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CROPPING ROTATIONS USING LIMITED IRRIGATION

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INTRODUCTION

With the declines in the Ogallala Aquifer system comes declines in well yield. At certain well capacities, the ability to fully irrigate becomes difficult without adequate precipitation. Grain yields decline with this reduced ability to adequately meet the evapotranspiration needs of crops. In some regions of the Ogallala Aquifer, local entities have instituted pumping restrictions to try and slow the decline and extend the economic life of the Ogallala Aquifer within that region.

WHAT IS LIMITED IRRIGATION?

Limited irrigation is a management practice that incorporates crop rotations, water management during the vegetative growth stages and farming practices to minimize water stress during the critical crop growth stages. When water supplies are restricted, so that full evapotranspiration demands cannot be met, limited irrigation results. Reasons that for limited water supplies include:

1) Limited capacity of the irrigation well – In regions with limited saturated depth of the aquifer, well yields can be marginal and not sufficient to meet the needs of the crop.
2) Restricted allocation upon pumping – In some regions that have experienced declining groundwater levels, restrictions have been implemented to decrease the amount of pumping by producers. In some instances, the allocations are less than what is required to fully irrigate the crops grown.
3) Reduced surface water supplies or storage – In regions that rely upon surface water to supply irrigation needs, droughts can have a major impact upon the amount of water accumulations that are available to producers for irrigation.

When producers cannot apply water to meet the ET of the crop, they must realize that with typical management practices, yields and returns from the irrigated crop will be reduced as compared to a fully irrigated crop. To properly manage the water for the greatest return, producers must have an understanding of how crops respond to water, how crop rotations can enhance irrigation management, and how changes in agronomic practices can influence water needs.

There are several important "pieces to the puzzle" that help to facilitate limited irrigation strategies. Many of these principles come from dryland water conservation management. They include: the relationships between grain yield and water use (evapotranspiration), understanding how water stress impacts crops during several growth stages, crop residue management for water conservation, plant population management, crop rotations to balance water use, and irrigation timing. These factors will be discussed separately and then combined in actual demonstration/case studies of limited irrigation.

CROP RESPONSE TO WATER

Yield and evapotranspiration

Evapotranspiration (ET) is the amount of water that is used by the crop and is the driving force behind crop yields. ET is both evaporation of water from the soil or crop surface and transpiration by the crop. Crop yields are a linear relationship to the amount of water that is used by the crop (Figure 1). Crops such as corn, respond with more yield for every inch of water that the crop consumes as compared to winter wheat or soybeans. However, crops such as corn require more water for development or maintenance that can be determined by where the yield-ET line intersects the X-axis. Corn requires approximately 10 inches of ET to produce the first increment of yield as compared to 4.5 and 7.5 inches of ET for wheat and soybeans. These crops also require less ET for maximum production.

Irrigation is important to increasing ET and grain yields. Irrigation is used to supplement rainfall in periods when ET is greater than precipitation. However, not all of the water applied by irrigation can be used for ET. Inefficiencies in applications by the system result in losses. As ET is maximized, more losses occur since the soil is nearer to field capacity and more prone to losses such as deep percolation (Figure 2).

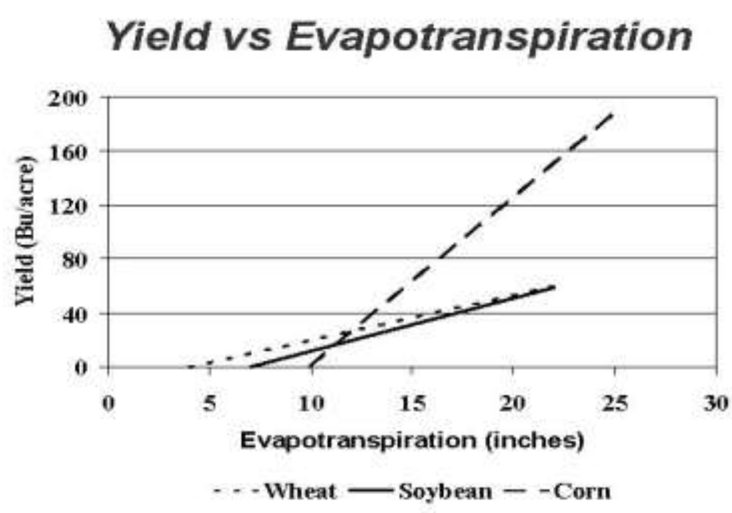

Figure 1. Grain yield vs ET relationship for corn, soybeans and winter wheat from North Platte, NE. (Schneekloth et al. 1991)

