A closer look at deficit high-frequency irrigation

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Encouraging results with previous deficit high-frequency irrigation experiments raised hopes that the technique could reduce water use on some California crops. But studies with sorghum, beans, and tomatoes proved the method unsuccessful.

Under good irrigation practices, most of the water applied is used consumptively by the crop in evapotranspiration (ET): the evaporation of water into the atmosphere from plant and soil surfaces. Water evaporating from the plant, in a process called transpiration, has been taken up by roots and transported to leaves. Evaporation of water from plants and the soil surface requires solar radiation and other climatic energy sources. Thus ET is regulated by the climate as long as the crops receive adequate water. Potential ET is the upper limit of crop water use in a given environment.

It has long been known that reducing crop water use below ET requirements results in reduced transpiration and harvestable yields. Nevertheless, numerous attempts have been made to produce near-maximum yields after maintaining crop consumptive use below its potential rate. Researchers using a new irrigation technique, called "deficit high-frequency irrigation" (DHFI), have reported good results by applying irrigations at very frequent intervals with amounts less than the ET demand. Experiments conducted in Prosser, Washington, show that peak irrigation requirements may be decreased through this technique and that it is possible to sustain yields of sugarbeets, wheat, and beans without fully meeting the seasonal ET requirements.

Fully automated irrigation systems provide the means for high frequency irrigation as a potential new management option without increasing irrigation labor costs. If the water-saving potential of the technique is substantiated, it should have immediate impact on the acreage placed under permanent irrigation systems, particularly in areas of the state where water is very expensive, limited, or both. Therefore, we conducted experiments using DHFI and a normal irrigation schedule on grain sorghum, beans, and tomatoes to determine the relationship between ET and yield under both irrigation regimes as well as to ascertain any advantages of DHFI under conditions of limited water supply.

Methods

Three experiments were conducted in Davis during summer 1977 on a deep Yolo loam soil which was partially dry because of the winter drought. Grain sorghum (cv. Pioneer 846) and kidney beans (cv. Dark Red) were planted on rows 30 inches apart; processing tomatoes (cv. VF145-7879) were planted on rows 60 inches apart. Sprinkler irrigation was used on the grain sorghum and beans, where a frequent irrigation regime (HF, every other day) was compared with the normal frequency of application (NF, every 8 to 14 days). The total amount of water applied to grain sorghum was the same under both regimes. In the bean experiment, the amount of water applied under the HF regime was increased to replace the higher soil evaporation losses of frequent irrigations. During the season, applications varied from about the normal ET demand to only 23 percent of ET. The tomatoes were drip-irrigated daily. The total amounts of water applied to three treatments were equivalent to 100, 78, and 55 percent of seasonal ET demand. No comparison was made between normal and high irrigation frequencies on tomatoes.

It is difficult to accurately measure ET under field conditions. In this study, total ET for the season was estimated by the water balance method, in which the applied water and the seasonal decrease in water stored in the soil are measured and added together. The method is inaccurate when the amount of water percolating below the crop root zone cannot be ascertained. However, in our experiments, the water content of the subsoil remained so low (15 to 25 percent, field capacity being 33 percent) that deep percolation could be ignored. Therefore, we believe that our calculations of ET based on field water balance are very close to the actual ET.

Soil water depletion was measured at frequent intervals using the neutron moisture meter and water applied through the drip system was metered to individual treatments. Catching cans were used to measure applied water in the sprinkler-irrigated plots. Irrigations were scheduled based on estimates of long-term potential ET which were periodically modified according to the observed changes in soil water content.

Results

In all crops and under both irrigation regimes, total dry matter yields were proportionally reduced as ET decreased below its maximum potential. Harvestable grain or fruit yields were even more sensitive to ET reductions than yields of total dry matter.

Grain sorghum yield decreased linearly as ET decreased. When ET was maintained at close to potential, the same production was obtained under both irrigation regimes. However, when ET was reduced to below 50 percent of the maximum, grain yields were less at the same ET level for the high-frequency regime than for the normal-frequency regime. (Fig. 1 presents the yield responses of grain sorghum to reduced ET under both irrigation regimes.)

