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Understanding the Concepts of Uniformity and Efficiency in Irrigation[1]

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Introduction

Agricultural irrigation systems are designed to maximize the rate of increase in agricultural output and income by increasing the quality and quantity of production, increasing the efficiency in the use of water, and by reducing the overall costs of system operation.

Crop yield is dependent on many conditions related to the interaction between plant, soil, water and atmosphere (climate). Many factors can reduce crop yield or cause a total failure of crop production. Irrigation helps remove limitations due to lack of water or low quality water. Irrigation may also serve other purposes such as modifying the microclimate and the chemical and biological properties of the soil. This is generally done by using the irrigation system to apply chemical products.

An irrigation system allows water to be available to the plant in sufficient quantities and quality to ensure that water is not a limiting factor in crop production. Water is available to plants only if it is within the root zone. Thus, irrigation is a means by which water is conducted to the active root zone of the crop.

Water within the root zone is absorbed and used by the plant as an essential material in plant tissue. However, most of the water used by the crop is transpired through the leaf surface. This water acts as a vehicle for the transport of the elements necessary for healthy plant growth. When water is depleted from the soil, the rate at which water and nutrients are absorbed is reduced. This causes a decrease in growth rate, sometimes to a degree that reduces yield.

To supply the root zone with adequate amounts of water, sprinkler and trickle systems are often used. Two terms that describe the performance of theses irrigation systems are coefficient of uniformity and water application efficiency.

Coefficient of Uniformity

Both trickle and sprinkler irrigation systems are hydraulic networks used to distribute water to the crop. Both systems rely on special delivery devices (emitters and sprinklers, respectively) to distribute

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water. The coefficient of uniformity is a measure of the hydrodynamic behavior of the system. Whatever its mathematical expression may be, it is an indicator of how equal (or unequal) the application rates resulting from the delivery devices are. In sprinkler systems the application rate is the "rainfall" produced by the system measured at ground level. In trickle systems the application rate is the discharge of the emitter. A low coefficient of uniformity indicates that the application rates from the delivery devices are very different, while a high coefficient of uniformity indicates that the application rates from the delivery devices are very similar in value. The coefficient of uniformity by itself is not a measure of how well the system is distributing water within the root zone.

Low uniformity in sprinkler irrigation is usually due to:

1. Inadequate selection of pipe diameters.
2. Inadequate selection of sprinkler head and nozzle.
3. Inadequate sprinkler overlap.
4. Wind.
5. Changes in systems components such as pump efficiency or pressure regulaton.

And, for trickle irrigation systems:

1. Inadequate selection of pipe diameters and/or emitter type and discharge.
2. Emitter clogging.
3. Changes in properties of emitters with time.
4. Changes in system components such as pump effeciency or pressure regulation.

In trickle systems where water must travel through the air, wind conditions might significantly affect the operation of the system.

Water Application Efficiency

"Water application efficiency may be defined as *the ratio of the quantity of water effectively put into the crop root zone and utilized by growing crops to the quantity delivered to the field*, the efficiency being expressed as percentage." (Sprinkler Irrigation Association, 1969).

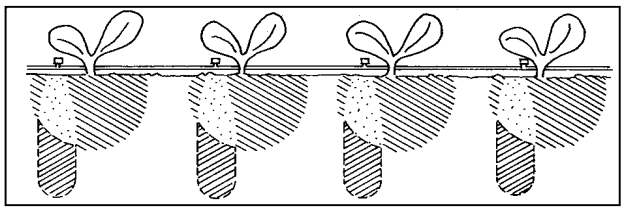

Figure 1. Hypothetical system in which the uniformity of emitter discharge is 100% but the efficiency is very low. Although the same amount of water is applied by the emitter at each outlet, soil water relationships are such that water moves out of the reach of the roots and is therefore not available to the plants.

