CENTER PIVOT SPRINKLER IRRIGATION REQUIREMENTS FOR CORN IN NORTHWEST KANSAS

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ABSTRACT

Corn irrigation schedules were simulated for 22 years (1972-93) at Colby, Kansas. The net irrigation requirement for fully irrigated corn ranged from a high of 20 inches in 1976 and 1984 to a low of 7 inches in 1992 with a mean value of 15 inches. The average date for the first sprinkler irrigation event (1 inch) was June 17 but occurred as early as June 5 and as late as July 5. Total irrigation during July and August averaged 82% of the total seasonal needs.

An irrigation capacity of 1 inch/4 days can supply the full irrigation needs of corn in approximately 88% and 98% of the years at application efficiencies of 85% and 100%, respectively. A capacity of 1 inch/6 days can only supply the full irrigation needs of corn in approximately 30% and 50% of the years at application efficiencies of 85% and 100%, respectively. The lower capacities (1 inch/8 days and 1 inch/10 days) can supply the full irrigation needs of corn in less than 20% of the years regardless of application efficiency. The severity of the irrigation deficits between full irrigation and the lowest irrigation capacities (1 inch/8 days and 1 inch/10 days) would probably indicate economically unacceptable corn yield reductions for the lowest irrigation capacities.

PROCEDURES

Irrigation schedules for corn were constructed for 22 different years (1972-1993) using weather data from the KSU Northwest Research-Extension Center at Colby, Kansas. The continental climate can be described as semi-arid with an average annual precipitation of 18.7 inches and approximate annual lake evaporation of 55inches. Simulations were conducted for gross irrigation capacities of 1 inch for 4, 6, 8 or 10 days. Three application efficiencies of 85% (typical sprinkler), 95% (LEPA sprinkler) and 100% were used in the simulations.

Irrigation was scheduled using a water budget to calculate the root zone depletion with precipitation and irrigation water amounts as deposits and the calculated daily corn water use as a withdrawal. If the root zone depletion became negative, it was reset to zero. All calculations of the root zone depletion were based on fully irrigated conditions. A 1-inch irrigation was applied at the indicated treatment interval unless the calculated water deficit was less than 1 inch in which case the irrigation was delayed until the 1-inch critical level was reached. Irrigation was to be limited to the 90-day period between June 5 and September 2. Therefore, irrigation amounts could not exceed 23, 15, 12, or 9 inches for the 4, 6, 8, and 10-day irrigation intervals respectively. The corn was assumed to emerge on May 15 and the water budgets were ended after 120 days on September 11. The depletion of the root zone soil water profile was assumed to be zero at crop emergence.

The reference evapotranspiration was calculated using a modified Penman combination equation. The basal-crop coefficients were calculated for the region by assuming 70 days from emergence to full canopy for corn with physiological maturity at 130 days. The crop coefficients were based solely on emergence date and long term average growth rates for fully-irrigated corn. No attempt was made to modify the actual crop water use with respect to soil-evaporation losses or soil-water availability.

The simulations were used to determine the number of irrigation events, total irrigation water application, the average date of the first irrigation and the fraction of the total seasonal irrigation required each month. The maximum calculated soil water depletion occurring during the simulation was also recorded. This value sometimes exceeded the available water holding capacity of the soil for the extremely deficit-irrigated treatments. Since, this is not possible, this value was redefined as the maximum irrigation deficit to represent the amount of irrigation water the plant needed. A small deficit will occur even for the full irrigation treatment during the period between September 2 and 11 after the irrigation season ends.

RESULTS AND DISCUSSIONS

Irrigation Requirements and Effect of Capacity

Irrigation schedules for irrigated corn were constructed for 22 different years using weather data from the KSU Northwest Research-Extension Center at Colby. The net irrigation requirement for fully irrigated corn ranged from a high of 20 inches in 1976 and 1984 to a low of 7 inches mm in 1992 with a mean value of 15 inches (Figure 1).

