STRETCHING LIMITED WATER SUPPLIES

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Surface water shortages plus declining groundwater in areas of southwest Nebraska, northeast Colorado, and western Kansas require that farmers develop strategies to manage limited irrigation to maximize profit. When producers change from a fully irrigated situation with no restrictions to a situation where water is limited either by well capacity or by water allocation, they need reliable information on yield response to irrigation inputs.

YIELD-INPUT RELATIONSHIPS

Management of declining or limited water supplies requires the need to understand how limited water will affect yields. This requires understanding a number of yield-input relationships shown in Figure 1. The most simple yield-input relationship is shown in Figure 1-A. It assumes that with no input there is no yield, and as inputs are added there is a linear relationship with yield. In most agriculture production situations this is not the case. The relationship is more like Figure 1-B. Even with no input there is some yield and with added inputs then yield increases. A variation of Figure 1-B is shown in Figure 1-C. In some instances there is no yield until a considerable amount of input is added and then there is incremental increase in yield.

In crop production, however, we are not 100% efficient in turning inputs into yield. With inefficiency, the yield-input relationship is like that shown in Figure 1-D. There is some initial yield without any input. Yield increases with an input but the yield levels off at higher inputs because that input is no longer the limiting factor in the yield. This is called a typical curvalinear response curve. In Figure 1-D, the sections labelled a, b, and c show the incremental efficiency of increasing units of input. The first unit of input produces a fairly substantial yield increase. The next unit produces less and the last unit produces only a small increase or no increase. This type of response curve is necessary for determining the economics of when it is no longer profitable to add an input even though there might be some yield increase. In economic terms, the yield of the crop times its price minus the cost of the input has to be greater than zero.

In some situations too much input can decrease yields. This is shown in Figure 1-E. For example, when too much irrigation leaches nitrogen or saturates soil, yield reduction can occur.

YIELD-INPUT RELATIONSHIPS FROM FIELD STUDY

The general yield-input relationships were used to help design a limited irrigation management research project that has been conducted at North Platte for the last 10 years. Limited irrigation management was coupled with season long water conservation techniques from the ecofallow system for a limited irrigation cropping system. Limited irrigation was defined as applying less water than required to meet the full evapotranspiration (ET) demand of the crop. As a result, the crop suffered water stress when full ET was not met. Even with irrigation, crops in the central Great Plains some times experience water stress when root development or irrigation system capacity cannot meet crop ET demands. In limited irrigation management, crop water stress is planned. Our goal has been to manage the water to minimize the impact of stress on grain yield.

Yield-ET Relationship

There is a strong relationship between yield and evapotranspiration (ET) for agricultural crops. The yield-ET relationships for corn, soybeans, and wheat grown at North Platte, Ne are shown in Figure 2. The relationship of corn, soybeans, and wheat to ET were linear and similar to yield response Figure 1-C. The yield-ET relationship can be used to determine which crop will responded most favorably to irrigation. The intercept of the horizontal (X) axis is the minimum amount of ET needed before any grain yield was obtained. After this point, grain yield increased in a linear response to increases in ET.

The slopes of the yield-ET lines show the relative yield response to total water use among the three crops. The relationship of wheat to ET was relatively flat compared to corn and soybeans. The minimum amount of water needed for wheat to produce grain ranged from 3 to 4 inches of ET. For each additional inch of ET, wheat yields increased approximately 3 bu/ac. The soybean yield-ET relationship was relatively flat, but sloped slightly more than wheat. The response of soybean yields to each additional inch of ET was about 4 bu/ac. Soybeans required approximately 6 to 7 inches of ET before grain was produced.

The corn yield-ET relationship showed the most increase in yield with increases in ET. Corn's response to ET was approximately 12 bu/ac for each additional inch of ET. It required approximately 10 inches of ET before any grain was produced (Fig. 2). Corn also required approximately 27 inches ET for maximum grain yield.