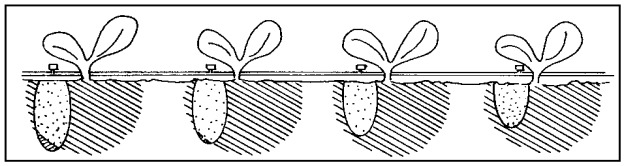

Figure 2. Hypothetical situation in which both the uniformity of the emitter discharge and the efficiency are high. Discharge variations are maintained within reasonable limits. Water is applied in sufficient quantities to supply crop needs but not in excess. This condition is sought in good design.

The concept of efficiency is related to the distribution of water within the root zone. Efficiency is always less than 100% mainly because of the limited control on the way in which water is applied and how it will distribute itself in the soil.

Low efficiency in sprinkler irrigation is usually due to a combination of the following factors:

1. Evaporation losses by sprinkler nozzle spray.
2. Losses due to deep percolation.
3. Direct evaporation from soil surfaces.
4. Runoff from the field.

Low efficiency in trickle irrigation is usually due to:

1. Poor moisture distribution pattern in relation to root distribution.

2. Losses due to deep percolation.

3. Losses due to evaporation from the soil surface.

4. In systems where travel through the air is necessary in the distribution o fwater, evaporation from emitter spray.

For further discussion of the concept of efficiency in irrigation see Bulletin 247: Efficiencies of Florida Agricultural Irrigation Systems.

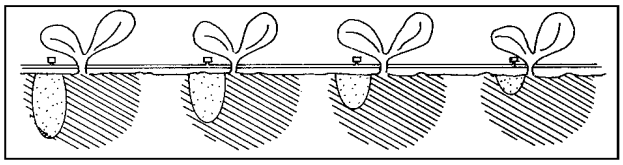

Figure 3. Hypothetical situation in which uniformity is low but efficiency is high. All water applied remains within the root zone and is therefore used by the plant. However, this situation leads to a significant part of the crop being under-irrigated. Thus, the water demands of the crop are not met.

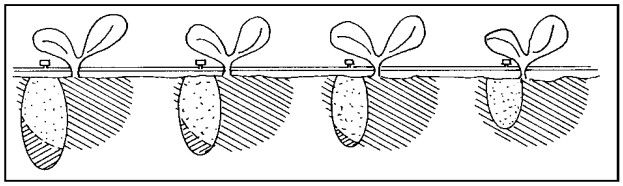

Figure 4. In order to compensate for the condition shown in figure 3 and supply sufficient water to the under-irrigated portions, the system must be operated for longer periods of time. In this way, water demands of the crop are met, but water use efficiency is sacrificed since a portion of the system becomes over-irrigated.

Discussion

With the uniformity and efficiency concepts understood it is easy to see why a system with high uniformity is not necessarily efficient. For example, one may conceive a 100% uniform system that has a very low water application efficiency such as the one shown in Figure 1. Even though the emitter discharge might be identical for all emitters, the distribution pattern is such that water moves out of the root zone. This results in low efficiency since a significant part of the water applied is beyond the root system. However, this does not imply that uniformity and efficiency are unrelated. To attain high levels of efficiency, a uniform discharge is required. In other words, it is not possible for a system to have high efficiency with a low degree of uniformity while supplying the crops demand for water.

Figure 2 illustrates the conditions that are sought in good design. First, because of pressure and emitter variations, the application rates of each emitter will vary. However, these variations are maintained within reasonable limits. Second, the total volume applied must be enough to maintain an adequate water supply to the crop.

Figure 3 shows the consequences of a system in which the uniformity is low. This results in a system in which part of the crop is over-irrigated and another part of the crop is under-irrigated. In order to compensate for the under-irrigated region, a larger volume of water is applied by running the system for longer periouds of time. This results in a decrease in water application efficiency since a significant portion of the crop becomes over-irrigated, as illustrated in Figure 4.

Conclusion

Uniformity is a parameter related to the hydraulics of the irrigation system. Water use efficiency is a parameter associated with the soil-water-plant relationships.

High uniformity of the discharge devices is required for efficient irriggation. However, high uniformity by itself does not lead to a system that is efficient. In order for the system to work adequately water must be applied in such a way that it stays within the root zone, it is always present in sufficient quantity to supply crop needs, and the variation from the different outflow devices is maintained within tolerable limits.

Works Cited

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