CROP WATER USE

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CROP WATER USE -- ECONOMIC

In the context of this irrigation workshop, the term crop water use will first be defined in terms of the amount of water needed to produce an economic return. Crops will use water even if an economic return is not produced. At the same time crops can use more water than is necessary to produce this economic return. Where water must be applied to the crop at considerable expense, it is not reasonable to apply more water than is needed, or conversely, to apply less water than is needed to produce the highest economic return.

The concept of crop water use on an economic basis is illustrated in Fig. 1. This graph shows that yield will increase as more water is available up to a point where some other factor becomes limiting, and the curve starts to reach a plateau. Curves #1, #2, #3, may represent different crops or could represent moving a crop up to another yield plateau by using additional fertilizer, or by using better weed, disease, or insect control. This plateau may be relatively flat for some crops, but the significance is that more water can be used without much increase in yield.

At some point, crop yield will begin to decline because the added water may actually be detrimental to the crop. Poor soil aeration, disease, or removal of nutrients could account for the decrease in yield at this point. Depending on the cost of applying water, the point of *maximum economic return* (point C, curve #3) is most likely to be the point where the curve begins to level off. It is also most likely to be at some point just below the maximum yield (point B). The additional yield produced at this point will not likely pay for the cost of the additional water. If the yield-water relationship is at point D, then the additional yield resulting from more water may be profitable.

Obviously the cost of the water and the price received for the commodity must be considered. The irrigator's goal should be to supply only enough water to reach this maximum return point. The goal of research should be to provide the irrigator with information about the amount of water different crops need to reach this maximum return point.

CROP WATER USE -- PHYSICAL OR PHYSIOLOGICAL

The other type of crop water use that must be considered is the actual or physical crop water use that is determined by an analysis of the prevailing conditions, such as the soil factors, microclimatic factors affecting evaporation and transpiration, and the physiological crop water use that is controlled by the plant.

It is in this context that evaporation and transpiration enter into the picture. Evaporation is used to express the loss of water from the soil surface. Transpiration is the term used for the movement of water through the plant itself. Water enters the plant roots, moves through the plant and is lost from the pores on the surface of the leaves. The term "evapotranspiration" or "ET" is used to describe this process collectively. ET can also be used as another definition for crop water use. One thing that should be remembered is that this process is not all bad. The crop plant would not survive if transpiration did not take place. Evaporation, on the other hand, can normally be considered a loss, since this water is lost to the atmosphere without passing through the plant. Research has shown that for most common crops there is a direct relationship between the amount of water transpired and crop yield.

CROP WATER USE -- PRACTICAL

With these two concepts of crop water use defined, it now becomes a matter of combining the information for use by the irrigator. First the irrigator needs to know what this magic economic crop water use figure is for the different crops being grown. Second, the irrigator needs to know how fast or in what pattern the crop is using water during the growing season.

Most crop plants thrive under a condition where the soil moisture content is high enough to adequately meet the evaporative demand of the atmosphere. Ideally, the plant would grow best if the soil were kept at a moisture level just below the point where aeration became a problem. If water could be added to a whole field to keep the soil at this constant moisture content each day, there would be some fantastic yields. This type of condition is used in a greenhouse situation where automatic mist systems replenish the water used by the plant on a daily or even more frequent basis. However, this is not presently practical with most field scale irrigation systems.

The next best approach is to know something about the crop needs at critical growth stages, and approach the irrigation scheduling plan to insure that the crop plants are least likely to suffer moisture stress during these critical growth stages. This may, in fact, imply that the crop will suffer some level of moisture stress during less critical growth stages.

There has been considerable research done on the water use by crops. Obviously, crops are going to use different amounts depending on the prevailing climate of the area. Crop water use values have been determined by various methods, but most commonly used is some variation of the water balance equation. The water balance equation can be expressed as follows:

$$\text{Water used} = ET = S_1 - S_2 + R + I - D$$

where: ET is evapotranspiration or water used by the crop; S_1 is the root zone soil water content at the beginning of the time period; S_2 is the soil water content at the end of the water use period; R is the amount of rain receive; I is the amount of irrigation applied; and D is the amount of water drained below the root zone. Researchers have used the water balance equation to evaluate seasonal crop water use. It is less accurate when trying to evaluate water use for short time periods.

