Irrigation scheduling under saline high water tables

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Approximately 400,000 acres in the San Joaquin Valley are classified as drainage problem areas. Levels of soil salinity detrimental to crop yield exist in these areas because of saline high water tables. One water district serving 264,000 acres needing drainage estimated that their production loss caused by drainage problems was about $17 million in 1981.

The traditional way of solving these problems is to install a subsurface drainage system, which removes the excess subsurface water to some disposal facility. Unfortunately, no completely satisfactory method of disposal exists in the San Joaquin Valley. Current disposal methods include discharging drainage water into surface water channels and evaporation ponds. Recommended future plans call for construction of a valley-wide master drain to convey drainage water out of the valley.

Regardless of the disposal method (present or future), growers in problem areas need to reduce the volume of drainage water discharged by means of proper design and management of their irrigation systems. One aspect of management is scheduling of irrigations.

Irrigation scheduling for well-drained soils involves estimating an allowable soil moisture depletion and then irrigating when this depletion has occurred. Methods of monitoring soil moisture depletion include using neutron moisture meters or tensiometers to estimate soil moisture or using estimates of crop evapotranspiration, which are then related to soil moisture depletion. The assumptions behind these scheduling techniques are that all soil water used by the plant is stored in the root zone and that plant stress is primarily caused by soil moisture depletion.

A saline high water table can invalidate these assumptions for two reasons. First, groundwater moving upward into the root zone can contribute significant amounts of the water needed by the crop. A study by UC researchers W.W. Wallender, D.W. Grimes, D.W. Henderson, and L.K. Stromberg, conducted on the west side of the San Joaquin Valley, found brackish groundwater contributing 59 to 70 percent of the total seasonal evapotranspiration of cotton. The electrical conductivity of the groundwater was 6 dS/m (6 mmhos/cm, or about 3800 ppm) and depth to the water table ranged from about 1.7 meters (5 feet) to 2.7 meters (9 feet). Second, plant stress may also be caused by high levels of soil salinity. Soil water salinity just after an irrigation may already be high where saline high water tables exist, and subsequent soil moisture depletion may rapidly increase the concentration of the salts in the water to a level injurious to plants. Thus, to minimize any adverse effects of salinity, irrigations may need to be more frequent than under low salinity.

Traditional methods of irrigation scheduling do not account for these effects. A method that does, however, is basing irrigations on plant response to changes in both soil salinity and soil moisture, since studies have found these effects are additive. Plant stress can be determined by measuring the leaf water potential of leaves with a pressure chamber. A leaf is cut from a plant and placed inside the pressure chamber with the cut stem, exposed to the atmosphere, protruding through a gasket. The chamber is slowly pressurized until sap exudes from the stem. The pressure (expressed as a negative number) at which exudation occurs is assumed to be the leaf water potential.

Research by D.W. Grimes and H. Yamada has provided information on using the pressure chamber for scheduling irrigation of cotton in the San Joaquin Valley. They recommend irrigating when the pressure chamber readings are between 18 and 20 bars. Measurements should be made between noon and 3:00 p.m. on three to five leaves using the third or fourth fully developed leaf from the terminal. Measurements for scheduling purposes should not be made on cloudy days.

We used this technique to develop a scheduling program for a farm of 48 hectares (160 acres) in a saline high water table area. Maximum depth to the water table during the summer was about 1.22 meters (4 feet). The electrical conductivity of the drainage water was about 7 dS/m (about 4500 ppm), while that of the irrigation water was about 0.2 dS/m (about 130 ppm). The soil type mainly consisted of an Armona clay for the top 10 inches. The rest of the soil profile was highly stratified with lenses of sand, silt, or clay. Cotton was grown during the period of this project.

Near the surface, soil salinity levels ranged from 1 to 5 dS/m (740 to 3200 ppm), but with increasing depth (to 1 meter below the surface), salinity levels increased to 10 to 12 dS/m (6400 to 7700 ppm). We therefore felt that soil salinity may be an important factor in irrigation scheduling.

