LIVING WITH LIMITED WATER IN SOUTHWEST NEBRASKA

Joel P. Schneekloth
NE Regional Water Resource Specialist
Colorado State University
Akron, Colorado
jschneek@coop.ext.colostate.edu

Nancy A. Norton
Assoc. Prof.
Albany State University
Albany, Georgia
nanorton@asurams.edu

PROJECT SUMMARY

Since 1996, an irrigation management demonstration project has been underway in the Republican River Basin. This demonstration project is based on 30 years of UNL irrigation research in west central Nebraska. The purpose of the project is to demonstrate implications of alternative irrigation management strategies on water use and profitability. Six sites are included in the project. The sites range in soil type from silt loam to fine sand.

Improved management of irrigation may reduce irrigation water use while maintaining or even improving grain yields. Good irrigation management involves knowing crop water needs and making adjustments for the amount of rainfall and moisture stored in the soil. Increased use of stored soil moisture allows for more efficient use of precipitation and is a critical factor in reducing required irrigation water.

There are certain growing season periods, such as the vegetative growth and late grain fill stages where, in general, irrigation amounts can be reduced with little or no effect on grain yield. UNL research and demonstration sites have shown that seasonal irrigation amounts may be reduced by one or more inches per acre with no significant effect on yield. This work also shows, however, that when available water (irrigation plus rainfall plus soil water) is less than the crop's ET demand, yield may be substantially diminished.

Water holding capacity (WHC) of the soil plays an important role in the ability to reduce irrigation amounts without diminishing grain yields. Irrigation water can be reduced to a greater extent (with little or no yield effect) on soils such as silt loams and sandy loams, which have a higher WHC, compared to lower WHC soils, such as fine sands.

This Demonstration Project illustrates that, under certain conditions, there is a potential for reducing irrigation water with little or no decrease in net revenue, especially on silt loams. In many counties in the Republican River Basin, high WHC soils, like loams and silt loams, are prevalent or even dominant. Although over 50% of the soils in Dundy county are low WHC sands, Chase has nearly 50% loams and silt loams, and Perkins' soils are predominantly (over 60%) in the high WHC category. Other counties, such as Frontier, Red Willow, Furnas, and Harlan have over 90% of their soils classified as loams or silt loams.

This demonstration project was funded by the Bureau of Reclamation and Upper Republican Natural Resources District. Support was also given to the demonstration project by the Middle Republican, Lower Republican and Tri-Basin NRDs, the Natural Resources and Conservation Service, and the University of Nebraska Cooperative Extension. This demonstration project will continue through 2001.

PROJECT DESCRIPTION

Sites In 1996, sites near Arapahoe, Dickens and Elsie, Nebraska were selected for the project. Two additional sites were added in 1997 (McCook and North Platte), and one was added in 1999 (Benkelman). Four sites are irrigated with center pivot systems (Arapahoe, Dickens, Elsie and Benkelman) while two are furrow irrigated (McCook and North Platte). These sites have been used to demonstrate corn yield response to different irrigation management strategies. Tillage and cropping practices are those used by the farmer. Timing and amount of irrigation water use are the only variables changed at each of these sites.

Irrigation Management Strategies Four different irrigation management strategies have been conducted at each of these sites: current farmer management (FARM); university best management practices (BMP); late initiation (LATE); and limited allocation (ALLOC). The four strategies are as follows:

1. FARM – irrigation water is applied according to farmer's current management strategy.
2. BMP – includes bi-weekly soil-water monitoring, use of predicted crop water use (ET), and maintaining plant available soil-water (in the active root zone) in the range of 50% depletion and field capacity (minus a rainfall allowance during the vegetative and reproductive growth stages).
3. LATE – emphasizes water application during the crops reproductive growth stage. Irrigation is not applied until two weeks prior to tassel emergence for corn unless soil-water becomes 70% depleted during the vegetative growth stage. Once the crop reaches the reproductive growth stage, LATE is managed the same as BMP.
4. ALLOC – managed the same as LATE except only 10 inches of water per acre are allocated (6 inches for Elsie and Benkelman site). These allocations are applied during a period beginning with the reproductive growth stage and continuing into the grain fill growth stage (approximately five weeks).

For all management strategies, soil-water was monitored to a depth of 10 feet. End of season management targeted 60% depletion of soil-water in the root zone at crop maturity (i.e. black layer for corn).

