IRRIGATION CAPACITY AND PLANT POPULATION EFFECTS ON CORN PRODUCTION USING SDI

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ABSTRACT

Corn was grown with subsurface drip irrigation (SDI) under 6 different irrigation capacities (0, 0.10, 0.13, 0.17, 0.20 and 0.25 inches/day) and 4 different plant populations (33100, 29900, 26800, and 23700 plants/acre). Daily SDI application of even small amounts of water (0.10 inches) doubled corn grain yields in 2000. Results suggest an irrigation capacity of 0.17 inches/day might be adequate SDI capacity when planning new systems in this region. Increasing plant population generally increased corn grain yield.

INTRODUCTION

As the Ogallala (High Plains) aquifer is being depleted in some areas of the U.S. Great Plains, well capacities have decreased. Irrigated corn producers in these areas of decreasing flow rates face difficult cropping decisions. Two important options are to decrease their irrigated area, and/or adopt cropping practices more similar to dryland production (such as planting at reduced populations) and use the available irrigation water for supplemental irrigation. Some producers are also upgrading their irrigation systems to SDI and need information about optimizing irrigation system capacity in relation to irrigated area.

In the western one-third of Kansas, 2.25 million acres were irrigated with groundwater in 1996. Of that area, 1.15 million acres (51%) were irrigated corn. Irrigation surveys indicate there are approximately 133,500 acres of microirrigation in the southern and central Great Plains. The SDI acres will continue to grow as aging alternative systems are replaced and because it is a very efficient water application technology.

The ultimate objective of this research is to define the optimal planting (acreage and population) strategy for irrigated corn production under conditions of limited (but highly efficient) SDI imposed by limited well capacity. However, this paper will focus on the direct effects of SDI capacity and corn plant population on corn yield components and water use data.

PROCEDURES

This experiment was conducted at the Kansas State University Northwest Research-Extension Center at Colby, Kansas, USA during the period 1997-2000. The deep silt loam soil can supply about 17.5 inches of available soil water for a 8 foot soil profile. The treatments were six irrigation capacities and four plant populations. The six irrigation capacities were limits of 0.25, 0.20, 0.17, 0.13, 0.10, or 0 inch/day (4.7, 3.8, 3.2, 2.5, 1.9, or 0 gal/min-acre). The 0.25 inch/day irrigation capacity will match full irrigation needs for corn for center pivot sprinkler irrigation in most years. Irrigation was scheduled using a climatic water budget, but was limited to the specific irrigation capacity treatment. Daily irrigations were scheduled when the calculated soil water depletion exceeded 1 inch for a given treatment. In many cases, especially for the very low capacities, this meant daily irrigation from early June through early September. The four target plant populations were approximately 33100, 29900, 26800, and 23700 plants/acre (100%, 90%, 80%, and 70% of the maximum population). The experiment was conducted in a randomized complete block, split-plot design with four replications. Plant population was the split plot variable and irrigation level was the whole plot variable.

The driplines with a 12-inch emitter spacing were spaced 60 inches apart with an installation depth of 17 inches. Each dripline was centered between two corn rows spaced 30 inches apart on the 60 inch crop bed. The flow rate was 0.25 gal/min for each 100 ft of dripline.

Pioneer hybrid 3162 was used in 1997-1998 and Pioneer 31A12 was used in 1999 -2000. Both hybrids are full season hybrids for the region with an approximately 118 day comparative relative maturity requirement. Pest (weeds and insects) control was accomplished with standard practices for the region. Nitrogen fertilizer was applied through the SDI system in 5 increments for a total of 220 lbs N/acre each season. A starter fertilizer application at planting banded an additional 30 lbs N/acre and 45 lbs P_20_5/acre. The nonirrigated treatment received its total of 220 lbs of nitrogen in a single SDI event of 0.1 inches of water about mid-June each year. These fertilizer rates can be described as non-limiting for high corn yields.

Data collected during the growing season included irrigation and precipitation amounts, weather data, yield components (yield, harvest plant population, ears/plant, kernels/ear, mass/100 kernels), and periodic soil water content with a neutron attenuation moisture meter. Weather data were collected with an automated weather station approximately 0.25 mile from the research site. Values calculated after final data collection included seasonal water use and water use efficiency.