Yield Irrigation Relationship

Yield-irrigation input relationships for corn, soybeans and wheat are in Figure 3. Yield response to irrigation, up to maximum grain yield, are typically a curvalinear response, similar to yield response Figure 1-D. Yield response to irrigation was not linear as was the yield-ET relationship due to inefficiencies of the irrigation system.

The grain yield response of wheat and soybeans to irrigation was similar. There was little grain yield increase when the amount of irrigation increased from 6 to 12 inches. Wheat required approximately 1 to 2 inches less irrigation for maximum yield than soybeans.

Corn showed the most yield response to irrigation when compared with wheat and soybeans. Corn following wheat yielded more than continuous corn when irrigation was limited. The reason for this difference was due to differences in stored soil water at the beginning of the growing season because of the added moisture storage period after wheat harvest. As the amount of irrigation water applied increased, the yield difference between continuous corn and corn grown after wheat decreased. Maximum yield for both continuous corn and corn grown after wheat were equal.

Combined Yield-ET and Irrigation Relationships

The yield-ET relationship and the yield-irrigation response for corn grown after wheat are combined in Figure 4. The straight line was the relationship between yield and ET for corn. The curved line was the response between yield and seasonal irrigation applied.

Dryland corn ET was approximately 18 inches. Stored soil water and seasonal precipitation combined for the dryland ET. As additional water was supplied by irrigation, ET increases in a linear matter as represented by the straight line. Fully irrigated corn ET was approximately 27 inches. To supply the additional 9 inches of water needed for maximum ET, approximately 17 inches of irrigation water was applied. A total of 35 inches of water (precipitation, stored soil water, and irrigation) were needed for maximum production. The difference between the straight line and the curved line, shown as "Non-ET" on Figure 4, was the water applied but not consumed by the plant. The curvalinear appearance of the yield versus irrigation illustrates that "Non-ET" losses increased as maximum yield and ET were approached. Those losses were due to surface runoff, deep percolation below the root zone, and system evaporation. Theses losses need to be minimized in order to irrigate crops more efficiently.

CONCLUSIONS

The yield-irrigation responses developed from the crop rotations work at North Platte show that rotations including wheat, soybeans, and corn have possibilities for stretching limited water supplies. The goal has been to conserve as much precipitation as possible with no-till farming, crop residue management, crop sequence, and to apply irrigation when the greatest yield increases occur. The "agronomics" for developing new management strategies are fairly well developed. The "economics" for alternative cropping sequences or irrigation levels are needed to predict the most profitable system with constraints of low well capacity or water allocations, soil type (sandy or fine textured), irrigation method (furrow or sprinkler), and government programs.