OVERALL YIELD RESULTS AND ECONOMIC IMPLICATIONS

Table 1 shows average corn yields and irrigation water used at the four project sites with center pivots during 1996-1999 (only 1999 for Benkelman). The annual yields and irrigation water use were influenced by rainfall amounts at the sites. For the four sites, FARM and BMP average yields ranged from 188 to 201 bu/acre. Cooperators at these sites have historically been using amounts of irrigation water at or near BMP levels. This point is important because reductions in water use from BMP levels can significantly affect yields. The All Sites category (in blue) in Table 1 is the average of yields and applied water at the sites during the four-year period. Overall, the LATE strategy shows an average yield decline of 4 bu/acre (from FARM) with water savings of nearly 3 inches/acre. The ALLOC strategy saved over 4 inches/acre of water with an average yield loss of 16 bu/acre.

Figure 1 indicates, in general, how crop yield responds to increasing amounts of applied irrigation water. At lower levels of applied water (e.g. at level A) the response to an extra inch of irrigation water can be large. However, additional water can generate additional yield only to a point. When the curve levels off (applied water level C for the silt loam and D for the sand), yield is at a maximum and does not increase when more water is applied.

This "decreasing extra yield response" is common to all soil types, but the level of applied water use at which the curve becomes flat differs by soil type. This is due primarily to the varying water holding capacities of the soils. Because very sandy soils can store only about one inch of water per foot of soil from rainfall or irrigation, larger amounts of irrigation water are needed to reach maximum yield. The results from the Elsie and Dickens sites illustrate (see Table 1) how yield drops when irrigation water is reduced below ET requirements (e.g. at ALLOC levels). Yield reductions are most dramatic on the Valentine sands at the Dickens site. The Arapahoe site (silt loam), which experienced increases in yield when applied water was reduced, suggests that production under FARM and BMP may have been on the dotted downward section of the yield curve (level D in Figure 1). Reducing irrigation (from level D to C), in this case, increased yield.

A decrease in yield will reduce gross revenue, but the decline in revenue is somewhat offset by a reduction in pumping cost. Table 2 shows an example of the net returns to land, labor, and management for each site and management strategy. These returns were calculated with 1999 average operating costs for southwest Nebraska, a $2.00/bu price of corn, and a pumping cost of $2.50/acre-inch. A black number means the net return for BMP, LATE, or ALLOC is greater than the FARM net return for that site; a red number means net return is less than the FARM net return. Arapahoe and Benkelman, the two sites with the highest water holding capacities (see Table 1), had net revenue gains when applied water was decreased to the levels used for LATE and ALLOC, whereas Elsie and Dickens had net losses.

Also shown in Table 2 are the net returns averaged over the four sites and four years (All Sites). This broader look at the results indicates a net gain of $3.58/acre when BMP management is followed compared to FARM management. Although the LATE management strategy decreases average net return by about $.30/acre, three inches/acre of water are saved. The ALLOC strategy (which cut water use by almost 4.5 inches) reduced net return, on average, by about $18/acre. The net return effects of the ALLOC strategy shows what can happen when crop ET demands are not met. The average net return data in Table 2 are clearly affected by pumping costs and corn prices. For example, a net loss (from diminished yield) will be greater if corn prices rise, and will be less if pumping costs are higher.

SPECIFIC RESULTS FOR CENTER PIVOT SITES

Elsie The soil type at the Elsie site is predominantly a Woodly fine sandy loam with water holding capacity of about 1.5 inches/foot. Corn grain yields and irrigation amounts for 1996 to 1999 for all four irrigation management strategies are shown in Figure 2. Yields for FARM and BMP were similar each of the four years. The amount of irrigation applied to FARM was 0.7 and 0.6 inches more than BMP in 1997 and 1998, and equal to BMP in 1996 and 1999. FARM irrigation management tended to result in more water being applied during the vegetative growth stage while BMP applied more water during the reproductive growth stage. The application of more water during the vegetative growth stage by FARM was done to reduce the risk of crop stress. However, the BMP strategy increased soil-water use, which encouraged more extensive root development.