A capacity of 1 inch/4 days was very similar to full irrigation in most years if the application efficiency is 100% (Figure 1). In most years there was insufficient capacity to fully irrigate corn at irrigation capacities of 1 inch every 6, 8, or 10 days even at 100% application efficiency. Lower application efficiencies further decrease the ability of the lower capacity systems to match the needs of fully irrigated corn (Figure 2). In 1983, even the 1 inch/4 days irrigation capacity fell behind the fully irrigated treatment by 5 inches at an 85% application efficiency. The lower capacity systems would have been able to nearly supply the full irrigation needs of the crop in only 5 of the 22 years, 1972, 1977, 1979, 1992, and 1993.

In the strictest sense, there is no minimum irrigation capacity for corn. It depends on the yield goal. However in a practical sense, the question can be answered by establishing a yield goal and estimating the contributions from the various sources of water-- soil water, precipitation and irrigation. High corn yield goals require water to be non-limiting. The 1 inch/4 days irrigation capacity will meet the full irrigation needs of corn in approximately 88% of the years even at an application efficiency of 85% (Figure 3). However, even at a 100% application efficiency, the 1 inch/6 days irrigation capacity can only supply full irrigation needs in about 50% of the years. For irrigators experiencing declining well yields, a low capacity system may be a better option than reverting the area back to a dryland operation, but the best option may be to reduce the irrigated area. The absolute advantage of increasing the application efficiency greatly decreases at the very low irrigation capacity of 1 inch/10 days. The increased efficiency from 85 to 100% only results in 1.30 inches additional irrigation water available to the crop. This could still mean over 8-12 bu/acre in increased yield, which might make the efficiency improvement economical.

Determination of the First Irrigation Date

The first irrigation varied from June 5 to July 5, with most years having the first 1 inch irrigation event between June 10 and June 15. Some irrigators attempt to cope with low capacity wells by starting irrigation sooner than normal. These results indicate there usually is not any need to start before June 10 unless the soil profile is extremely dry from the previous crop or from a dry overwinter period. The results also point out that the problems of decreased irrigation capacity in July and August can not be alleviated much by the excess capacity in June, because the soil profile is relatively full of water.

Monthly Distribution of Irrigation Needs

Some irrigators are utilizing limited-capacity systems that do not meet the peak irrigation needs. Instead, these systems seek to meet the needs over a wider timeframe, such as a month, and utilize soil water reserves to buffer out water stress. The simulation revealed highest corn irrigation needs were in July and August with average needs of 39.2 and 43% of the total seasonal irrigation, respectively (Figure 4).

Maximum Irrigation Deficits as affected by Irrigation System

The ability of the irrigation systems to meet full irrigation needs does not really address the severity of the crop water stress imposed by the lower capacity systems. It would be useful to determine estimates of the severity of the irrigation deficits. The irrigation schedules calculate a soil water depletion based on the fully irrigated condition for each day of the irrigation season. The actual depletion level in the soil profile will vary from this level depending on the amount of crop water stress imposed on the crop. However, this value can be thought of as an maximum irrigation deficit. The maximum irrigation deficits for the various irrigation system capacities and the 100% application efficiencies are shown in Figure 5. Yields would probably be reduced when the maximum irrigation deficit was more negative than -6 to -8 inches. The 6-ft soil profile will hold approximately 15 inches of plant available water at field capacity. An irrigation deficit of 7.5 inches would represent the 50% critical soil water value for yield reduction often expressed in the literature. Yield reductions are very probable in many years for the lower capacity systems. The 21-year mean seasonal maximum irrigation deficit was calculated for the various irrigation systems. The maximum irrigation deficit for the three lower capacity systems is generally about twice that of the full irrigation and 1 inch/4 days system capacities (Figure 6). Even under average conditions the lower capacity systems would be expected to have reduced yields.

