SPRINKLER IRRIGATION BASICS

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INTRODUCTION

Sprinkler irrigation systems provide a greater control than is possible with many irrigation systems. It also has the advantage of being automated more easily. Sprinkler systems spray the water through a device to the soil which can be mounted rigidly on a riser or on a machine. The machine can irrigate while stationary or moving. The center pivot is the most common type of moving sprinkler irrigation system used in the Great Plains.

The objective of an irrigation system is to efficiently and economically apply sufficient water for crop production. Efficiency is important to conserve water, energy and labor. Sprinkler irrigation systems should be designed to prevent runoff and apply water uniformly over the entire area. Minimization of evaporation is important in the design and management of an irrigation system. The selection and management of an irrigation system must consider many factors. These include the soil, crop, water source, topography and climatic conditions. This paper has the objective of examining basic factors that must be considered when selecting and managing your irrigation system.

SOIL CONSIDERATIONS

The soil is the media that we use for crop production. We store water and plant food in the soil profile for use by the plant through its' root system. An irrigation system can apply water and fertilizer to replenish this supply. Excess water that deep percolates through the soil can leach valuable nutrients and waste water. The intake rate of the soil is important and often controls the amount of water that we can apply with an irrigation. With surface irrigation, the intake rate controls the amount of water infiltrated as a function of the amount of time that water is maintained on the surface. However with a sprinkler system our objective is to apply the water at a rate that is less than the intake rate to achieve a uniform application of water and eliminate runoff.

Water Holding Capacity

The water holding capacity per unit depth of the soil determines the amount of water that can be stored in the root zone. Clay and silt soils will hold more water per unit depth of soil than sandy soils. The amount of water that can be held in the soil root zone for each plant (engine) is like a fuel tank on a tractor or other vehicle. The bigger the tank, the more hours or miles you can go without refilling. The plant (engine) requires the same amount independent of the water holding capacity (tank size). The amount of fuel that you can add when refilling is also a function of the tank size. You don't add 50 gallons of fuel if the tank only holds 25 gallons. The same holds for the depth of an irrigation. You should not apply more than can be held in the soil to prevent the excess from moving below the root zone and leaching fertilizer and wasting water. The size of your soil reservoir must be considered both in the design and operation of an irrigation system.

Intake Rates

Intake rates are highly variable under most field conditions. This variability changes the uniformity and depth of an irrigation most with surface systems. When sprinkler application rates exceed low intake rates, runoff may result. The factors affecting intake rate includes soil type, surface conditions, mulch, crop and soil water content. Tillage practices can be used to increase the intake rate. Compaction by wheel traffic can reduce the intake rate while chiseling and loosening of the soil can increase it.

The SCS classifies the intake rates of various soils into intake families. Sandy soils will typically have the highest intake rate and silty soils the lowest rate. Rain storms and high application rates from sprinkler systems can reduce the intake rates, particularly before the crop canopy develops to intercept the drops which can cause the sealing of the surface. Any tillage after the formation of crusts can significantly increase the intake rate.

Figure 1 illustrates the intake rate for several SCS intake rate families typical of many field conditions. The gradual decline of the intake rate versus time is a characteristic of the intake function. These curves are the limiting conditions and any water applied at a higher rate is potential runoff.

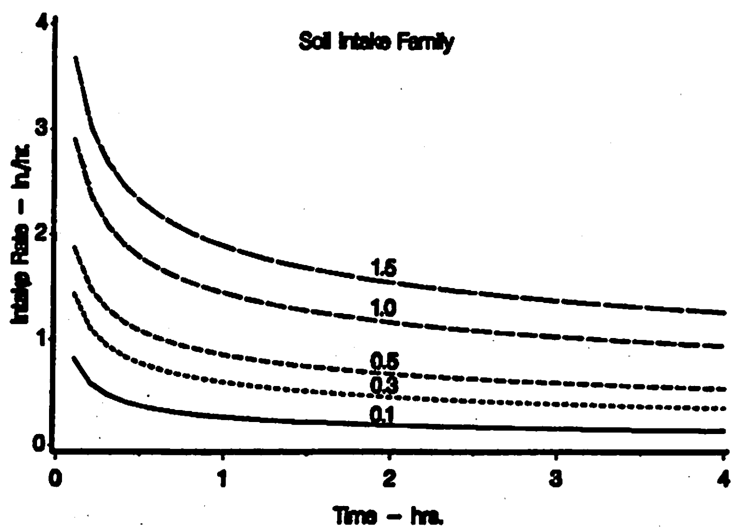

Figure 1 SCS intake rate curves for selected families.