The yield responses for beans (fig. 2) are similar to those for grain sorghum: there was no yield difference between irrigation regimes near maximum ET, but at low ET levels the high-frequency regime yielded less than normal frequency. The low yields under frequent irrigations at low ET levels may be explained by the fact that full vegetative cover was never achieved. As a result, direct evaporation from the soil became a significant component of ET, was increased even more by the frequent wetting of the soil surface, and left less water available for plant transpiration.

The tomato response to deficit drip irrigation applied daily is presented in the table. Again, any decrease in ET below its maximum potential brought about a reduction in harvestable yields.

In all three crops, the water use efficiency (WUE, yield per unit of water used) either decreased or was maintained at the same level when ET dropped below potential. In these treatments, where water applied was significantly less than the ET, noticeable soil water extraction was detected. However, because of the dry subsoil conditions, the amount of water extracted was much less than would be expected for deep Yolo loam soil with a fully charged profile. The maximum observed seasonal soil water depletion was about 6 inches for sorghum, 4 for beans, and less than 2 for tomatoes, the crop located in the driest area.

Effect of Deficit Irrigation on Tomato Yield

Water applied (in.)	ET (in.)	Fruit yield total (tons/acre)	Fruit yield ripe (tons/acre)	Relative ET (%)	Relative ripe fruit yield (%)
26.9	25.0	82.3	59.5	100	100
21.7	22.6	64.2	50.3	90	85
16.1	17.7	48.0	38.2	71	64

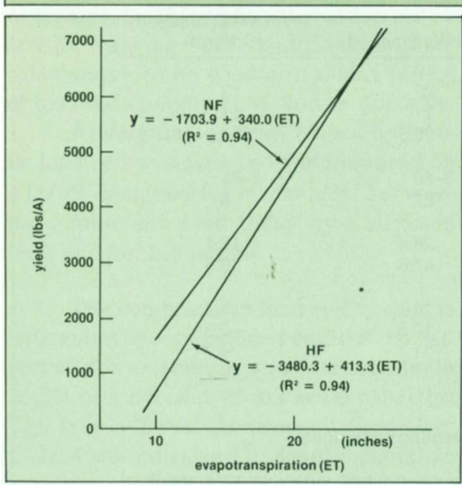

Fig. 1. Yield responses of grain sorghum to reduced evapotranspiration.

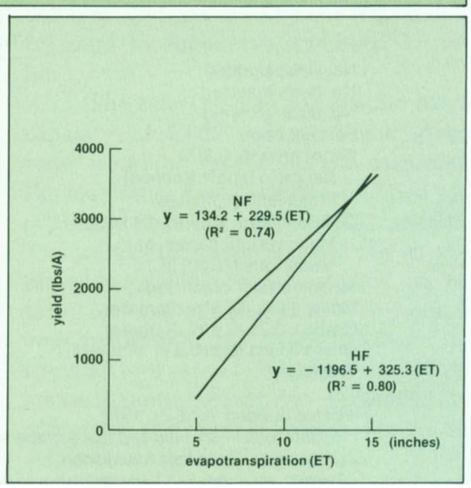

Fig. 2. Yield responses of beans to reduced evapotranspiration.

Conclusions and applications

Under the conditions of these experiments, with little water stored in the soil, frequent irrigations at a rate less than the ET will result in substantial reduction in economic yields with no increase in water use efficiency. In fact, WUE may be reduced by more evaporation from the soil surface. If enough soil water is stored in the profile, it may be possible to use deficit high-frequency irrigation and still obtain maximum yields, but only by meeting ET through a combination of water applied and soil water depletion. Certainly, the term "deficit" does not apply to the latter situation as no ET deficits result under such an irrigation regime. Comparing the results presented here with previous yield/ET relationships obtained at Davis on a fully wet profile, it appears that if the seasonal water supply will be less than the ET, water use efficiency may be maximized by storing the water in the profile rather than by frequent, light applications.

In applying the results presented above to other situations where water supply is limited, two possibilities must be considered. If the crop has not achieved full cover and sprinkler or flood irrigation is used, WUE will be lower under a DHFI regime than with more infrequent irrigations. If the crop is fully shading the ground, a localized irrigation technique (such as drip) is used, or both, there should be no difference in yield or WUE between high-frequency and normal irrigation schedules as long as the allowable depletion is not exceeded under normal irrigation. Finally, to maximize crop productivity and water use, it is most important to irrigate efficiently so that ET requirements are met at all times. Frequency of application becomes less important if crop water deficits are avoided by appropriate scheduling.

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