Limited irrigation may drop yield, up profit

Highest return per unit of water applied should be goal

By R. WAYNE SHAWCROFT
Extension Irrigation Agronomist
Colorado State University

IF YOU, as a farmer operating an irrigated farm in eastern Colorado, were told that you would be allowed only one irrigation this year, you would plan to get the highest possible return, in terms of crop yield and profit per acre, for that irrigation.

Although the single irrigation might be a little extreme, the concept of obtaining the highest return per unit of water applied is the goal of most irrigators. This is particularly true as pumping costs rise and water supplies dwindle.

Simple Definition

This concept of limited irrigation or deficit irrigation, as it is sometimes called, can be defined simply as reducing the amount of water that is applied to a crop as opposed to "full" irrigation. Under "full" irrigation, water is applied at a rate slightly above that needed for "maximum" yield. This concept can be described, using Fig. 1, showing a theoretical relationship between crop yield and water used. Three yield vs. water use curves depict the principle of limiting factors. Point A on curve 1 shows that the yield maximum has been reached and adding more water will not result in a higher yield. It also states that some other factor such as fertilizer, weeds, crop variety, insects, disease, etc., are limiting yield. Removing other possible limiting factors may shift the yield-water use response to that of curve 2 or 3.

To further define the concept of limited irrigation, attention is called to Fig. 1, points B, C and D. At point B, enough water was applied to obtain a yield maximum, but also note that the yield increase from points C to B was very small for the additional increment of water added. When water is in plentiful supply and relatively low in cost, irrigated agriculture uses water at the maximum level to insure the capability of reaching yield maximum. From the analysis in Fig. 1 it is obvious that the water added to reach point C is more profitable than at point B, since the added cost of applying this extra increment of water could not be offset by an increase in crop yield.

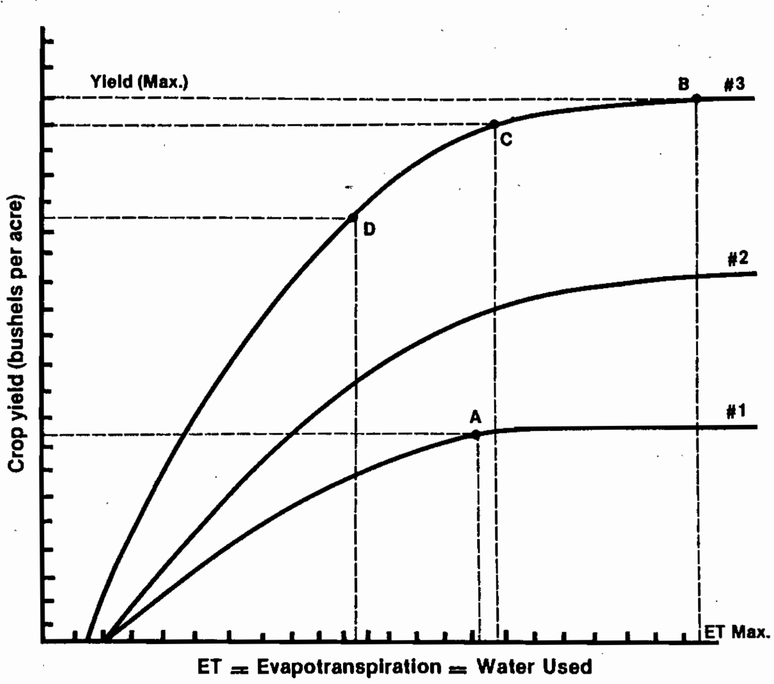

Figure 1. Theoretical relationship between crop yield and the amount of water used.

The limited irrigation approach carries this principle a little further and says that with less water added (Point D, Fig. 1) there will be a yield reduction, but with the goal that the yield reduction will be offset by the reduced expense of adding the full amount of water necessary for obtaining maximum yield. The intent then is to maximize profit in relation to the amount of water pumped.

The question remains: Can, in fact, this type of irrigation management work? There have been both positive and negative results. Before discussing a case of positive results, let's outline some principles that are necessary to obtain positive results under limited irrigation.

