Irrigation management conserves water

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Californians are acutely aware that water is a valuable and scarce resource and are concerned about protecting its quantity and quality. Irrigated agriculture, the state's biggest water user, depends on good-quality water; it also degrades the quality of the drainage water. Supplying irrigation water and disposing of drainage water account for a significant part of our fossil energy consumption. Furthermore, even though irrigated agriculture is crucial to the economy and makes a substantial contribution to supplying the world's need for food, it must compete with other demands—municipal, industrial, and recreational. The question, then, is what can be done practically to conserve water, in quantity and quality, while maintaining a viable irrigated agriculture.

At the U.S. Salinity Laboratory in Riverside, we visualize changes in management that can lead to reduced volumes of water applied to irrigated fields, with consequent reductions in drainage volumes, in amounts of salts discharged, and in energy consumed—while maintaining crop yields. But implementation will not come easily. Good packages seldom come for free.

What are some of these concepts? When irrigating alfalfa with relatively good-quality water (salt concentration of 1,400 mg/l or less), Leon Bernstein, U.S. Salinity Laboratory, found that the yields were hardly affected when the amount of irrigation water was reduced to allow only a very small amount of drainage—a small leaching fraction. This led to the hypothesis that plants are able to extract water from the root zone up to a relatively high threshold salt concentration, as long as sufficient water is more freely available elsewhere in the root zone. (The actual threshold level is unique to each crop species.)

Thus we can reinterpret the previous, widely known crop tolerance data for salinity. As illustrated in the figure, we can plot the relative yield against the average salinity of the root zone. By extrapolating the resulting curves to zero yield, we arrive at the threshold value of salinity that should not be exceeded at the bottom of the root zone. (This is thought to be the salinity beyond which the roots can no longer extract any water.)

When translating such data to required leaching fractions, we find that the leaching requirement is about one-third to one-quarter of that previously recommended. There seems no question that, generally, far lower leaching requirements than customarily recommended will be entirely adequate. In other words, less irrigation water needs to be provided.

Needed: better irrigation methods

To put these findings into practice requires good irrigation management—especially if soil salinity is built up to higher levels, because then the margin of permissible error is reduced. For example, although extending the interval between irrigations saves labor, the combined stresses due to soil water and salinity may become excessive. A minimum leaching fraction must be obtained everywhere, which necessitates uniform water distribution over the field. The soil water content should also be as uniform as possible over time.

Traditional furrow irrigation practice often results in uneven water distribution. However, relatively high irrigation efficiencies with uniform application can be obtained with conventional gravity systems. Graded furrows with tail-water pump-back systems and deadlevel basins, especially when laser plane graded periodically, are examples. However, none of these surface-flooding systems overcomes the inherent nonuniform soil intake rates found in almost all fields. Sprinkler or trickle systems, in principle, avoid this problem but introduce new ones: wind drift and high energy requirements for pressurization, for example.

A new system, developed at this laboratory by S.L. Rawlins, permits high efficiency at low cost and low energy consumption for tree crops. It uses buried, relatively inexpensive, corrugated and unperforated drain tubing to distribute the water along the rows, and 3/8-inch plastic tubing to deliver water to each tree. It requires no filters, no emitters, and a hydraulic head less than 3 feet—which is frequently available in the supply canal without use of pumps.

Efficiency's payoff

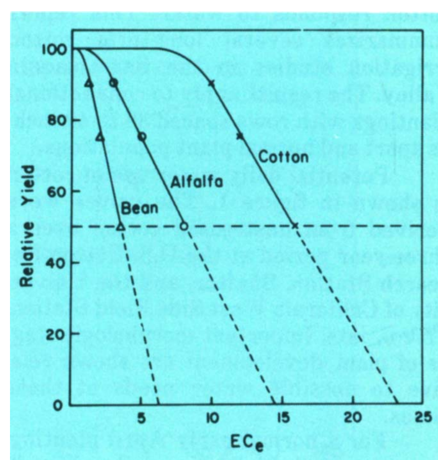
Why the interest in irrigation efficiency? Efficient systems use less water and leave less drainage water to dispose of; they allow savings in energy and in fertilizer. However, efficiency does not necessarily produce savings in water per se. Actual consumptive use does not change significantly and—in any system—drainage water is generally returned to the water supply. The most important consequence of increased efficiency has to do with water quality.

As crops use water from the soil and leave salts behind, the salt concentration of the soil solution, and thus of the drainage water, is increased. Leaching, by applying more irrigation water than the crop requires for consumptive use, removes excess soluble salts from the root zone. However, the outcome is significantly influenced by the salt level in the water supply. Dilute waters tend to dissolve more salts out of the soil, while salts in concentrated waters tend to precipitate out into the soil. Therefore, as irrigation efficiency is increased and salt levels in the soil solution rise, there is a gradual shift from conditions favoring the dissolving-out of salts to conditions favoring their precipitation.

Effects on receiving water

Because of the phenomenon just described, an increase in irrigation effiency always reduces the amount of salt removed in the drainage water. The effect of this reduction in salt loading on the receiving water, however, may range from very significant to none—depending on the chemical composition of the irrigation water and the possible presence of foreign salts in the soil and in underlying strata through which the drainage water flows.