RESULTS AND DISCUSSION

Weather conditions

Weather conditions varied appreciably across the 4 cropping seasons. The calculated cumulative crop evapotranspiration (modified Penman equation) was approximately normal (22.0-22.5 inches) for the first 3 years, but was a record high 27.3 inches in 2000. Precipitation during the growing season was near normal in 1997 and 1998 at approximately 12-12.5 inches. However, rainfall was more evenly distributed in 1998. Only about 25% of the seasonal rainfall occurred during the first half of the 1997 growing season. The crop year 1999 was considerably wetter than normal with nearly 17 inches of rainfall which was relatively well distributed across the summer. Precipitation in 2000 was about 50% of normal with 6.21 inches during the season and with about 40% occurring during the first half of the season. Coupling the low precipitation with the record evapotranspiration in 2000, resulted in much greater irrigation needs.

Yields and yield components

Maximum corn yields in the study years 1997, 1998, 1999, and 2000 were very high at 270.6, 304.1, 253.2, and 257.5 bu/acre, respectively. The extremely high yield in 1998 reflected nearly perfect growing conditions characterized by clear days, mild temperatures during critical periods, and evenly distributed rainfall. Corn pollenation in 1998 was nearly perfect for the adequately irrigated treatments and the grain filling stage was very long with mild temperatures.

Relative corn yields were generally increased by irrigation capacity with the exception of the wetter crop year 1999 in which case all yields were very high (Figure 1). The greatest relative increase occurred between the nonirrigated control and the 0.10 inch/day irrigation treatment. Although, the 0.10 inch/day irrigation treatment provides much less than the peak water use of corn (0.3-0.4 inches/day in the region), the daily provision of this amount apparently attenuated an appreciable amount of water stress, allowing the corn to scavenge through the deep silt loam profile for the remaining water needs. Even in the extremely dry crop year 2000, the 0.10 inch/day treatment resulted in approximately 80% of maximum yield (Figure 1). Irrigation capacities greater than 0.17 inches/day gave somewhat similar corn grain yields in most years with the exception of 1998, where the higher irrigation capacity (0.25 inch/day) gave a higher yield.

