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 properties of soils (see figure 2). Sandy soils of relatively low water-holding capacity must be irrigated until early September. Soils that retain large amounts of water in the profile can maintain productivity if a final irrigation during the first week of August completely rewets the soil profile.

The production function provides a useful means of analyzing water-productivity relations. This function gives necessary information for cotton price and water cost to be considered in determining an optimum amount of water to be used. Figure 3 gives a cotton function derived by combining field studies conducted at two locations over a three-year period. Total available water (W) is made up of plant-available water held by the soil at planting plus irrigation water added during the growing season. In establishing the function, yield loss from a water deficit was minimized by careful scheduling of irrigation. This provided the greatest yield possible with a given amount of water.

Cotton responds to increasing amounts of water with a conventional increase in production, although the rate decreases as greater quantities are used. Additionally, after the yield reaches a maximum, further watering decreases production.

It can be shown that, with a limited water supply, the total crop product can be greater if water is used on each individual acre up to the amount that gives maximum water use efficiency (pounds of cotton lint produced per inch of water used). Figure 3 shows this value where a water input of 21.8 inches gives a maximum 38.5 pounds of cotton lint for each inch of water (840 pounds per acre) at that input level. This input amount is a minimum that should be considered even if a water shortage means that the planted acreage must be reduced. The 38 inches needed for maximum yield provides an upper limit that should be considered. The profit-maximizing water use quantity is dependent on cotton price and water cost but will be within the rational-use zone of figure 3. For example, if the market value of cotton is $0.60 per pound of lint and water costs $30 per acre-foot, profit is greatest with a water use of 35.6 inches.

Consideration of profit-maximizing water quantity and proper scheduling provides a valuable tool for managing this important California commodity.

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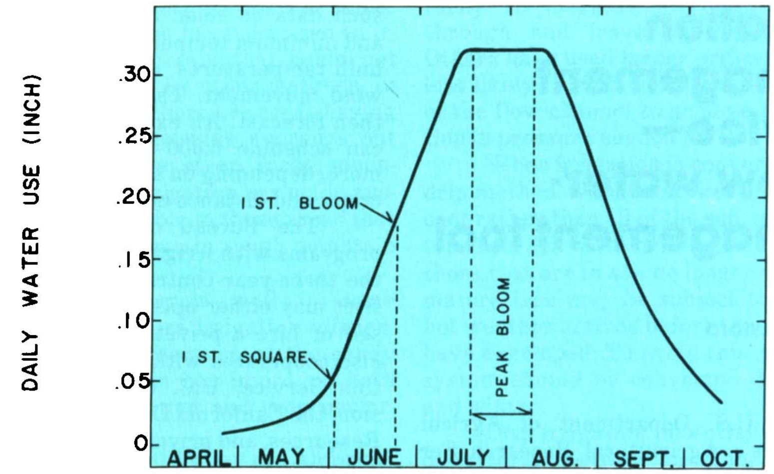

Fig. 1. Daily water use (evapotranspiration) of unstressed cotton in the San Joaquin Valley.

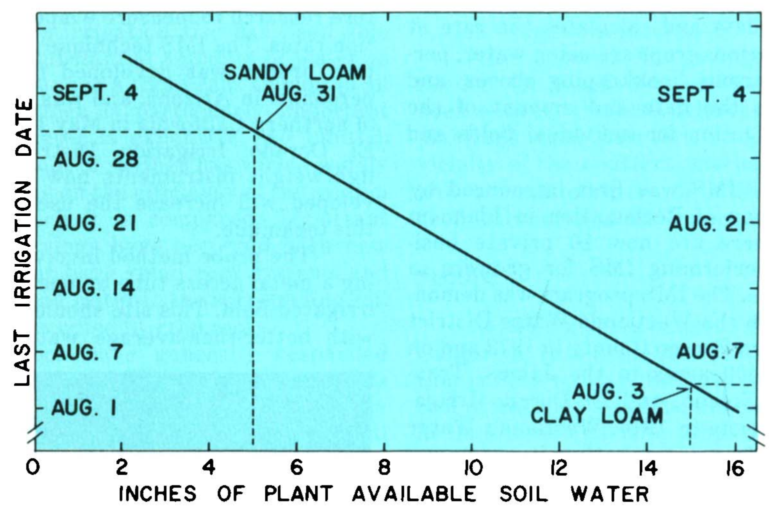

Fig. 2. Relation between soil-water-retention capability and last irrigation date to achieve 98 percent of maximum yield.

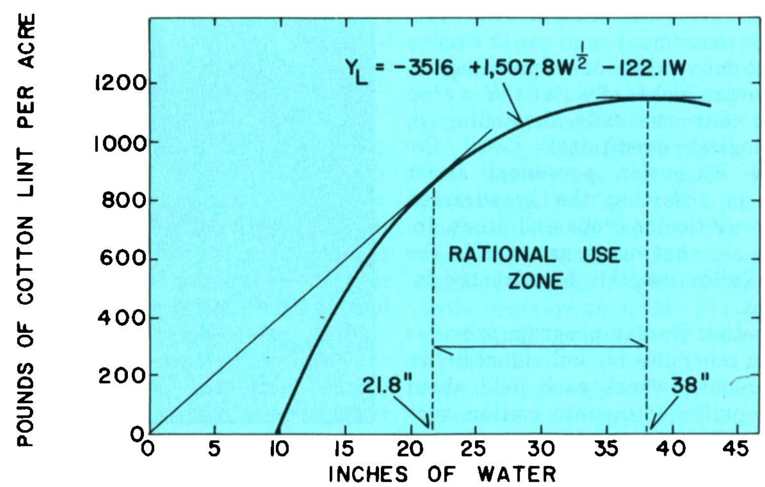

Fig. 3. Yield-water function for cotton, with the minimum and maximum water amounts that should be considered in a production system.