Yields for LATE and ALLOC were similar to BMP and FARM in 1996. In 1997 to 1999, grain yields for LATE were 10 bu/acre less than BMP and FARM. The savings in irrigation water applied when changing management from BMP to LATE ranged from one inch/acre in 1999 to 3.5 inches in 1996. Grain yields for ALLOC were about 40 bu/acre less than BMP in 1997 and 1998, and 25 bu/acre less than BMP in 1999. Reductions in the amount of irrigation water used for ALLOC compared to FARM ranged from 2 to 7.5 inches.

In 1996, precipitation and small amounts of irrigation during the pollination and grain fill growth stages met ET rates for the crop and no water stress was observed for either LATE or ALLOC. During June of 1996, precipitation and stored soil moisture met crop needs for LATE and ALLOC. Irrigation began in late June and ended during July when precipitation exceeded crop needs. In 1997, precipitation during June was more than crop ET during vegetative growth stage. This caused root development to be limited. Precipitation during July and August was below normal. As a result of these factors, water stress was observed during late August in

ALLOC, and resulted in a larger reduction in grain yield as compared to 1998 and 1999. During 1998 and 1999, little rain occurred during the vegetative and early reproductive growth stages. No precipitation occurred from June 10 to July 25 during 1998 and from July 2 to August 1 in 1999. These periods coincided with the greatest ET for corn. Severe water stress was observed in 1998 prior to tassel emergence for both LATE and ALLOC, while moderate water stress was observed in 1999.

In 1999, most of the LATE management field area yields were similar to BMP and FARM. However, the areas of the field with soil-water-holding capacities lower than the average WHC of the field had decreases in grain yield of 20 to 50 bu/acre. Variability in grain yield increased as water became limited with water management strategies such as LATE and ALLOC.

Benkelman The predominant soil type at the Benkelman site is a Jayem loamy sand with a water holding capacity of about 1.8 inches/foot. Grain yields for the irrigation management strategies in 1999 were 191 bu/acre for FARM, 199 bu/acre for BMP, 183 bu/acre for LATE, and 178 bu/acre for ALLOC. The amount of irrigation applied to each of the treatments was 7.8, 6.7, 5.5, and 3.5 inches/acre for FARM, BMP, LATE, and ALLOC, respectively. A portion of the area (approximately 5 acres) within LATE and ALLOC had a significant reduction in yield. A lower grain yield was also observed in this five-acre area in prior years. Grain yields for LATE and ALLOC were 188 bu/acre when adjusted to exclude the lower yields in these five acres.

Rainfall during June was adequate to meet crop ET. However, there was no precipitation during the first 30 days of July. The amount of soil moisture that was available to the crop was enough to meet ET needs for 18 days, with no crop stress observed for LATE and ALLOC.

Dickens The soil type at Dickens is generally a Valentine fine sand with a water holding capacity of 1.1 inches/foot. Corn grain yields and irrigation amounts for 1996 to 1999 for all four irrigation management strategies are shown in Figure 3. Grain yields and irrigation amounts for FARM and BMP were similar in 3 of 4 years. In 1997, grain yields for BMP were 28 bu/acre less than FARM. This yield loss resulted from not irrigating BMP, LATE and ALLOC at the four leaf growth stage. Water stress during that growth stage resulted in a yield cap (lower maximum potential grain yield) for BMP, LATE and ALLOC.

Grain yields in 1996 were similar for all water treatments. This was due to above normal precipitation during the reproductive growth stages starting in early July. When precipitation is above normal during the reproductive growth stage, reducing irrigation during the vegetative growth stage has little or no impact upon grain yield (although does save on pumping costs). With above normal precipitation in 1996, leaching of nitrogen fertilizer was observed by changes in coloration of the corn crop. After large rains, the vegetation began to appear as a lighter green. To alleviate the nitrogen stress the crop was fertigated, even though irrigation was not required to meet crop water needs. These fertigations applied approximately 2.5 inches/acre of water.

Grain yields for LATE and ALLOC were less than BMP and FARM in 1998 and 1999. Growing season precipitation in 1998 was below normal. Six inches of rainfall occurred in three separate events of 2 inches each. Much of this precipitation was unusable by the crop because of leaching beyond the root zone. With the low water holding capacity of a fine sand, both LATE and ALLOC treatments were under water stress for much of the vegetative growth stage. Irrigation was needed to prevent soil moisture from dropping below 70% depletion and to maintain some crop growth. Yields for LATE and ALLOC were 30 and 50 bu/acre less than BMP and FARM for 1998.