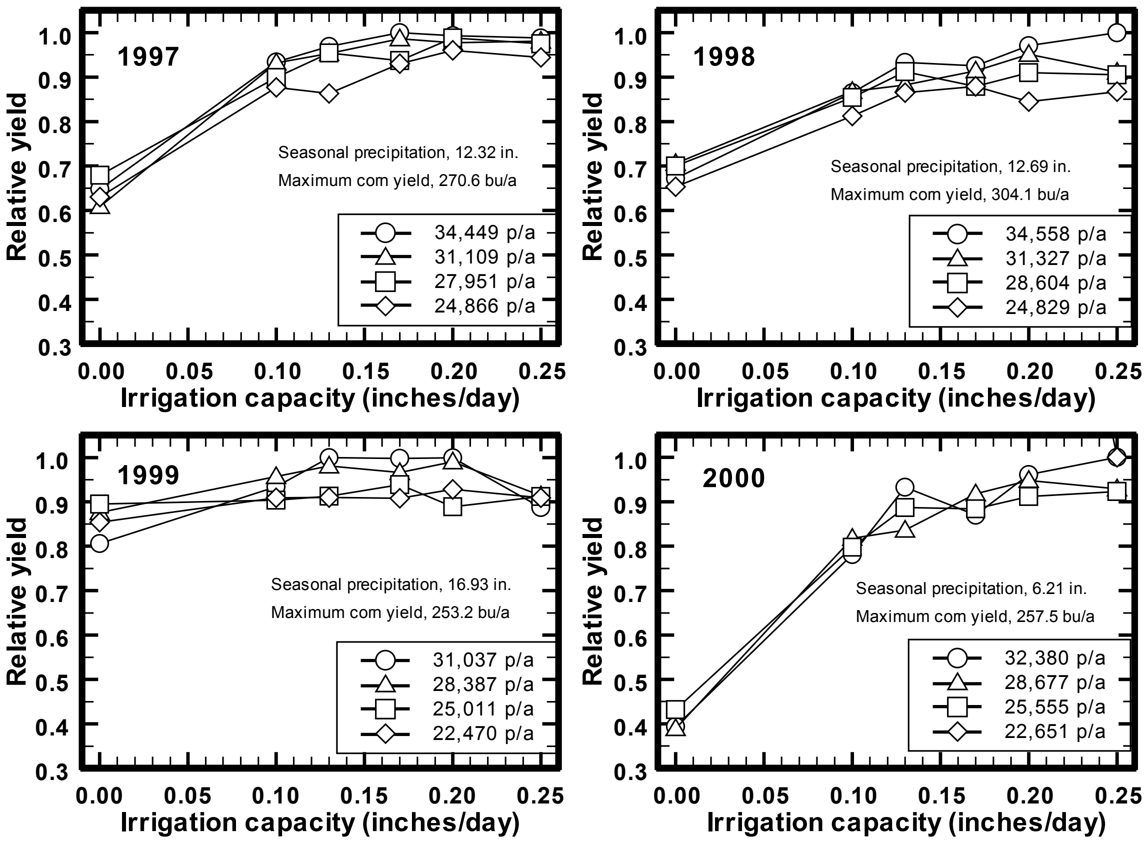

Figure 1. Relative corn grain yield as affected by daily SDI capacity and plant population. Note: Seasonal precipitation and maximum corn grain yield for the given year is shown in each panel.

Increasing corn plant population over the range of 22500 to 34500 plants/acre generally increased relative corn grain yield when the corn was irrigated (Figure 1). Even when the crop was nonirrigated, there was little additional yield penalty for the higher plant population. The higher plant populations resulted in sizable yield increases in 1998, the nearly perfect season.

Examination of the yield components explains the yield effects to a greater degree. The relative number of kernels/acre (plants/acre x ears/plant x kernels/ear) was relatively stable as affected by irrigation capacity as long as the corn did receive irrigation (Figure 2). This emphasizes that in most years on these deep loam soils that the number of kernels/acre is "fixed" before sufficient crop water stress occurs to reduce it. The exception was 2000 where both evapotranspiration was extremely high and rainfall was extremely low. In this year, higher irrigation capacity tended to increase the relative kernels/acre. The potential number of kernels/acre is set before the reproductive period that occurs 60-70 days after emergence. The actual number of kernels/acre can be reduced by water stress during the reproductive period. Higher plant populations increased the relative number of kernels/acres as long as irrigation was received (Figure 2). This emphasizes that it is a good strategy to increase plant population to increase the total number of sinks for yield accumulation. The number of kernels/ear decreased with higher plant population (data not shown) but was more than compensated for by the increased number of ears/acre. There was very little difference across this plant population range in the number of ears/plant (essentially 1.00) as affected by irrigation capacity (data not shown).