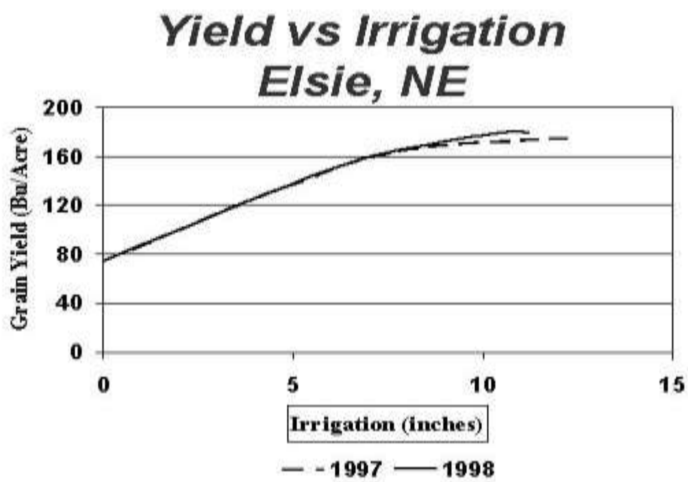

Figure 2. Grain yield vs Irrigation relationship for corn from Elsie, NE.

Impact of water stress

Crops respond to water stress differently at several growth stages. Many grain crops have little or no yield response to water stress during the vegetative growth stage and during late reproductive or grain fill growth stages. However, crops are sensitive to water stress during the reproductive growth stages and yields will be impacted in a negative factor during this time period.

When water is limited over the entire acreage, limiting water during the growth stages that are least responsive and saving water for the critical growth stages is important to maximizing the return to water. Figure 3 shows the yield susceptibility of corn thru the growing season. Early water stress has less impact on grain yield as compared to tassel to silk. Water stress reduces transpiration as compared to a non-stressed crop. Stressing a crop during the time periods when water use is lower limits the total impact of water use reductions as compared to water stress during growth stages that have higher transpiration rates.

Although beginning soil moisture is essential when dealing with limited capacities, water during the reproductive time period has a greater response. When irrigation is applied at the critical time periods for maximum water use efficiency, production by each unit of water will be maximized. Applying irrigation too early or too late will minimize the water use efficiency of water. Nielsen et al. 2009 found that beginning soil moisture had a significant impact on dryland corn yields, however precipitation received during the 6 week critical period had a greater response to that beginning soil moisture (Figure 4). Each additional inch of beginning soil moisture had 3 times greater yield response in years with above normal precipitation during that critical period as compared to years with average precipitation.

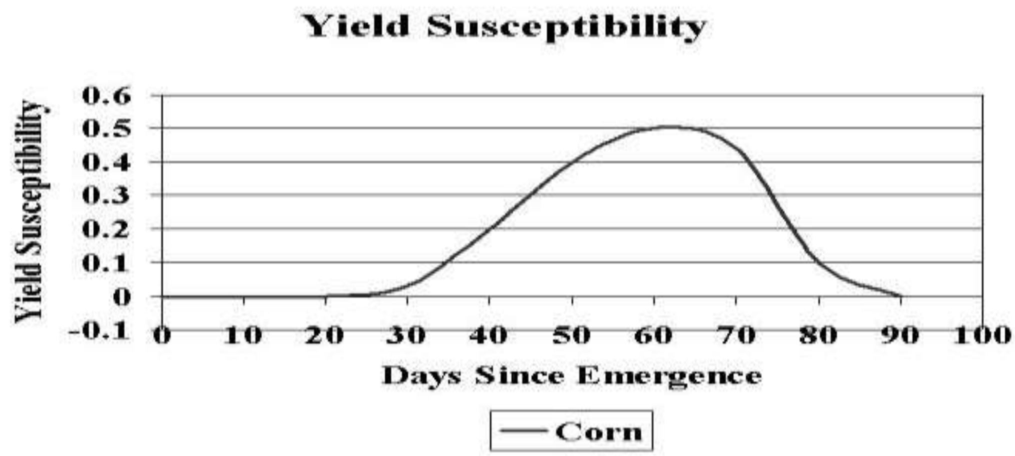

Figure 3. Yield susceptibility to water stress for corn (Sudar et al., 1981).

Irrigation Capacity

When dealing with limited capacities and/or quantities of water supplies for irrigation, the potential for maximum production of a single crop on the entire irrigated acreage declines. Approaches to irrigation management and cropping will be dependent upon when and how much irrigation water can be supplied to the crop during the critical time periods. How many acres to grow of a particular crop with a given capacity is important to consider.

As irrigation capacities are less than adequate, producer strategies to try and alleviate that reduced capacity include pre-irrigation, beginning irrigation earlier in the growing season and not shutting off the system during wet time periods. Many times, this management results in more irrigation water being applied than what would be required with an adequate capacity and less grain yields. These strategies are used to keep soil moisture at or near field capacity as long as possible into the growing season before ET is greater than the irrigation capacity and potential average precipitation.