Limited irrigation will take more management in terms of an awareness of:

(1) Crop water needs, on a daily, weekly and seasonal basis.

(2) A knowledge of the crop growth stage where water needs are critical.

(3) The amount of water being applied by the irrigation system.

(4) The amount of water stored in the soil at various time periods and at various rooting depths.

(5) The potential marketability and market price of the crop and a careful accounting of the cost of pumping or applying water.

In addition, other management practices such as soil fertility, weed, insect and disease control, crop variety selection and conservation tillage for saving as much water as possible from snow and rain, will be just as important, if not more so, as in full irrigation.

Actual Results

Now for some actual results, using the limited irrigation approach. Research soil scientists at the USDA-Agricultural Research Service Research Station at Akron have been using a scheme first developed in California and other states to evaluate response to varying amounts of water at different growth stages. This system is outlined in Fig. 2. A grain producing crop is divided into three broadly defined growth stages. After establishing the same soil water content by pre-plant irrigation, if necessary, the field plots are either irrigated or not irrigated, according to Fig. 2.

The treatment OII, for example, indicates that irrigations were withheld (O) during the vegetative stage, and ap- /continued on page 36

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plied (I) during both the flowering and grain filling stages. The "I" may mean one or more irrigations, depending on crop needs and rainfall during the period. The intent in withholding irrigations is to develop a degree of water stress during a growth stage. This works best during a low rainfall year so a greater contrast in the degree of water stress can develop between the irrigated and non-irrigated treatments.

Studies as outlined in Fig. 2 have been conducted by USDA-Agricultural Research Service personnel at Akron since 1977. Various crops have been tested with this system with the emphasis on corn,

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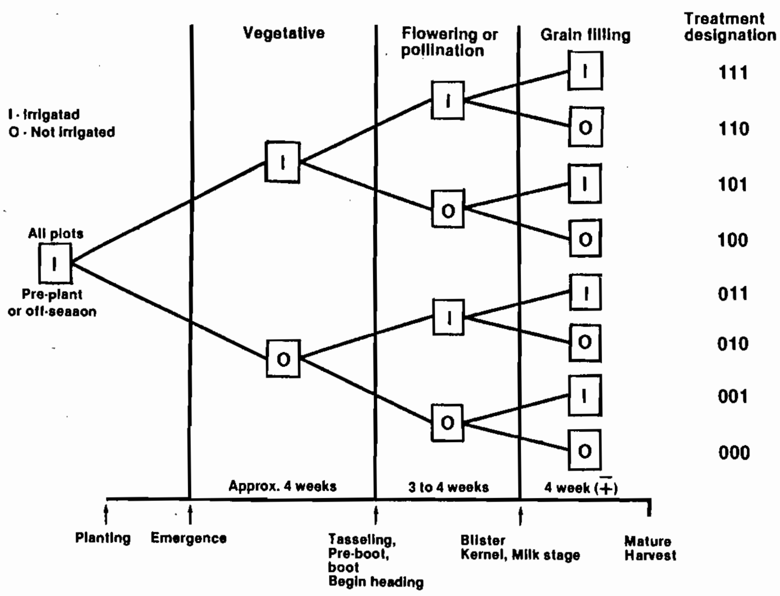

Figure 2. Schematic of irrigation treatments USDA-ARS, Akron.

Table 1. Yield and water use efficiency* for limited irrigation studies, USDA - ARS, Akron, Colo. Corn and sorghum, 1977; winter wheat, 1978. See figure 2 for explanation of irrigation treatments represented by the letters I and O.

Corn			Sorghum			Wheat[1]		
	Bu./ac.	Bu./ac. inch		Bu./ac.	Bu./ac. inch		Bu./ac.	Bu./ac. inch
111	132	5.46	110	111	5.64	011	70	3.98
110	121	5.50	011	100	6.77	111	61	3.08
011	109	6.48	111	100	4.78	010	54	3.29
101	75	3.96	101	94	6.27	110	43	2.55
100	53	3.21	100	88	5.55	0000	26	1.89
010	48	3.52	010	62	4.98			
000	8	0.87	001	48	3.68			
001	3	0.23	000	40	4.44			

* Water use efficiency = bushels/acre per inch of water used.