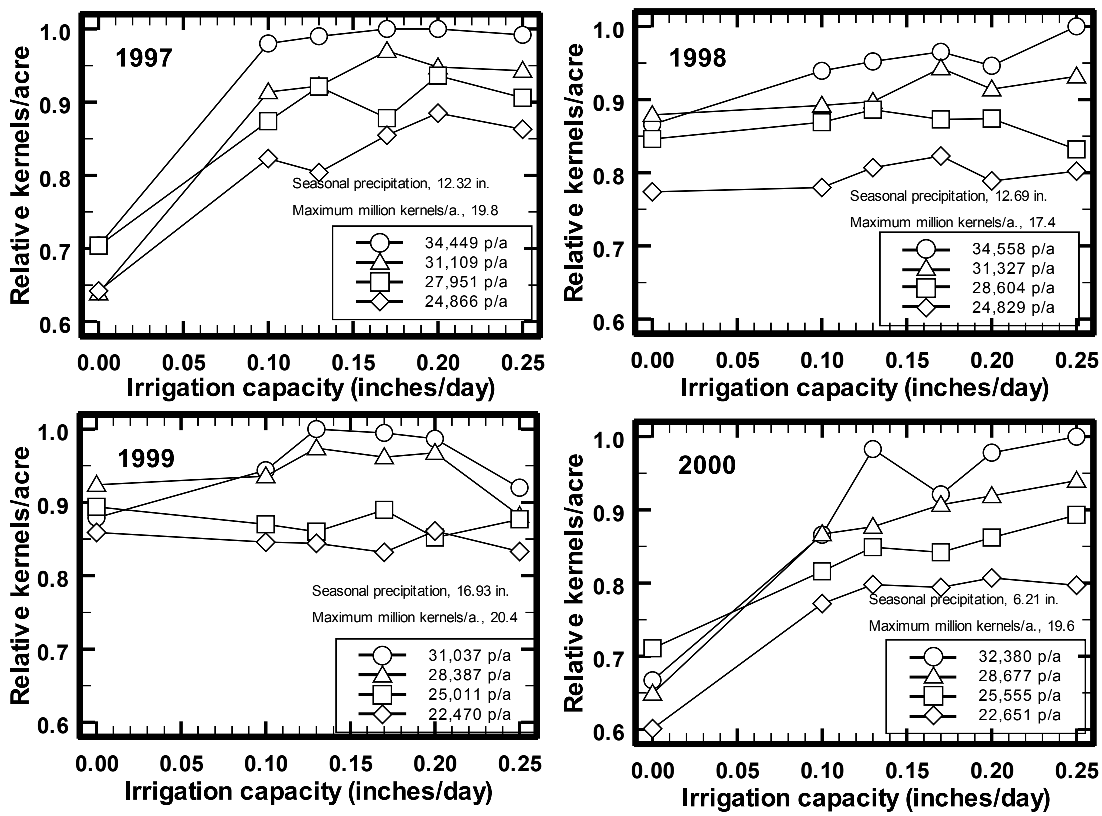

Figure 2. Relative number of corn kernels/acre as affected by daily SDI capacity and plant population. Note: Seasonal precipitation and maximum number of corn kernels/acre for the given year is shown in each panel.

The cumulative effects of decreased irrigation capacity would tend to have greater effects on plant processes during the later portions of the crop season. This is particularly true for this deep silt loam soil which allows deep corn plant rooting and high utilization of the stored water reserves. The grain filling stage occurs during the last 50-60 days of the growing season. The mass or weight of 100 kernels at harvest is a good indicator of the amount of cumulative water stress that may have occurred during the latter part of the season. Kernel mass when multiplied by the number of kernels/acre results in the corn grain yield. The relative kernel weight was strongly affected by whether the corn was irrigated or not (Figure 3). Above the 0.10 inches/day irrigation capacity, the relative kernel weight was less affected but tended to increase with higher irrigation capacity with the exception of 1999, the wet crop season. Increasing plant population decreased the relative kernel weight as would be expected (Figure 3). However, the decrease in kernel weight was generally compensated for by higher numbers of kernels/acre (Figure 2).