Topography

The potential runoff is just a potential and actual runoff depends on the slope of the land. If the land is very level the water will not move any significant distance. With slopes greater than 5%, actual runoff may equal the potential runoff. Land forming may be needed to prevent runoff. This may be in the form of contour farming and terraces. Small pits may be formed in the soil to provide small depressions to temporarily hold the water and allow time for it to infiltrate. Without land forming, Dillon, Hiler, and Vittetoe (1972) suggested allowable surface storage values of 0.5, 0.3, and 0.1 inches for slopes of 0-1, 1-3 and 3-5%, respectively. These surface storage amounts are important when operating center pivot systems that often have application rates higher than intake rates.

CLIMATIC CONDITIONS

The precipitation and evapotranspiration (ET) demand are not constant but vary both by location and by year. The variation is generally much higher for seasonal precipitation than for seasonal ET. The expected rain and ET for your area is important when designing and operating your irrigation system.

Precipitation

Precipitation provides a significant amount of the water for crop production in the Great Plains. Irrigation is used to supplement the rainfall during periods when rain does not supply enough water. Not only the amount but the distribution is different from year to year. Some years we have more rainfall than is needed during short periods of the growing season. It is important to measure the rainfall on each field for the proper scheduling of an irrigation system to prevent over or under irrigation. The expected distribution for your area is important in selecting the capacity for the irrigation system. Rainfall is the most economical water that is available for crop production.

Evapotranspiration

The irrigation requirement for any irrigation system is dependent not only on rainfall but also the amount needed to satisfy ET for crop production. Each crop has a unique water requirement for a season with its' own distribution. The current meteorological conditions establish a potential ET that can be different for each year and crop depending on its' growth stage. The planting date can effect the crop development and the resulting seasonal distribution of ET. Different crops have more effect on the seasonal distribution of ET than a wide range of planting dates for a single crop. The total amount of water needed by a crop is also influenced by the wetness of the soil surface. Immediately following a rain or irrigation there is an increase in the ET due to the evaporation from the soil surface. Irrigating with as large a depth as possible without overirrigating or stressing the plant requires less total water.

The design of sprinkler irrigation systems must select the type of system, sprinkler heads, spacing and nozzle size and required pressures. Stationary systems are generally designed with sprinkler heads and spacing to have application rates less than the limiting intake rate of the soil. The spacing is a function of the amount of overlap to achieve the desired uniformity. The number of heads run simultaneously determines the discharge capacity of the system. The number of sets and time per set to apply the desired amount determines the maximum frequency of irrigations. Center pivot systems do not have a fixed application rate and the depth is determined by the configuration and capacity of the system.

Application Rate

The application rate under a center pivot sprinkler system varies continuously along the lateral. The application rate is highest at the outer end of the pivot where the maximum area per unit length irrigated. Figure 2 shows the typical application rate near the outer tower for an average system with 3 different types of sprinkler heads. The application rates are lower nearer the pivot since the discharge per unit length of the lateral is smaller in direct proportion to the smaller area being irrigated.