During 1999, precipitation was near normal in June, below normal in July and above normal during August. However, much of the precipitation that occurred in August was unusable since two of the precipitation events were greater than 3 inches. Most of the irrigation water (all treatments) was applied during July (7.4 inches/acre for BMP and FARM; 5.5 inches/acre for LATE and ALLOC). All treatments received an additional 1.5 inches/acre of applied water in May and June and 3.3 inches/acre in August and September. Grain yields for LATE and ALLOC were 10 and 25 bu/acre less than BMP and FARM.

<u>Arapahoe</u> The soil type at the Arapahoe site is a Holdredge silt loam with a water holding capacity of 2.0 inches/foot. Grain yields and irrigation amounts for 1996 to 1999 for all four irrigation treatments are shown in Figure 4. In 1996, grain yields for LATE and ALLOC were more than FARM and BMP. Precipitation during July and August was above normal and leaching of water occurred. Leaching occurred for all irrigation management strategies, but was greater in FARM and BMP because soil moisture was closer to field capacity in mid-July when above normal precipitation occurred. Soil samples were taken in the fall of 1996 for residual soil nitrate levels. Higher nitrate concentrations were found below 6 feet in FARM and BMP, as compared to LATE and ALLOC. Grain yields for all four irrigation treatments were similar for 1997 to 1999. However, irrigation amounts were reduced significantly by delaying irrigation during the vegetative growth stages. During 1997, irrigation water applied for FARM (15 inches/acre) was the highest of the four years. BMP management, with increased monitoring of stored soil moisture, reduced the amount of water applied to 12 inches/acre -- a savings of 3 inches/acre. Delaying irrigation during the vegetative growth stage as with ALLOC utilized stored soil moisture and precipitation more effectively and decreased the amount of irrigation applied by one-third as compared to BMP management.

In each of the four years, delaying irrigation until the reproductive growth stage (LATE and ALLOC) did not reduce grain yields compared to BMP.

SPECIFIC RESULTS FOR FURROW SITES

McCook The soil type at McCook is a Holdredge silt loam with a water holding capacity of 2.0 inches/foot. Irrigation practices at McCook were furrow irrigation with a surge valve. Irrigation management for BMP, LATE and ALLOC was irrigation of every other row with 12 hour set times. Management for FARM was irrigation of every row and a 24 hour set time. Grain yields and irrigation amounts are shown in Figure 5. Hail damage occurred each of the three years. Damage that also occurred in 1999 included green snap resulting in 25 to 40 percent loss of stand and herbicide damage due to the cool spring.

In 1997, grain yields for FARM management were 8 bu/acre more than that of BMP. However, the total amount of water applied on BMP was 12.5 inches less than that applied to FARM. Changing from every row irrigation to every-other row irrigation improved use of precipitation and reduced deep percolation. Reducing irrigation amounts below that of BMP diminished grain yields by 10 to 15 bu/acre, but saved 2.5 and 5 inches/acre of irrigation water for LATE and ALLOC, respectively.

Grain yields in 1998 for all treatments were similar to 1997. However, water savings for BMP compared to FARM were smaller. Water savings by using BMP were 4 inches/acre compared to FARM. Management of FARM was changed from irrigating every row to every other row. Several difficulties have been evident at the McCook site. They include short field lengths, low intake soils and moderate slopes on the field (greater than 1%). With these problems, excessive runoff has occurred. These problems will be addressed in future work.

North Platte The site at North Platte is a University managed research plot. Management treatments are BMP, LATE, ALLOC, and dryland. The soil type is a Cozad silt loam with a water holding capacity of 2.0 inches/foot. Corn grain yields and irrigation amounts are shown in Figure 6. Grain yields for BMP, LATE and ALLOC were similar for 1997 and 1999. This was due to adequate precipitation during the growing season. Higher than normal precipitation resulted in above normal dryland grain yields of 175 and 165 bu/acre for 1997 and 1999 respectively. Precipitation during 1997 was evenly timed and resulted in less water stress. In 1999, no precipitation was recorded during a 30 day time period during July. However, precipitation during August was above normal, as were dryland grain yields.

The greatest difference in grain yields between BMP, ALLOC and dryland occurred in 1998. Grain yields for BMP, ALLOC, and dryland were 216, 204, and 114 bu/acre, respectively. The yield response for the first 6 inches of water applied increased grain yield 90 bu/acre or 15 bu/acre on average for each inch of applied water. The yield response for the next 6 inches of water applied was 12 bu/acre or 2 bu/acre on average for each inch of water applied. In situations where the pumping costs are relatively high, the additional yield gained beyond that of ALLOC may not always pay for the cost of the additional water.