After irrigation water is withdrawn from a stream or canal, the drainage water—after a sometimes circuitous path—frequently returns to the stream. Along this path, it may displace saline ground water, dissolve salts (e.g., gypsum) out of the soil materials through which it flows, or simply move along without chemical changes. The drainage water, or the displaced ground water, then mixes with the water in the stream. J.D. Rhoades and D.L. Suarez, U.S. Salinity Laboratory, showed that effects of changes in irrigation management on the quality of the stream could vary dras-



Reinterpretation of crop yield reduction data as a function of the salinity of the saturation extract (EC_e).

tically—all the way from a substantial reduction in salt addition to the stream to no effect.

For example, the soils of the Grand Valley in Colorado overlie a highly saline shale formation. Reducing the water input to the soil system—by lining canals, increasing irrigation efficiency, and eliminating tail water—would reduce the outflow from the valley. Since this water picks up salts from the shale, the reduction in salt would be approximately proportional to the reduction in subsurface drainage flow.

In contrast, in the Palo Verde Irrigation District, there seem to be no foreign salts in the aquifer. Decreasing the average leaching fraction would still reduce the amount of $CaCO_3$ in the drainage water. But, because the Colorado River at that point is saturated with $CaCO_3$, this drainage water would not be expected to affect the composition of the river downstream. Similar analyses can also be made for closed ground-water basins.

The details of the water chemistry processes involved are very complicated. Each situation needs to be evaluated separately, and the outcome often does not bear out intuitive judgment.

Good management requires consideration of alternatives. For example, an agreement between the United States and Mexico requires drastic reduction of salt additions to the Colorado from the Wellton-Mohawk Irrigation District in Arizona. This objective can be achieved by construction of a huge desalting plant near Yuma to treat the drainage water before discharge into the river. An alternative would be to change irrigation practices on the 62,000 acres of cultivated land of the district. If the average irrigation efficiency were increased from the 1972 level of about 56 percent to 85 percent, and if other conditions remained constant, then the increase in river water salinity due to salt input from this project would be only 100 mg/l rather than 400 mg/l. At this high efficiency, the volume of drainage water would be similar to the amount of brine from the desalting plant, and could be bypassed to the ocean. Even though such a change in management is technically quite feasible, it would be difficult to obtain and impossible to guarantee.

An increased understanding of the reaction of plants to soil salinity can lead to changes in water management. Such changes can mean more efficient use of water, an improvement in water quality, and a savings of scarce fossil energy. Arbitrary attempts to force decreases in water use would serve no good purpose, and could cause substantial harm. However, judicious application of the concepts outlined, tailored to the specific situation at hand, can help us meet national goals of natural resource conservation.

For more information on irrigation management, see "Conservation irrigation of field crops: a drought-year strategy," *California Agriculture*, April 1977.

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Cotton responses to irrigation

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Irrigation is a major management consideration in cotton production. The plants require water delivered at intervals through 65 to 85 percent of the growing season. Not only is water a significant production cost, but its regulation through proper scheduling provides a unique opportunity to control plant growth and development in a way that favors high productivity. Such regulation requires an understanding of how cotton responds to water. This report summarizes several long-term cotton irrigation studies in the San Joaquin Valley. The results apply to conventional plantings with rows spaced 38 to 40 inches apart and normal plant populations.

Potential daily water use of cotton is shown in figure 1. The values were derived from unstressed cotton over a three-year period at the U.S. Cotton Research Station, Shafter, and the University of California West Side Field Station, Five Points. Important morphologic stages of plant development are shown relative to possible water needs at those times.

For a normal early April planting, water use is initially low, being largely evaporation from the soil surface. A rapid increase in early June closely parallels leaf canopy development, reaching maximum water use with full canopy development (mid-July). A rapid decline in mid-August results from plant aging. Water use will be lower if moderate plant water stress is imposed at specific stages.

A desirable practice is to irrigate before planting, applying sufficient water to wet soils through the effective rooting depth. Cotton develops roots to a maximum depth of 6 to 7 feet if no restrictions are met.

With good soil moisture at planting and a normal climate, an optimal first irrigation for sandy loam soils can be delayed until the first week in June. Very sandy soils should be irrigated in late May. Soils able to hold large amounts of plant-available water (for example, clay loams) give best results if the first irrigation is in mid-June. Earlier irrigation may be desirable with temperatures higher than normal or high winds. A first irrigation that is excessively early or late will adversely affect the vegetative plant.

Proper timing of irrigations will stress cotton sufficiently to slow vegetative growth before water addition. For most soils, this corresponds to about 60 percent depletion of plant-available water in the effective rooting depth. This procedure improves production by giving a better balance between the development of vegetative plant parts and seed cotton. Avoid stress that is sufficient to cause prolonged plant wilting and leaf loss.

A severe water stress or deficit is most injurious during peak flowering. In one study, a 30 percent yield loss was caused by a severe water deficit for nine days during peak bloom. Severe stress in either early or late bloom was less harmful but still reduced yield by 20 percent. Close observation is needed to avoid severe stress during peak bloom, because that is the period of highest potential water use, as shown in figure 1.

Water management not only has a strong individual effect on the cotton plant but also interacts strongly with other management considerations, often in a complex way. Any factor causing loss of fruiting forms may complicate a desired plant water state and cause rapid vegetative growth (unfavorable to seedcotton production). Imposing a greater water stress than normal before irrigation can provide a degree of control over this phenomenon.

Studies were conducted over several years to determine the earliest date that irrigation could be stopped without a yield loss. Optimal timing of the final irrigation was found to be closely related to the water-retention proper-