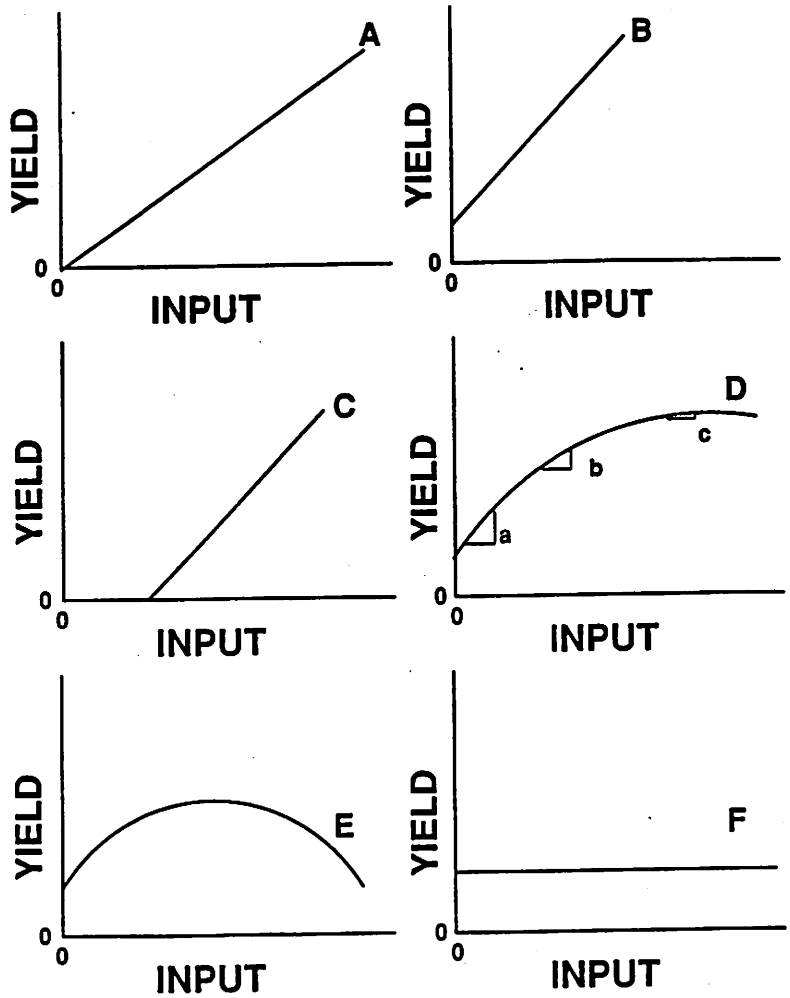

Figure 1. Generalized yield-input relationships.

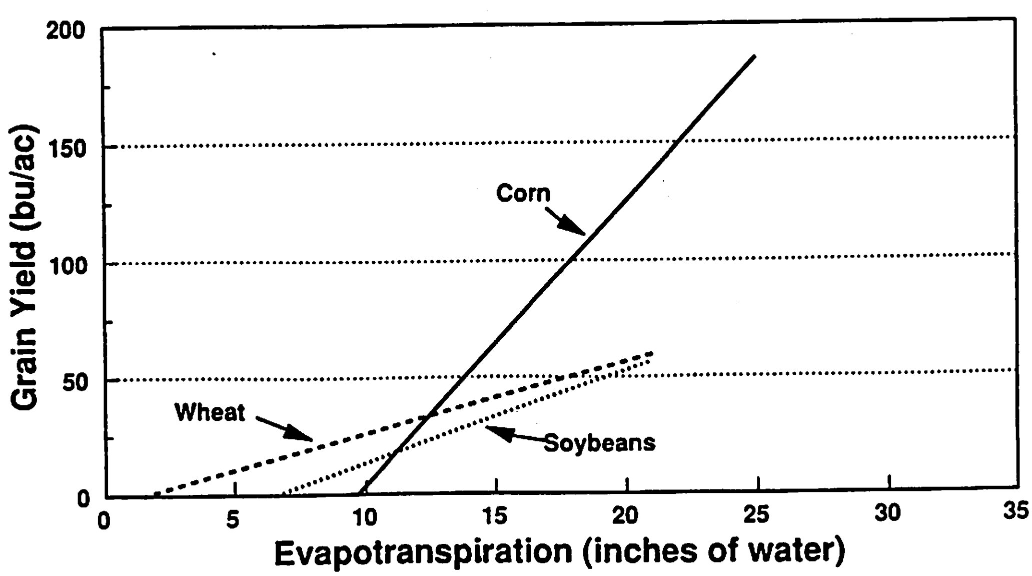

Figure 2. Average yield vs ET relationship for corn, soybeans, and wheat from 1986 to 1989.