Irrigation capacity on a per-irrigated acre basis is important when considering how many acres to irrigate. In western Kansas, Lamm (2004) found that net returns to land and management are reduced when all acres are irrigated with less than adequate capacities as compared to reducing irrigated acres and maintaining an adequate capacity. Maximum potential corn yields are reduced as irrigation capacity is reduced as compared to maintaining an adequate capacity with fewer acres.

Schneekloth et al. (2012) found that cutting acres to increase irrigation capacity per irrigated acre increased yields and decreased variability in year to year yields. In years with above normal precipitation, irrigation capacity did not result in different yields. However, when precipitation is limited during the growing season, irrigating more acres with a low capacity well decreased yields. At Akron, CO, an irrigation capacity of 0.125 in day^{-1} decreased yields by 30 to 40% of a fully irrigated yield (0.25 in day^{-1}). However, they found that not irrigating during the vegetative growth stage and fully irrigating during the reproductive and grain fill time periods did not decrease grain yields. However, fewer acres of corn must be grown when not irrigating during the vegetative to fully irrigate during the reproductive time periods when precipitation is below average.

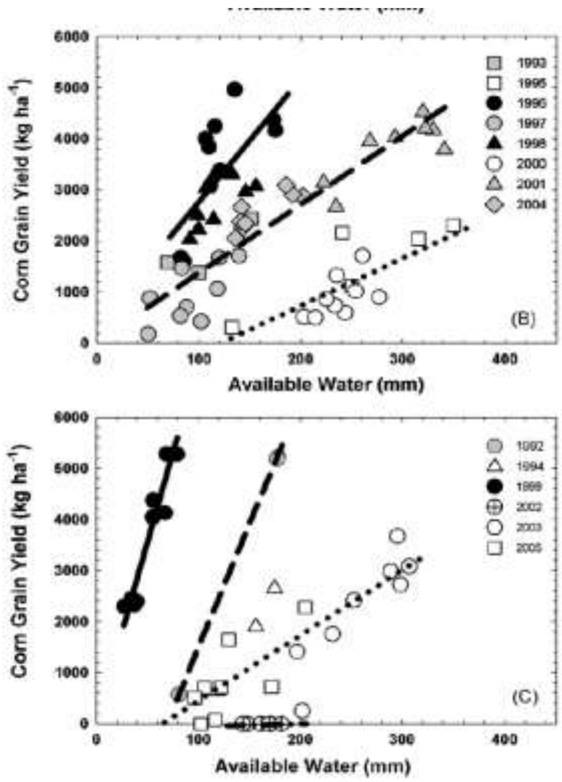

Figure 4. Response of dryland corn yields to available soil water at planting. Nielsen et al. 2009

A study conducted at Tribune, KS found similar results with reduced capacity. Decreasing capacity from 0.20 to 0.15 or 0.10 in day^{-1} decreased grain yields by 20 to 27% as compared to the higher capacity. Year to year variability increased as the yield gap was greater in drier years as compared to wetter years. The standard deviation of grain yields was 2 to 3 times greater with the reduced capacity systems as compared to the higher capacity.

Cropping Systems

Alternatives to stretching water include cropping systems and including crops that have lower water requirements. Also, with low capacity systems, utilizing crops that have different critical growth stages is important. Incorporating crops that have different water timing allows for fewer acres to be irrigated at any one point in time so that crop water needs can be met. It is important that major water use time periods do not overlap which will decrease the amount of water that can be applied during those critical periods. Few long term studies have been done looking at cropping systems with both capacity and quantity implications. The number of potential combinations that could be utilized is infinite while space, time and money for these type of studies is limited.

Two major studies looked at cropping systems in conjunction with water allocations. Capacity for both studies was not incorporated into the studies. One study was conducted at North Platte, NE in the late 1980's-1990's and another was conducted at Tribune, KS in the 2000's.

At North Platte, NE (Schneekloth et al, 1991), the study looked at corn, soybeans and winter wheat in rotations of Corn-Soybean-Winter Wheat and continuous Corn with full irrigation, a water allocation of 6 inches for each crop and dryland. When water was limited to 6 inches, corn following wheat yielded 12 bu acre^{-1} (9%) greater than continuous corn. As irrigation levels were increased to full irrigation, this difference was decreased to where corn yields were nearly equal. However, grain yields for soybeans and winter wheat were nearly maximized at 6 inches and additional water did not significantly increase yields. Economics of a 6 inch allocation favored the rotation over continuous corn (Schneekloth et al., 1995). Utilizing wheat's lack of response to water and allocating a portion of that water to corn increased net returns so applying water equally to each crop was not the optimum management practice.