CONCLUSIONS

The 22 years of simulations showed that a capacity of 1 inch/4 days will generally supply full irrigation needs. The lower irrigation capacities 1 inch for every 6, 8, or 10 days would fall behind in many years and would probably result in appreciable yield reductions.

Irrigators can typically plan for the first sprinkler irrigation event to occur between June 10 and 20.

Highest irrigation needs are in July and August with the two month average needs exceeding 82% of the total seasonal irrigation amount. The inability of the lower capacity systems to match irrigation needs will adversely affect the corn during these two critical months.

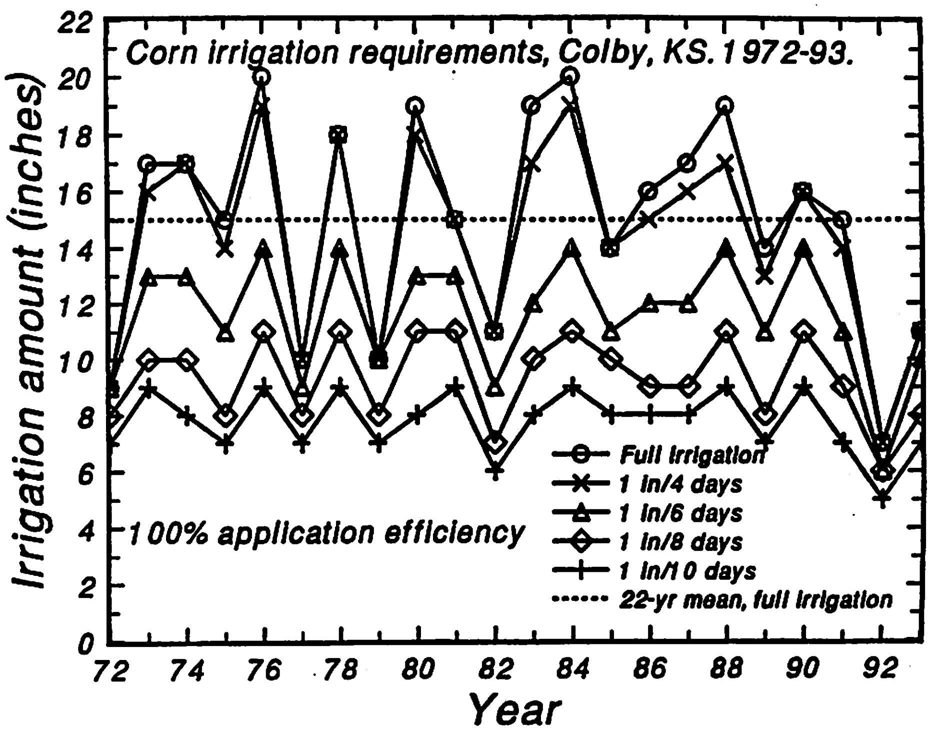

Figure 1. Net irrigation amounts for corn that could be applied at 100% application efficiency by various capacity irrigation systems during the years 1972 through 1993 at Colby, Kansas.