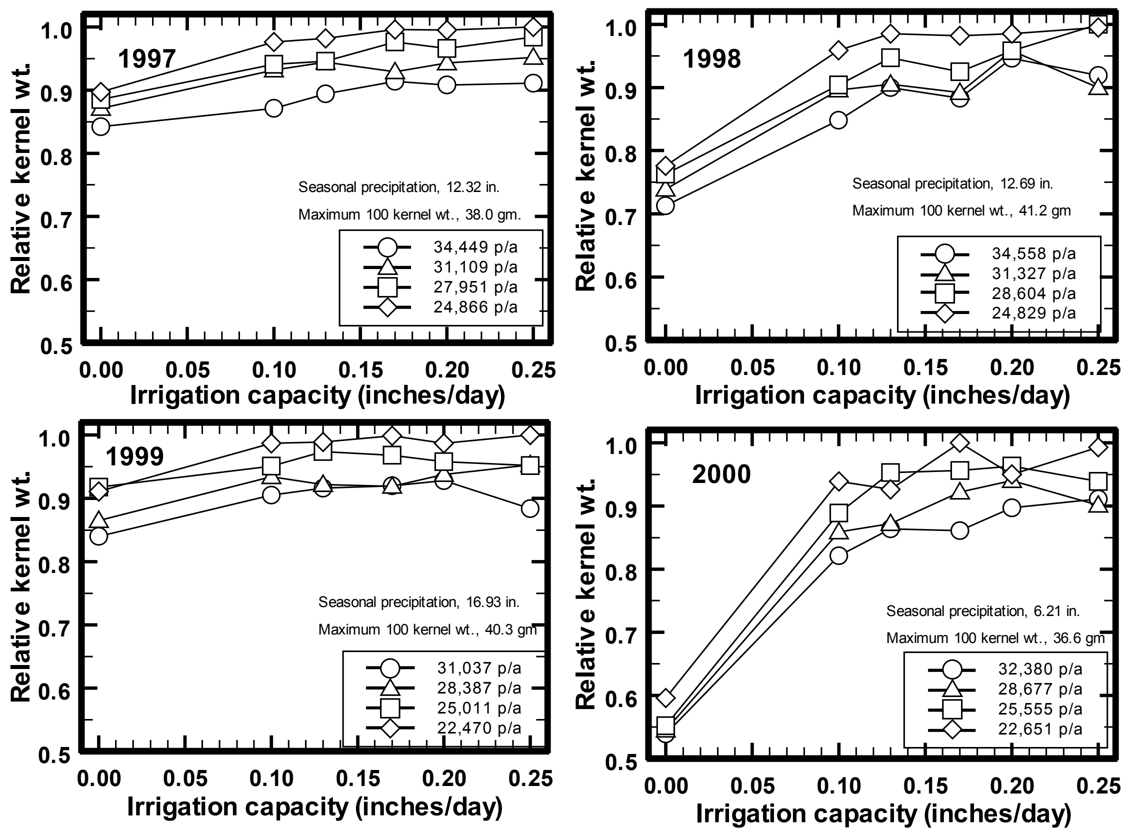

Figure 3. Relative kernel mass as affected by daily SDI capacity and plant population. Note: Seasonal precipitation and maximum 100 kernel weight for the given year is shown in each panel.

Water use efficiency (WUE)

Water use efficiency is defined as the corn grain yield divided by the total water use (irrigation, precipitation and change in seasonal soil water storage). The nonirrigated control had lower relative WUE in 1997 and 2000 than the irrigated treatments (Figure 4). This reflects the dry early portion of the 1997 season and the overall dry 2000 season. Yields were lowered to a larger degree than water use. This emphasizes that proper irrigation management often increases the productive use of stored soil water and precipitation. In 1999, the wet season, WUE was decreased by increasing irrigation capacity which is often the case when timing of rainfall and irrigation events interfere with the productive use of the water. In 1997, 1998, and 1999 WUE was relatively stable across a wide range of irrigation capacities as long as irrigation was practiced. This suggests that there was very little overirrigation for the higher capacities when irrigation was scheduled according to the water budget. Increasing plant population generally increased WUE as long as irrigation was practiced (Figure 4). The one exception was 1999, the wet season, where mixed results occurred. Lower plant population was sometimes better when the corn was nonirrigated, but this effect was not consistent.