At Tribune, KS (Schlegel et al., 2014) utilized 4 crops in 4 rotations which included corn, soybeans, grain sorghum and winter wheat with equal acreages of each crop grown. A water allocation of 10 inches was utilized for this study. However, when corn was grown in a rotation with winter wheat, irrigation water was reallocated from winter wheat to corn because of the greater productivity of corn. In this study, continuous corn with an allocation of 10 inches was economically optimum as compared to rotations. Even when more water was allocated to corn in rotation, the economic gain of nearly $100 acre^{-1} from that yield increase was not enough to offset the lower economics of the remaining 3 crops with the primary limiting factor being the return by winter wheat. In this study, winter wheat was basically a break even return.

The studies at North Platte and Tribune both utilized adequate irrigation capacities that would allow for full irrigation of crops at any one point in time, even when those irrigation requirements overlapped one another. If capacities were limited, this would not be available to producers. Unfortunately, neither study incorporated capacity considerations in their studies. In both studies, system capacities were able to supply 1.5 to 2 inches week^{-1} (Tribune and North Platte). If system capacities were 50% of those stated, the ability to apply water at the time needed is nearly impossible without help from precipitation which is generally the lowest during the time of year when the reproductive stages of summer crops occurs.

Crop Choices

Crop choices can include any crop that has a marketing potential within a region. These options can vary from location to location depending upon markets within a reasonable distance of hauling as well as equipment that producers have. Crop choices can include: corn, winter wheat, soybeans, grain sorghum and sunflowers. Newer options that are currently being looked at include oil seeds such as canola which is a new early season option but has not been widely grown in the High Plains region.

When capacity is limited, crops that have different critical times for water needs is important or that can utilize limited amounts of water applied at key time periods is important in irrigation management as corn is typically the most important and critical crop for economics.

Sunflowers is one option that can utilize limited amounts of irrigation effectively because of its extensive rooting ability. Lamm et al. (2013) found that an irrigation capacity of 1 inch every 12 days was adequate in 2 out of 3 years with oilseed sunflowers. The grain yield in the one year was still within 5% of the maximum grain yield with adequate capacity. Average amount of irrigation water applied was 11.0 in $acre^{-1}$ for full irrigation compared to 5.2 in $acre^{-1}$ for the 1 inch every 12 days.

Schneekloth (2005) found that similar results with oilseed sunflowers that less water is needed than that applied for full irrigation for near maximum yields. Timing of irrigation to the R4-R5 growth stages in 2 out of 3 years had equal yields as compared to full irrigation. Irrigation requirements for full irrigation averaged 10.3 inches as compared to 4.0 when irrigation was timed to R4-R5 growth stages. The year where grain yields were less than full irrigation was a year where winter precipitation was approximately 50% of average and beginning soil moisture was limited.

Winter wheat has been grown under irrigation within this region. Yields can vary widely from North to South on the High Plains with yields generally greater as you go north. Irrigated yields in several publications in Texas have fully irrigated yields approaching 70 bu $acre^{-1}$. Irrigated winter wheat yields in western Nebraska can approach 100 bu $acre^{-1}$ (Hergert, 2010). The differences in yields and the differences when water is limited are significant in the use of winter wheat in southern locations.

Grain sorghum is a potential crop for the southern region. Uses of grain sorghum is limited as the crop is grown further north due to limited growing conditions such as cooler days and nights. However, grain sorghum is a drought tolerant crop that can be utilized with limited amounts of irrigation.

Water Management

Grain yield increases as crop water use increases for all crops. However, typically managing water to the critical time periods of crops also coincides with higher crop water use as well as the lower precipitation time period in the high plains. Irrigation management by the literature also varies by north to south because of higher potential crop water use with generally similar precipitation amounts for the year. Irrigation management also varies east to west in the region with lower crop water use in the west as well as lower precipitation during the year. Several crops were discussed on water management such as timing and quantity and the impact on grain yield.

CONCLUSIONS

Universal cropping and water management decisions for the High Plains are difficult to impossible because of dramatic differences in climatic conditions in precipitation and potential evaporative demand. Utilizing local research information on dryland cropping systems as well as irrigation responses of crops to limited irrigation (capacity or quantity) can help producers make better decisions. Soil types will also have a major influence on management decisions. Lower water holding capacity soils generally are not as responsive to limited amounts of water as compared to higher water holding capacity soils.

Management decisions will be different within a location and dependent upon capacity limitations as well as allocations. Higher capacities typically will produce significantly greater yields because of the irrigation system's ability to more closely meet crop water demands during the peak water use time periods. Reducing irrigated acres of a specific crop generally has the potential to create slightly lower returns as compared to spreading the water over all acres for the same crop. However, the unirrigated acres have a return potential return from either dryland management or limited irrigation of a crop that does not have the same water timing needs.

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