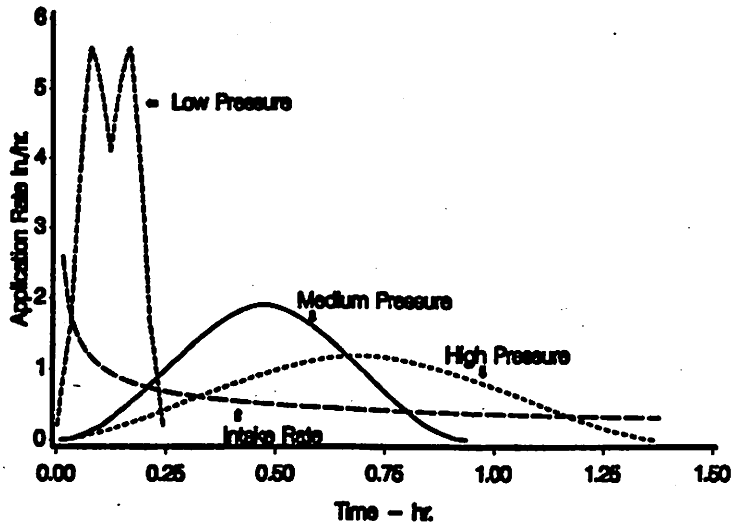

Figure 2 Application rates from a center pivot system with high, medium, and low pressure heads near the outer end of a 1/4 mile system and a typical intake rate curve.

The first center pivot systems were installed with high pressure (65-75 psi) impact sprinkler heads. The increase in energy costs resulted in the demand for lower pressured sprinklers. Many systems are now configured with medium pressure (40-50 psi) impact heads and low pressure (25-35 psi) impact and spray heads (Gilley, 1984). This change in sprinkler heads resulted with peak application rates going from 1 inch/hr for the high pressure impact heads to 6 inches/hour with

360 degree spray. These higher rates are like a heavy thundershower of approximately 1 inch in 15 minutes. Few soils have intake rates high enough for this type of rain storm and we have a real gully washer with lots of erosion and runoff. The area between th application rate and intake rate is the potential runoff.

The typical approach to limit the runoff is to speed up the pivot by increasing the percent timer and apply less water per irrigation. This does not decrease the application rate but does reduce the depth and therefore the potential runoff. Another option is to decrease the system length which also decreases the application rate. However, the longer the system the smaller the cost per acre since each additional foot of length irrigates a larger area than the previous foot.

Another option to reduce the application rate or thunderstorm effect is to decrease the discharge of each sprinkler head. A system discharge decrease by 1/2 decreases the application rate by 1/2. However, this will directly effect the amount of water that can be applied during the season and may result in less water applied for crop production than required even if operated continuously.

The recent change to Low Energy Precision Applicators (LEPA) has allowed the pivot systems to operate at even lower pressure to further reduce pumping costs. However, when the water is applied in a bubble the application rate is very high. This system can not be correctly classified as a sprinkler irrigation system. I would prefer to call it a "traveling gated pipe" system as it is a form of surface irrigation. The system if implemented as designed would use either pits or small dams to check the water and not allow any surface movement of the water. Only then can high efficiencies be obtained. When the heads are run in a so called "irrigation mode" the system is a low pressure spray system. The drop tubes often are extended below the top of the canopy and the uniformity can be quite different depending on row direction and the degree of canopy interference with the spray.

System Capacity

The net irrigation requirements for the crops to be irrigated will establish the lower limit for the system capacity. Consideration must also be given to the efficiency of the designed system. Allowance must also be given for the actual hours of operation and desired down time to provide for maintenance and expected failures. Heermann et. al. (1974) and von Bernuth et. al. (1984) reported irrigation system capacities required for eastern Colorado, southwest and south central Nebraska. They simulated a number of irrigation seasons to include the variability in precipitation and ET. Figure 3 shows the net irrigation system capacities to prevent depletion from exceeding 50 % of the available water in 9 out of 10 years for corn. The allowable depletion is less for sandy soils or shallow root zones and systems must have higher capacities.

The net system capacity for an eastern Colorado sandy soil that has 1 inch of allowable depletion is 0.3 in./day which is equivalent to 5.6 gpm/acre. Assuming that the system would allow one day off per week and an 85% efficiency, the capacity needed is 7.7 gpm/acre. The 85% efficiency is what I have found to be typical for well designed high pressure systems. In the same area if the soil had an allowable depletion of 5 inches the system capacity could be reduced to 4.4 gpm/acre. If the lower pressure systems could be operated at an efficiency of 95%, the system capacities could be reduced to 6.9 and 3.9 gpm/acre, respectively. Note the change in efficiency of 10% does not allow a major reduction in capacity.