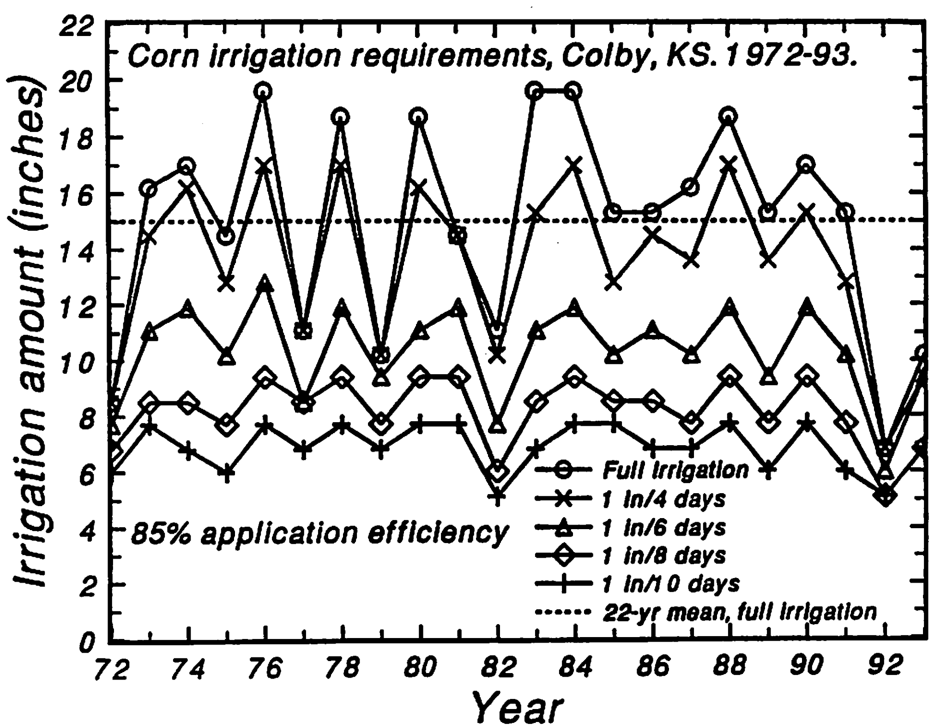

Figure 2. Net irrigation amounts for corn that could be applied at 85% application efficiency by various capacity irrigation systems during the years 1972 through 1993 at Colby, Kansas.

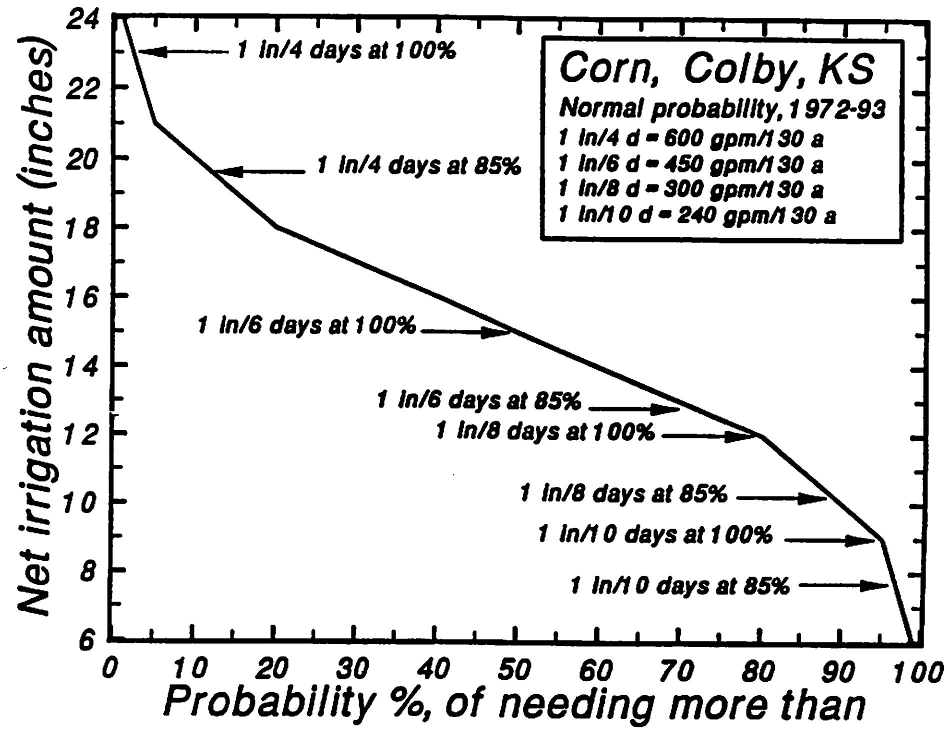

Figure 3. Probability of needing more than the indicated net irrigation amount for corn at Colby, Kansas for various capacity irrigation systems and application efficiencies based on climatic data from 1972 through 1993.

