are weighted by the number of years of data at each site.

irrigated populations (26-31,000 plants per acre at harvest). The data is for the center two plots, one on each side of the sprinkler lines. The applied water numbers are a net irrigation amount and would need to be increased by five to ten percent to represent a center pivot.

Table 1 contains 10 site years of data, two from Holbrook (2003-04), two from Culbertson (2003-04), two from Holdrege (2004-05), two from Curtis (2005-

06), and two from Arapahoe (2005-06). The data for 2002 is not included in this table because of startup problems.

Yields and Water Usage

The yields and water usage from 2003-2006 averaged over the five sites are shown in Table 1. It shows that the Water Miser BMP strategy obtained 102% of the yield, as compared with the Fully Watered strategy, requiring only 85% as much irrigation or 1.3 inches less. Using the Deficit Irrigation strategies, 88% of the Fully Watered yield was obtained, using only 62% of the irrigation water.

The Water Miser and Fully Watered yields were only four bushels apart and were very close to the farmer=s yield in the rest of the field. Considering these facts, the Water Miser and the Fully Irrigated strategies produced essentially the same yield and the yields were not limited by a lack of water. However, the Water Miser strategy reduced the pumping requirement by 1.3 inches. So the advantage is in saving on pumping costs which range in southwest Nebraska from $2.50 to $15.00 per acre. Thus, the Water Miser would create a savings of $3.25 to $19.50 per acre in pumping cost.

An economic comparison of the Deficit Irrigation is shown in Table 2 over a range of corn prices and irrigation water pumping costs. This table is important to study and find where each irrigation system would fall because in southwest Nebraska pumping cost are extremely variable. Also, with the price change in corn over the past year, the economic returns have changed as well. An important point to understanding how to interpret this chart is that the corn price is to be the cash price less the harvest, storage, and marketing costs. This number can easily be $0.40 to $0.50 per bushel less than the cash price.

Working through an example of using the chart will make this point clearer. Assuming the cash sales price for corn is $3.50 per bushel and the combining, grain cart, trucking to the bin, drying costs, storage costs, trucking to market, and marketing costs would equal $0.50 per bushel, than the corn price to use in this chart would be $3.00 per bushel. The idea is getting to the value of the corn standing in the field, because if we do not produce it, we do not need to spend the money to harvest and market it. The chart ignores any reduced input costs for nitrogen, seed, etc. associated with planning for a lower yield goal. Using the $3.00 price for corn and with the average pumping cost of $7.50 per acre-in, the Deficit Irrigation would return $48.02 per acre less than the Fully watered. The difference would be made up of $73.18/acre less corn to sell and a savings of $25.16/acre on pumping costs.

A second example with higher pumping costs and lower corn prices is worth looking at. Consider if the price of corn is $2.00 per bushel and the harvest cost would still be $0.50 per bushel or a net price of $1.50 per bushel and the pumping costs were $12.50 per acre-inch. Looking these numbers up on the

Table 2. Sensitivity analysis over a range of water costs and corn prices comparing the Fully Watered to the Deficit Irrigation strategy (using the 24.4 bushels per acre less corn produced and the 3.4 inches less water used for the Deficit Irrigation strategy from Table 1).

Comparison of Deficit to Fully Watered Strategies

Corn price, $/bu less harvest cost	Cost to apply 1 inch of water/acre, $/a: $2.50	$5.00	$7.50	$10.00	$12.50	$15.00
$1.50	-$28.20	-$19.82	-$11.43	-$3.04	$5.34	$13.73
$2.00	-$40.40	-$32.01	-$23.63	-$15.24	-$6.85	$1.53
$2.50	-$52.59	-$44.21	-$35.82	-$27.44	-$19.05	-$10.67
$3.00	-$64.79	-$56.40	-$48.02	-$39.63	-$31.25	-$22.86
$3.50	-$76.99	-$68.60	-$60.21	-$51.83	-$43.44	-$35.06
$4.00	-$89.18	-$80.80	-$72.41	-$64.02	-$55.64	-$47.25

chart reveals that even though the yield would be 24 bushels less with the Deficit Irrigation than the Fully Watered, the bottom line would be $7.94 per acre better. The difference would be made up of $36.59/acre less corn to sell and a savings of $41.93/acre on pumping costs.

Table 2 shows that in most situations the Deficit Irrigation strategy is not the highest profit method if adequate water is available. However, when water supply is not adequate to fully water, the more important question is, should one consider reducing acres to more fully water the crop or deficit irrigate more acres. To fully analyze this problem is beyond the scope of this paper, but in general it is usually more profitable to deficit water more acres. For more help analyzing these decisions, use the Water Optimizer program. It is a University of Nebraska-Lincoln Extension product designed to be a decision support tool to help make these types of decisions when irrigation water is in short supply. The Water Optimizer program and an instruction manual can be down loaded at http://extension.unl.edu/wq/index.htm.

Keys to Making the Water Miser BMP Strategy Work on the Farm

The Republican River Basin Irrigation Management Project=s original goal was to help farmers use less water in irrigated crop production, not just show that it could be done. So, lets talk about some of the important things that need to be done by producers to make these strategies work on their farms. Taking the time to get good information and putting it into an irrigation scheduling system is the key. Knowing when to start irrigating for the season, what to do after a rain, and when to stop for the season are the main questions to be answered. The differences between each systems capacity or it=s ability to deliver water to the field varies greatly and is another important point to focus on. Some systems need to run every hour of every day all summer to irrigate the field adequately and others need only run three or four days per week. Add this to the variability of the rain that each field receives and it emphasizes the importance of recording how much water the field has received.

In almost all cases, the producer's fields received more irrigation water than the Fully Irrigated treatments and yet resulted in essentially the same yields. The differences were usually that the fields were irrigated earlier in the season and quicker after a rain. Moreover, the field was wetter when the corn matured. The advantage that the plot manager had was better soil moisture readings, good rainfall records for each individual field, and accurate irrigation application amounts. This information was put into an irrigation scheduling program that was used to manage the data and help determine when the next irrigation would be needed and how much to apply. The biggest advantage of the scheduling program was organizing the data and helping determine the last irrigation.

The four keys to making the Water Miser BMP work are:

1. Invest in soil moisture monitoring equipment and use it. Spending the money to purchase devices that log the readings as they are taken is worth the extra cost.
2. Critically evaluate when to start irrigating. Most producers start irrigating before it is needed, particularly with center pivots that can water the entire field in 2-4 days. The crop should be lowering the soil moisture levels in the second foot of soil (depth of 12 to 24 inches) before irrigation is started. Caution: On low capacity systems, start irrigating as soon as the field can store the irrigation water.
3. Keep good rain and irrigation application records and compare them to what the ET has been for the field. The problem is that every irrigation system has a different capacity and every field receives a different amount of rain, so running all system about the same numbers of hours will over water some fields and under water others.
4. Starting at the dough stage, calculate the amount of rain and irrigation that is needed to get the crop to maturity. The water levels in the soil depths from 12 to 36 inches should be getting dryer by the start of the dough stage. The goal is to have the soil moisture level lowered to 40 percent of plant available water by maturity. Delay the last irrigation with center pivots as long as possible to see if a late rain will provide the needed water.

CONCLUSIONS

The Republican River Basin Irrigation Management Project has provided numerous educational opportunities that have helped farmers produce top yields while using less water. It has also generated valuable on-farm real world numbers for the management strategies that conserve irrigation water.

The Water Miser BMP and Deficit Irrigation strategies proved to be valuable water conserving practices at the research level and have now shown to be effective in plots in farmers= fields across south west Nebraska.

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