Acknowledgments

The authors of this publication would like to acknowledge their appreciation for the cooperation of the farmers involved in this demonstration project. Without their involvement, this project would not have happened.

Table 1. Four-Year Average of Corn Yields and Water Use by Management Strategy and Site.

		Management Strategy			
	Soil WHC[1]	**FARM**	**BMP**	**LATE**	**ALLOC**
Site	**(in/ft)**	**Average Yields (bu/acre)**			
Arapahoe	**2.1"**	**188**	**189**	**198**	**190**
Elsie	**1.5"**	**193**	**193**	**184**	**165**
Dickens[2]	**1.1"**	**200**	**201**	**184**	**174**
Benkelman[3]	**1.8"**	**191**	**199**	**188**	**188**
All Sites[4]		**193**	**194**	**189**	**177**
		FARM	**BMP**	**LATE**	**ALLOC**
Site		**Applied Water (acre-inches/acre)**			
Arapahoe	**2.1"**	**8.1**	**7.4**	**5.3**	**4.3**
Elsie	**1.5"**	**9.5**	**9.2**	**6.6**	**5.0**
Dickens[2]	**1.1"**	**13.0**	**13.0**	**10.5**	**8.7**
Benkelman[3]	**1.8"**	**7.9**	**7.2**	**5.5**	**3.5**
All Sites[4]		**9.8**	**9.4**	**7.0**	**5.5**

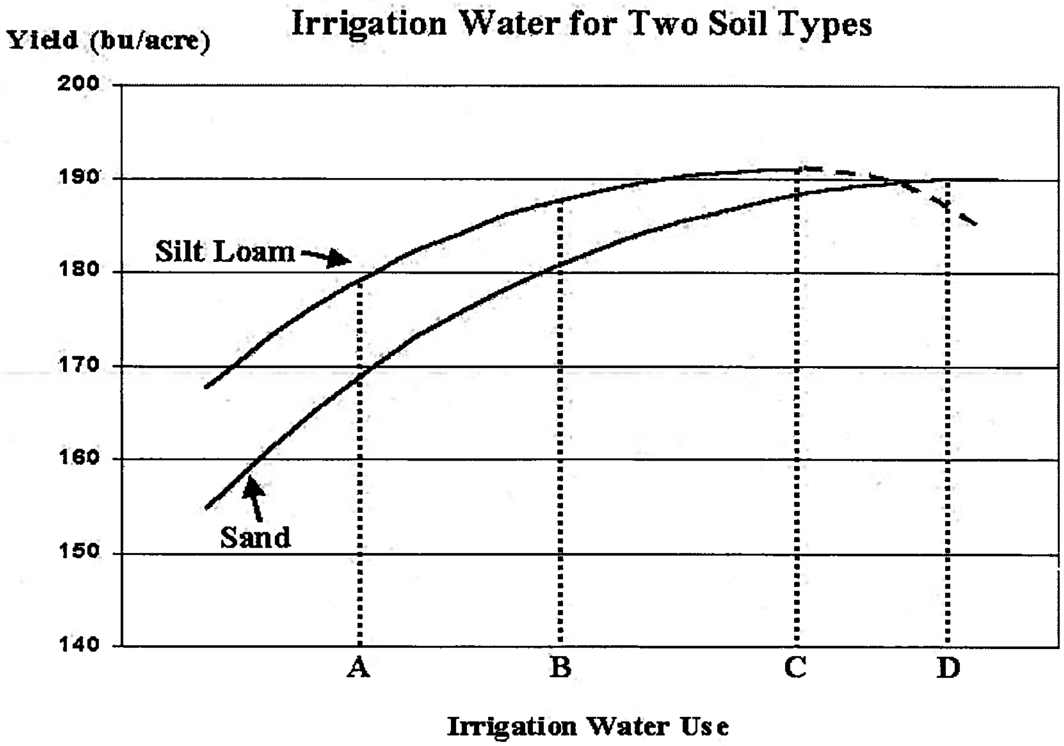
[1]Soil water holding capacity.
[2]Data for Dickens in 1997 not included due to irrigation error.
[3]Only 1999 data for Benkelman site; average yields for LATE and ALLOC at this site were adjusted as discussed in brochure.
[4]Yield and applied water are weighted by the number of years of data at each site.