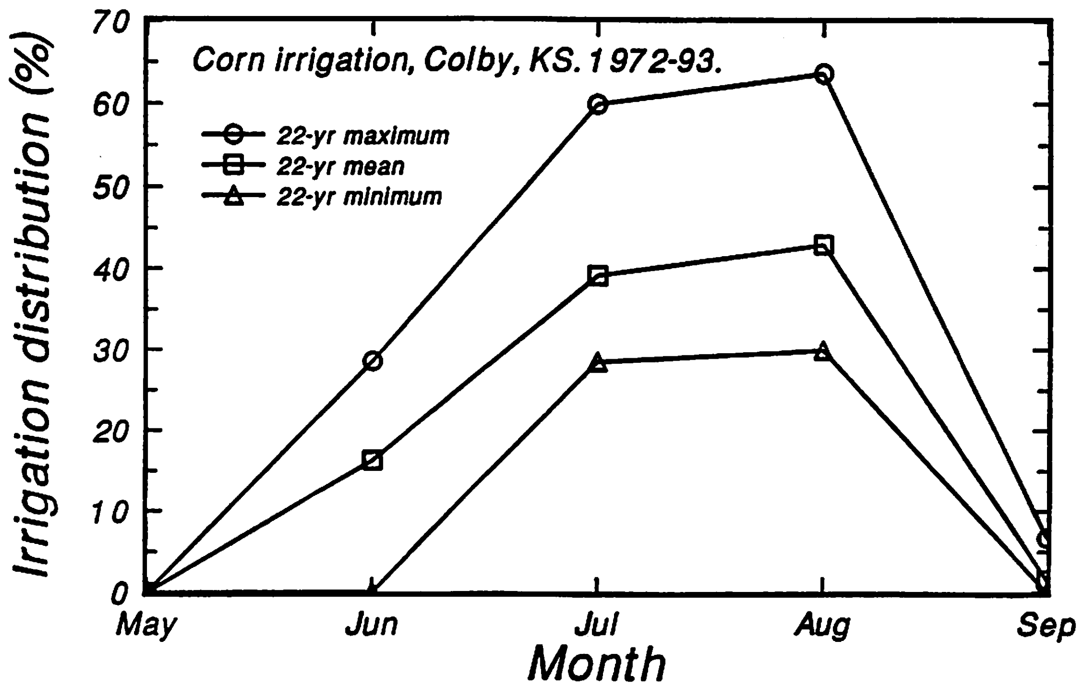

Figure 4. Monthly distribution of irrigation needs for corn at Colby, Kansas based on climatic data from 1972 through 1993.