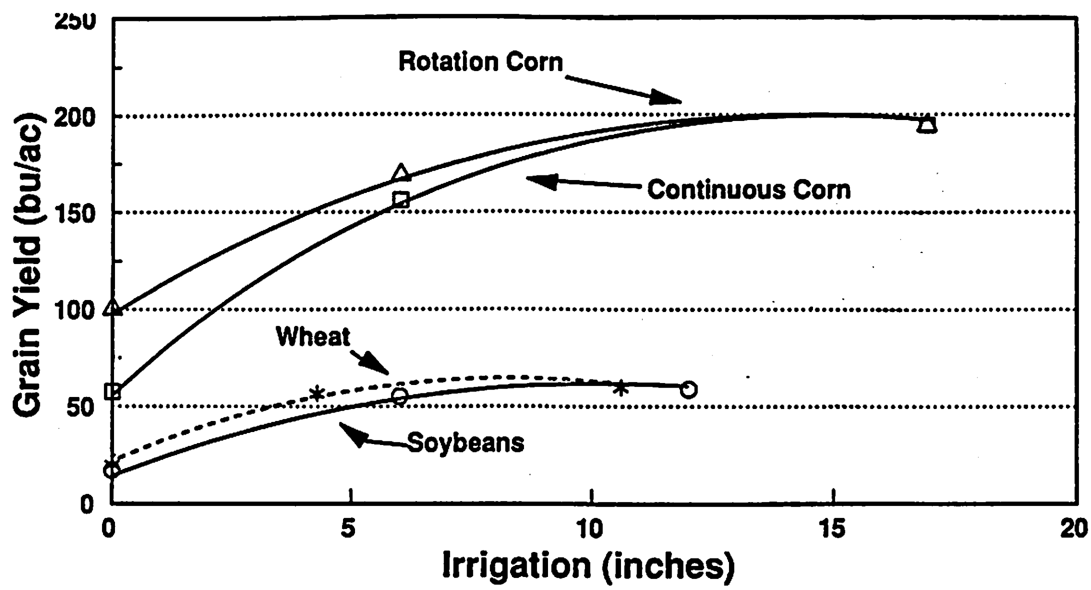

Figure 3. Average yield versus irrigation response for continuous corn, corn after wheat, soybeans, and wheat from 1986 to 1989.

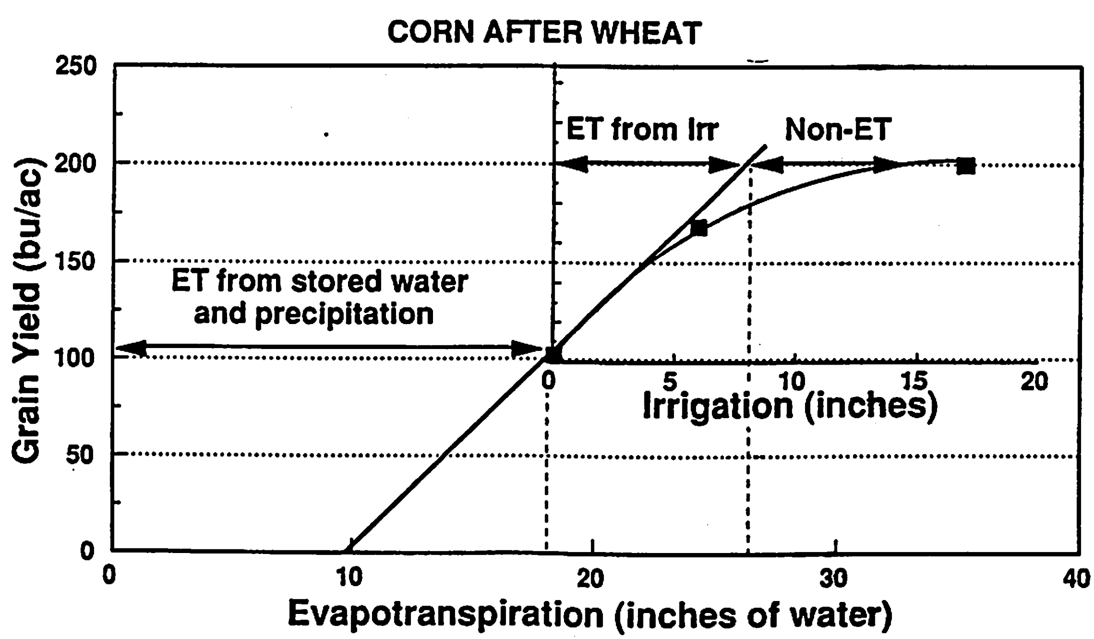

Figure 4. Generalized relationship between yield and evapotranspiration showing the contributions of stored soil water, growing season precipitaion and irrigation to yield.