Table 2. Average Four-Year Net Returns[1] by Management Strategy and Site.

	Management Strategy			
	FARM	BMP	LATE	ALLOC
Site	Net Return ($/acre)			
Arapahoe	$186.69	$191.70	$212.69	$200.86
Elsie	$193.55	$193.92	$184.68	$153.86
Dickens[2]	$196.30	$198.09	$163.08	$161.57
Benkelman[3]	$193.52	$209.61	$194.15	$199.15
All Sites	$191.95	$195.53	$191.66	$173.73

[1]Net returns to land, labor, and management using 1999 average regional operating costs; assumes price of corn is $2.00/bu and pump cost is $2.50/acre-inch.
[2]Data for Dickens in 1997 not included due to irrigation error.
[3]Only 1999 data used for Benkelman site.

Figure 1. Example of Corn Response to Irrigation Water for Two Soil Types



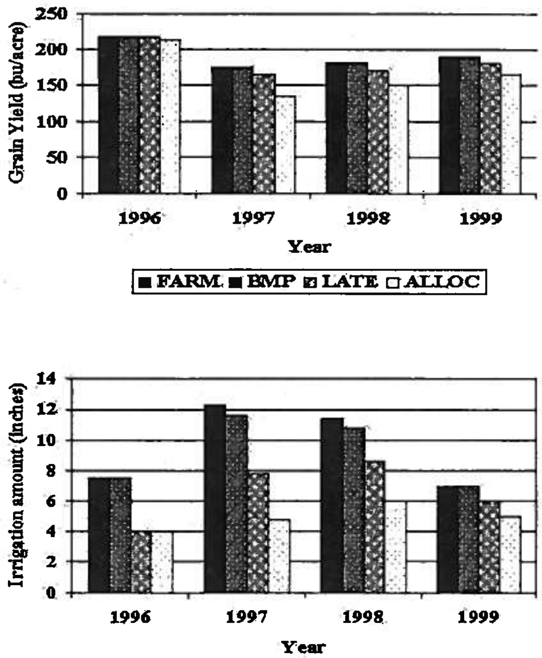


Figure 2. Grain yield and irrigation amounts at Elsie for 1996 to 1999

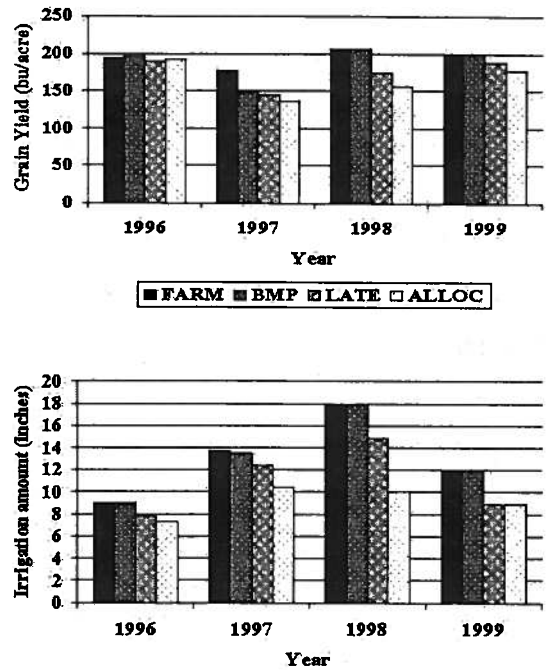


Figure 3. Grain yield and irrigation amounts at Dickens for 1996 to 1999

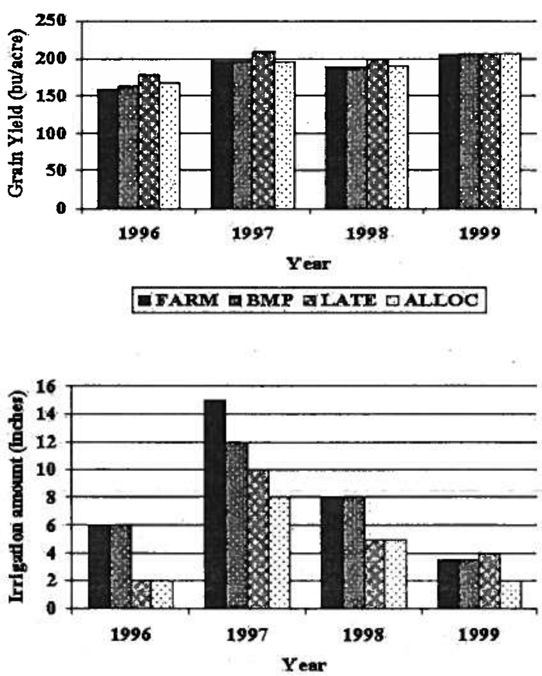


Figure 4. Grain yield and irrigation amounts at Arapahoe for 1996 to 1999

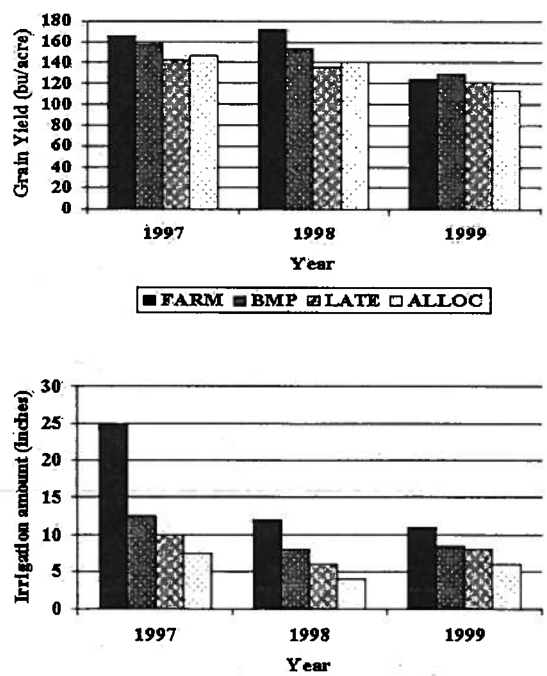
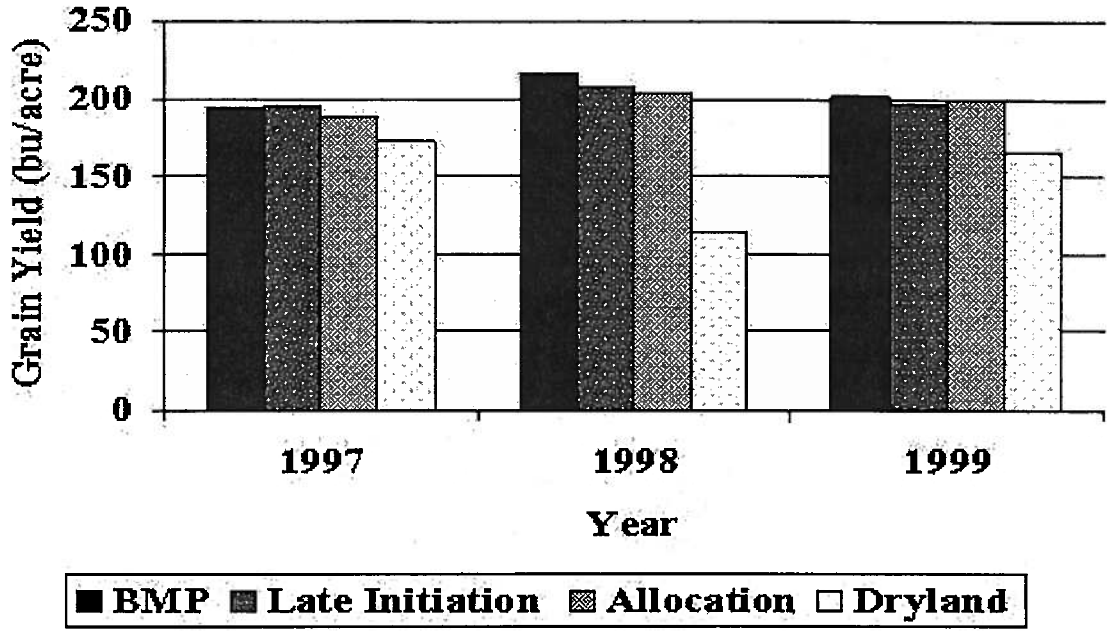