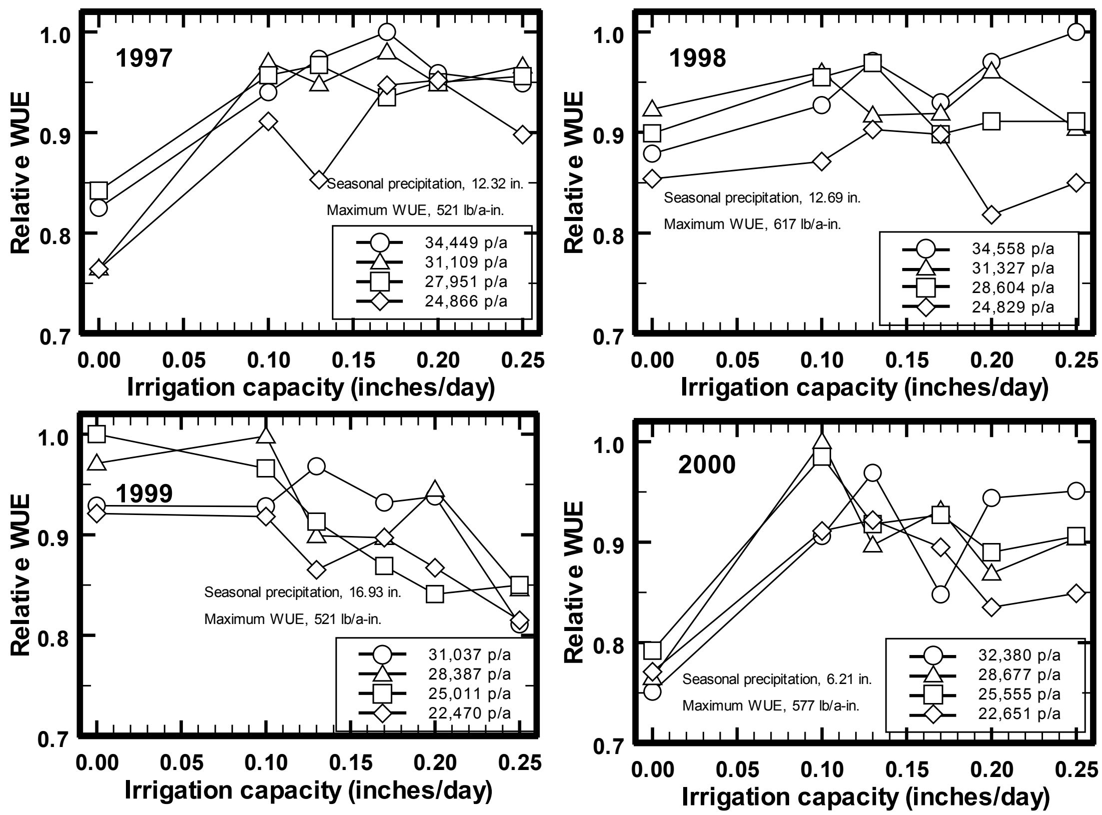

Figure 4. Relative water use efficiency (WUE) as affected by daily SDI capacity and plant population. Note: Seasonal precipitation and maximum WUE for the given year is shown in each panel.

Soil Water Reserves

Examination of the seasonal progression of available soil water for the different treatments shows some interesting patterns (Figure 5). Across all four years there tends to be a distinct grouping near the end of the season (DOY 230-270) of the upper three irrigation capacities and another grouping for the nonirrigated treatment and the lower two irrigation capacities. There is some possible rationale to explain the grouping. The upper three treatments may group together because the range of 0.17 to 0.25 inches/day is sufficient to provide a large enough portion of the daily soil water needs. Even in the drier years, there are a few opportunities to shut off irrigation for the 0.20 - 0.25 inches/day treatments, because the irrigation deficit is below 1 inch. This would allow these treatments to be closer to the effective value of 0.17 inches/day. The 0.25 inches/day irrigation capacity is approximately the long term full irrigation requirement for northwest Kansas for corn using other irrigation methods. The higher efficiency, daily irrigation may allow the SDI to be more effective than other irrigation methods.