[1] All irrigation treatments for wheat, except the check (0000), received a fall irrigation. The sequence of growth stages during which the wheat was irrigated (I) or not irrigated (O) are as follows: Spring vegetative, heading-flowering, and grain filling.

Table 2. Gross return per acre less pumping at $215 per inch of water for a 130-acre center pivot, plus an estimated annual investment cost of $48 per acre. Market prices: Corn and sorghum at $2.24 per bushel; wheat at $3.50 per bushel (does not include cost of seed, fertilizer, tillage, harvest, etc.). See Figure 2 for explanation of irrigation treatments represented by the letters I and O.

Corn		Sorghum		Wheat[1]	
011	$257	101	$211	F011	$190
111	216	011	187	F111	156
110	201	110	177	F010	136
101	148	111	143	F110	96
010	71	100	139	*0000	92
100	59	010	119		
*000	18	*000	89		
001	—51	001	49		

* No water pumped — dryland gross return per acre.

[1] All irrigation treatments for wheat, except the check (0000), received a fall irrigation. The sequence of growth stages during which the wheat was irrigated (I) or not irrigated (O) are as follows: Spring vegetative, heading-flowering, and grain filling.

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grain sorghum and wheat. The results for corn and sorghum from 1977, a dry year with only 3.6 inches of summer season rainfall, are shown in Table 1. The results for irrigated winter wheat for the 1977-78 crop are also shown in Table 1.

The results, in general, follow the yield-water use curves depicted in Fig. 1, with the highest yields for corn being produced where the most water was applied. Note the greater yield reduction in corn with the IOI treatment. This indicates that stress during the tasseling-silking period was enough to severely reduce yields as opposed to treatment where irrigations were not withheld during this reproductive stage, i.e., OII and IIO. This is less pronounced in grain sorghum, which is a more drouth tolerant crop.

The gross return per acre less pumping costs based on approximate pumping costs in 1977, the net amount of water pumped and a prevailing market price are shown in Table 2. Note that the OII treatment for corn gave the highest return and illustrates the case discussed earlier in that the highest profit came at some yield below the maximum yield and with less water applied.

Withholding irrigations during the vegetative stage forces roots to more fully explore the soil profile for water. It also allows the soil surface to dry, thus reducing direct evaporation losses from the soil surface. The highest water use efficiency (bushels per inch of water used, see Table 1) is usually produced with treatment OII, provided the deep soil water reserve has been established. Wheat actually produced the highest yield when water was withheld during the spring vegetative stage.

As stated before, these are some positive results, but negative results have also occurred where management was not as carefully followed.

Key Features

The key management features in operating a limited irrigation scheme are:

(1) Start the growing season with adequate stored soil water. This involves possible preplant irrigations, conservation practices to store as much water from rain and snow as possible and the use of a soil probe to know how much deep soil water is available. Preplant irrigations for summer crops could be applied the previous fall for soils with relatively high water holding capacities, i.e., silt loams, clay loams. The same concept should be followed with fall irrigation of winter wheat.

(2) Know how much water the crop is using and the critical growth stages that are most sensitive to water stress. This may involve following the ET reports for daily or weekly crop water use that are available in various locations. Most grain crops are particularly sensitive to water stress during the reproductive period, i.e., tasseling-silking, boot-flowering. Plan irrigations so that water is readily available at these stages.

(3) Understand the application efficiency of your pump and irrigation system by having tests and analyses made, and keep the system operating at a high efficiency. Monitor the amounts of water applied by irrigation and rainfall.

(4) Use all other proper management procedures for the yield goal. For example, for a planned yield reduction the fertilizer level can be adjusted, but make sure low fertility does not become the limiting factor.

These factors imply a more careful analysis and an added awareness of details of irrigation systems and techniques. And, as pumping costs increase and water supplies dwindle, they will become even more important for profitable operations. Extension personnel are available throughout the state to help with any specific problems or questions about limited irrigation or irrigation scheduling techniques.■