Since crop water use is weather driven, more work has been done on measuring the weather factors that drive evapotranspiration and using this indirect method to calculate or estimate crop water use. It is this method that is now commonly used to calculate daily, weekly, and seasonal ET data, that are now generally available in most irrigated areas. The research in calculating crop water use in this manner, by comparing the calculated ET with the water balance equation measurements and by more elaborate lysimeter methods, has made these ET calculations about the most reliable methods presently available.

Crop water use values for various crops have been determined by one or a combination of the methods discussed. They are reliable, but each irrigator must recognize that these are general guidelines, and they will vary from region to region, field to field, and from year to year. The most careful determinations of crop water use may have as much as 10 to 15% error, but nevertheless provide a good guideline if we are going to operate at that maximum economic return level.

The following table (Table 1.) lists a number of crops common to the Central Great Plains area. The seasonal crop water use values shown are based on research from a number of locations in this area. These seasonal values can be considered as the crop water use values that will provide the best economic return as discussed above. A range in seasonal water use is shown to account for regional climatic variation. Some actual water use values may fall outside these bracketed amounts due to site to site, year to year, etc. variation.

These seasonal values, remember, are the total crop water use values. Part of this amount is offset by rain, and the remainder must be provided by irrigation. A good rain gauge at each field and good record keeping are valuable in determining precise irrigation needs.

The daily and weekly peak ET values are included so irrigators can evaluate the amount of water that a crop might use during peak use periods. The question is often asked about the capability of crops to actually use large amounts of water in a single day. Although plants have internal self regulating mechanism, a good rule is, that if the crop is adequately watered, the water loss is generally related to the prevailing evaporative demand conditions, and large daily ET values are real. These are most likely to occur for a few days immediately after an irrigation while the soil surface is wet. If the root zone water supply is low and the plants become stressed, the regulating mechanism takes over and ET is less. Most methods of calculating ET take this into account when calculating actual crop ET.

This information helps irrigators make a judgement about their irrigation system. The irrigator must determine if his system, with its capacity and application efficiency for the acreage being irrigated, can meet the ET demand. Some crops have definite critical growth stages, while others do not. Some crops are sensitive to both too much as well as too little water. Dry beans, soybeans, and potatoes are sensitive to overirrigation in that disease problems are aggravated when irrigation coincides with cool, humid conditions. Alfalfa is adversely affected by overirrigation and flooding.

SUMMARY

1. Think of seasonal crop water use values in terms of the maximum economic return point on the yield vs. ET curve.

2. Keeping records of ET, rainfall, and the amount of water applied by irrigation is the only way to reach the maximum economic return point.

3. Crops have different seasonal, weekly, and peak demands. Be aware of the critical growth stages for different crops.

4. Water lost directly from the soil surface is a loss! Yields are generally directly related to the amount of water used by the plant. Conservation tillage, mulching, etc. can reduce water loss from the soil surface thus making more water available to the plant.

TABLE 1. SEASONAL CROP WATER USE (ET), DAILY PEAK WATER USE, WEEKLY PEAK TOTAL WATER USE, AND CRITICAL GROWTH STAGES FOR VARIOUS CROPS COMMON TO THE CENTRAL PLAINS AREA...(KANSAS, NEBRASKA, AND COLORADO).

CROP	SEASONAL CROP WATER USE (ET)	---PEAK USAGE--- WEEKLY	DAILY	CRITICAL GROWTH STAGES, etc.
	(inches)	(in/wk)	(in/day)	
Alfalfa	32 - 48*	2.8	.55	after harvest
Corn	24 - 30	2.5	.50	tasseling, silking
Dry Beans	16 - 24	2.1	.40	early bloom
Wheat	16 - 22	2.0	.40	boot - heading
Sorghum	16 - 22	2.2	.40	boot - heading
Potatoes	18 - 22	2.0	.32	blossom - harvest
Sunflowers	16 - 20	1.8	.28	flowering - maturity
Soybeans	18 - 24	2.2	.32	germination, bloom - podding
Vegetable Crops	16 - 20	2.0	.26	reproductive stages

*Forage crops generally respond directly to the amount of water available. Alfalfa can use large amounts of water when growing seasons are long.

Figure 1. Theoretical relationship between crop yield and the amount of water used.