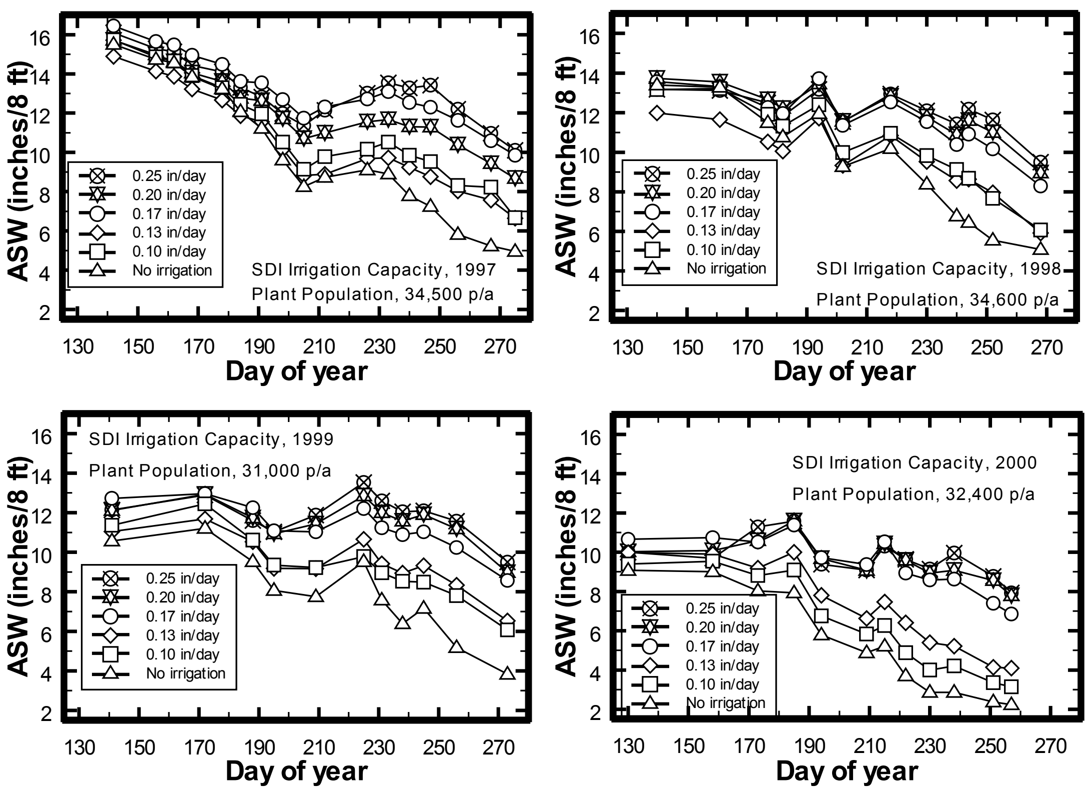

Figure 5. Progression of the available soil water in a 8 ft profile as affected by daily SDI capacity for the highest plant population treatment.

The lower three treatment may group together for almost the opposite reason. Available soil water reserves become depleted to a large extent and the corn crop begins to shut down plant processes that use water. This shutting down tends to reduce grain yields depending on the severity and length of the water stress period. The fact that the 0.10 and 0.13 inches/day treatments obtain respectable corn yield increases over the nonirrigated control may be a good indication of how well this balancing of water use/water conservation is being handled by the daily infusion of at least some irrigation water.

The grouping of the upper three treatments suggests that an irrigation capacity of 0.17 inches/day might be an adequate irrigation capacity if the producer has the desire to allocate water to an optimum number of acres. More economic analysis is planned to examine the previous statement.

SUMMARY AND CONCLUSIONS

Daily irrigations with SDI of amounts as low as 0.10 inch greatly increased corn yields in an extremely dry year. Analysis of the yield component data indicated that the number of kernels/acre is largely determined by providing just a small amount of SDI capacity over the nonirrigated control. It is concluded that small daily amounts of water can be beneficial on these deep silt loam soils in establishing the number of sinks (kernels) for the accumulation of grain. The final kernel weight is established by grain filling conditions between the reproductive period and physiological maturity (last 50-60 days of crop season). Thus the extent of mining of the soil water reserves during this period will have a large effect on final kernel weight and ultimately corn grain yield. An irrigation capacity of 0.17 inches/day appears to be sufficient SDI capacity for corn on the deep silt loam soils of this region.

Increasing plant population from approximately 22500 to 34500 generally increases corn grain yields for SDI in this region, particularly in good corn production years. There was very little yield penalty for increased plant population even when irrigation was severely limited or eliminated.

Economic analysis of the results of this study is warranted to determine the optimum allocation of water and land area for corn using SDI.

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It is also available at http://www.oznet.ksu.edu/sdi/Reports/2001/icppdoc.pdf

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