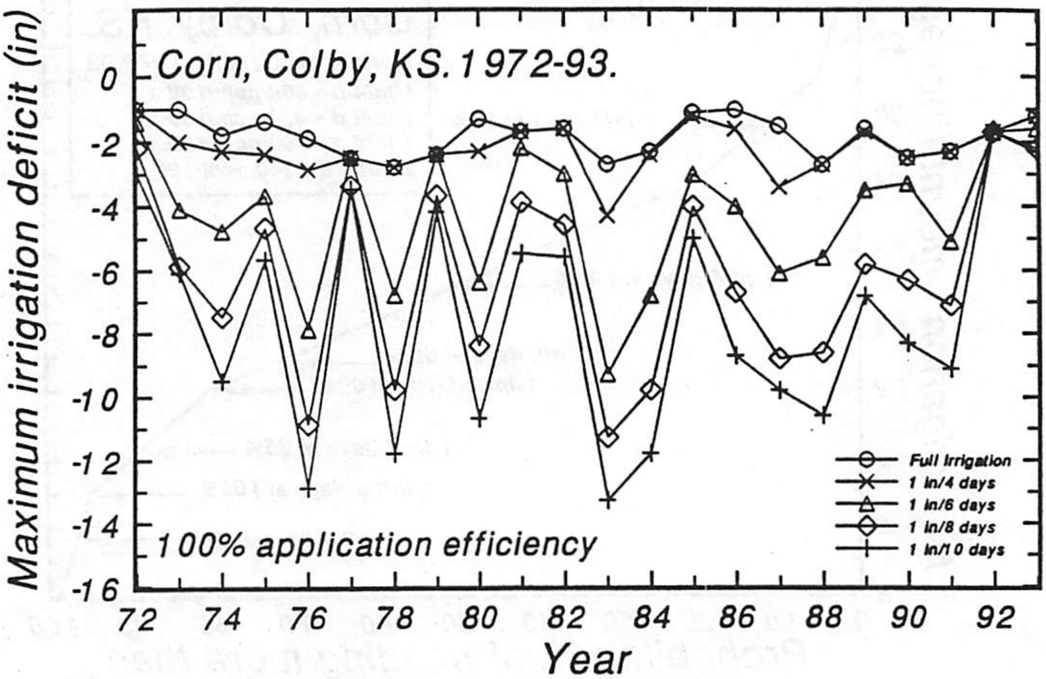

Figure 5. The maximum irrigation deficit that would occur during the season for corn at 100% application efficiency for various capacity irrigation systems during the years 1972 through 1993 at Colby, Kansas.

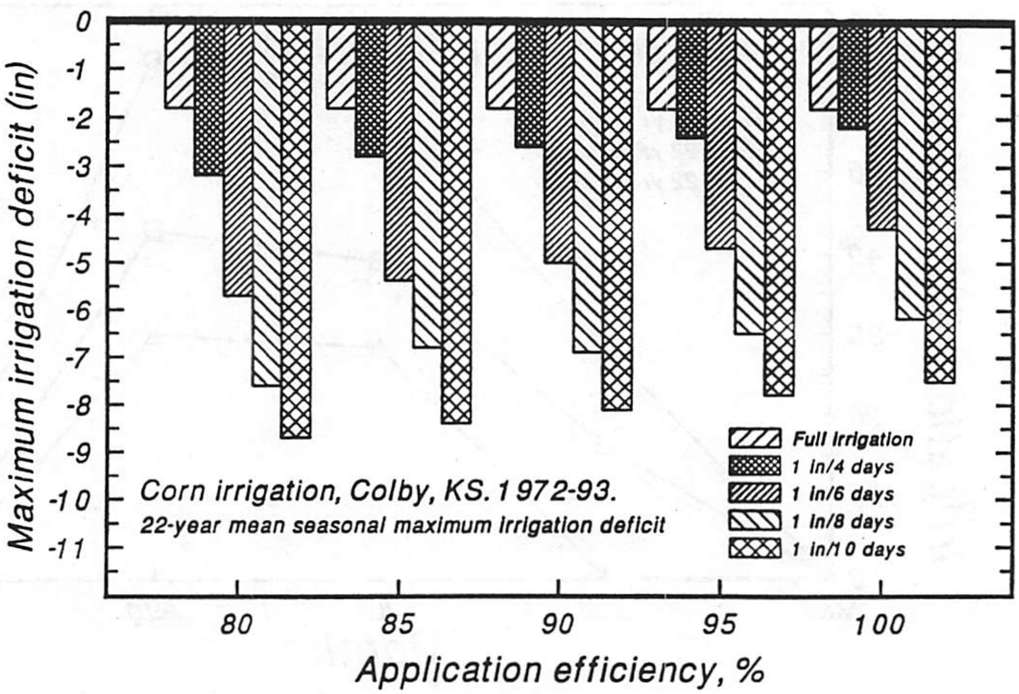

Figure 6. The 22-year mean (1972-1993) seasonal maximum irrigation deficit that would occur during the season for corn for various application efficiencies and various capacity irrigation systems at Colby, Kansas.