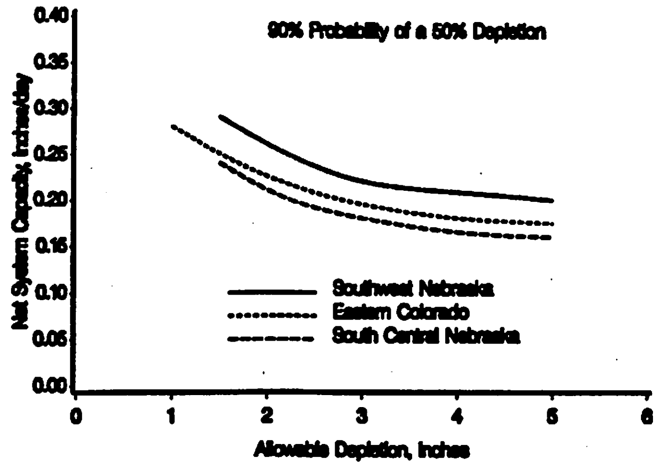

Figure 3 Design capacaties for center pivots irrigating corn in selected areas of the Great Plains. The net capacaties will meet the needs 9 out of 10 years and not deplete in excess of 50% of available water.

The example assumed that the capacity would be adequate 9 out of 10 years. Figure 4 illustrates how the capacity could vary if the system capacity would be reduced to allow satisfactory only 5 out of 10 years (50%). For the previous example the capacities could be decreased to 2.8 and 5.5 gpm/acre for the 95% efficient system for the 1 and 5 inch allowable depletion, respectively. Systems with even lower capacities could be adequate for years with higher rainfall and uniform time distribution. It is important to recognize that smaller capacity systems could contribute to significant yield reduction due to water stress.

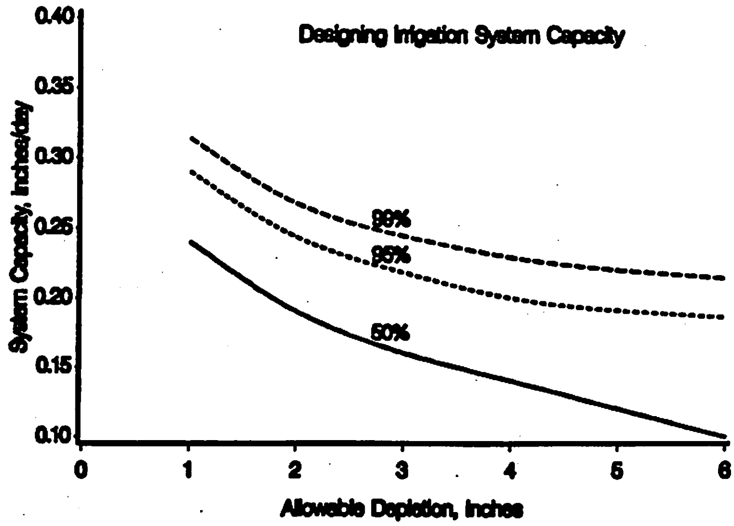

Figure 4 Design capacities for eastern Colorado with 3 probabilities of not exceeding 50% depletion of the available water.

Uniformity

A center pivot system has the distinct advantage of high uniformity if properly designed. Stationary systems will generally have lower uniformity since they typically do not have the same amount of overlap and do not move to remove some of the uniformity. The systems that are converting to low pressure with smaller diameters of coverage can result with some nonuniformity in the direction of travel. The typical alignment of well designed systems have uniformities in the direction of travel that are adequate for irrigation. If the system is used to chemigate, this nonuniformity may become important in determining the minimum chemical that can be applied and still be effective.

CONCLUSIONS

Sprinkler systems are an efficient way to conserve energy, water and labor. The system capacities should be selected at the minimum required to provide sufficient water for crop production in the majority of years to avoid costly yield depressions. The factors to consider include seasonal ET, precipitation, system efficiency, and available soil water for your soil. The type of sprinkler package must match application rate with the intake rate for your soil. If the application rate exceeds the intake rate it is necessary to use appropriate tillage or form small dikes or pits. The final conclusion is <u>Don't make changes until you investigate the interactions of all the basic factors</u> presented.

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