Figure 5. Grain yield and irrigation amounts at McCook for 1997 to 1999



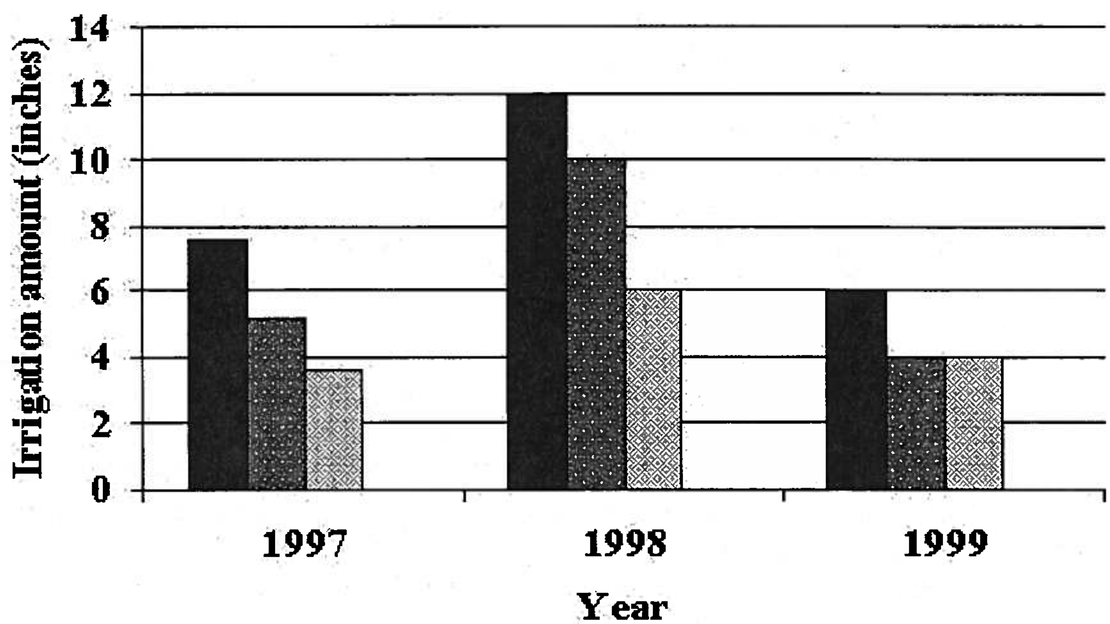


Figure 6. Grain yield and irrigation amounts at North Platte for 1997 to 1999

DESIGN AND MANAGEMENT CONSIDERATIONS FOR SUBSURFACE DRIP IRRIGATION SYSTEMS

Freddie R. Lamm
flamm@oznet.ksu.edu
Research Agricultural Engineer
K-State Research and Extension
Northwest Research-Extension Center
105 Experiment Farm Road,
Colby, Kansas 67701

Danny H. Rogers
drogers @ksu.edu
Extension Agricultural Engineer
K-State Research and Extension
Dept. of Biological & Agricultural Engineering
Seaton Hall
Manhattan, Kansas 66502

William E. Spurgeon
spurgeon@www.wncc.net
Agricultural Engineering Consultant
Spurgeon Engineering & Consulting
1719 Avenue X
Scottsbluff, Nebraska 69361

INTRODUCTION

If the goal of the irrigator is to develop and operate a successful subsurface drip irrigation (SDI) system, what is the purpose? Water conservation and water quality protection have often been cited as possible purposes to consider SDI. If so, it is imperative that the SDI system be designed and operated in a manner so that there is a realistic hope to satisfy those purposes. It should also be noted that an improperly designed SDI system is less forgiving than an improperly designed center pivot sprinkler system. Water distribution problems may be difficult or impossible to correct for an improperly designed SDI system.

The intent of this paper is not to show the producer how to step-by-step design and manage their SDI system. Rather, it is to discuss some of the concepts necessary in a properly designed and management system. The hope is this discussion will enable the producer to *ask* the right questions of those designing or selling them an SDI system. As with most any new technology in a region, there are unscrupulous individuals trying to take advantage of unknowledgeable buyers. These SDI systems could easily end in failure. At the same time there are many reputable distributors, sales people and installers that are trying to promote the successful use of SDI technology. System failures hurt all those involved with SDI, the enduser, the industry selling it, and the university and government entities promoting it. *Don't be afraid to ask questions and to seek clarifications. Time spent now will be rewarded down the road.*