In 1981, the grower's normal irrigation schedule was used, based on a soil moisture depletion of 76 mm (3 inches). With an average cumulative evapotranspiration for the southern San Joaquin Valley, a soil moisture depletion of 76 mm would occur every 15 days during June and every 10 days in July and August, and the grower followed that schedule. The schedule did not account for any upward movement from the water table or for soil salinity effects.

In 1982, we scheduled irrigations using pressure chamber measurements of leaf water potential. During both years, soil moisture and water table depths were measured. Measurements were also made with tensiometers to determine the direction of water movement above the water table.

Predawn and midday measurements were made with the pressure chamber in 1981. The predawn measurements failed to provide any information on changes in plant stress; little change in these measurements occurred between irrigations, except after the final irrigation. Changes between irrigations were observed for the midday measurements, but the data indicated the interval between irrigations could be increased, which was contrary to our expectations.

The pressure chamber data of 1982 show a linear relationship between leaf water potential and time after an irrigation (fig. 1). We took advantage of this relationship and extended the line to the day when a reading of 19 bars (−1900 kPa) would occur, which was then the day of the next irrigation. This procedure allowed us to predict the time of the next irrigation so that water could be ordered.

The interval between irrigations during the peak evapotranspiration periods (July and August) averaged about 14 days in 1982, compared with 10 days in 1981. Seven irrigations were applied in 1981, whereas six were applied in 1982. Thus, use of the pressure chamber allowed us to increase the interval between irrigations by about 4 days and to reduce the number of irrigations by one. The last irrigation of 1982 may not have been necessary since other UC research indicates that the final irrigation for this soil type should be between August 12 and 17. The grower felt, however, that our August 11 irrigation would not be adequate if weather was hot in September, as it was in 1981.

One might be tempted to attribute the difference in irrigation intervals to differences in seasonal evapotranspiration between the two years. The unusually

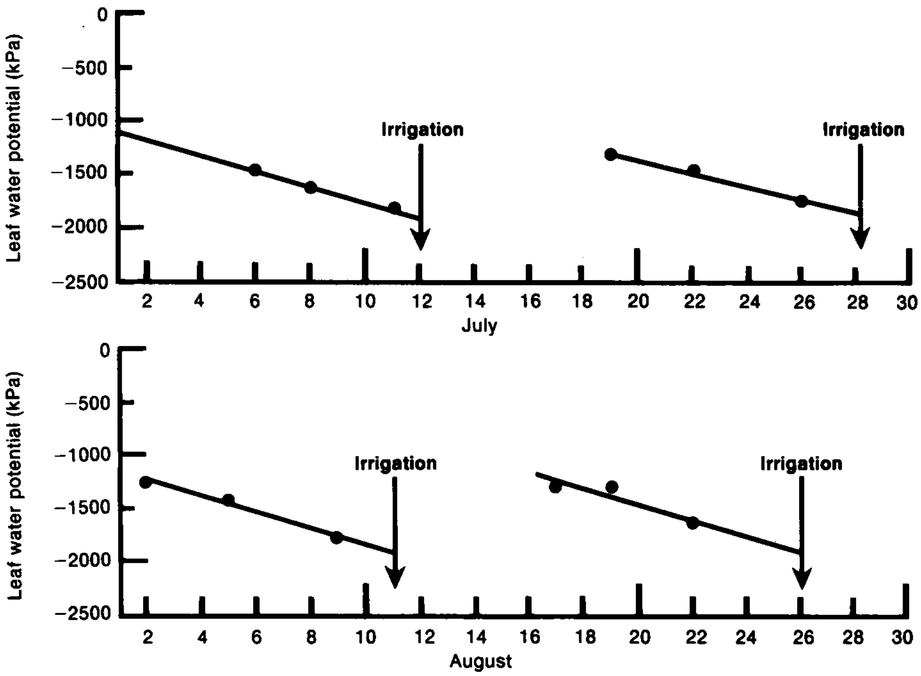


Fig. 1. Leaf water change with time made it possible to schedule irrigations in advance. (1 kPa = 0.01 bar)

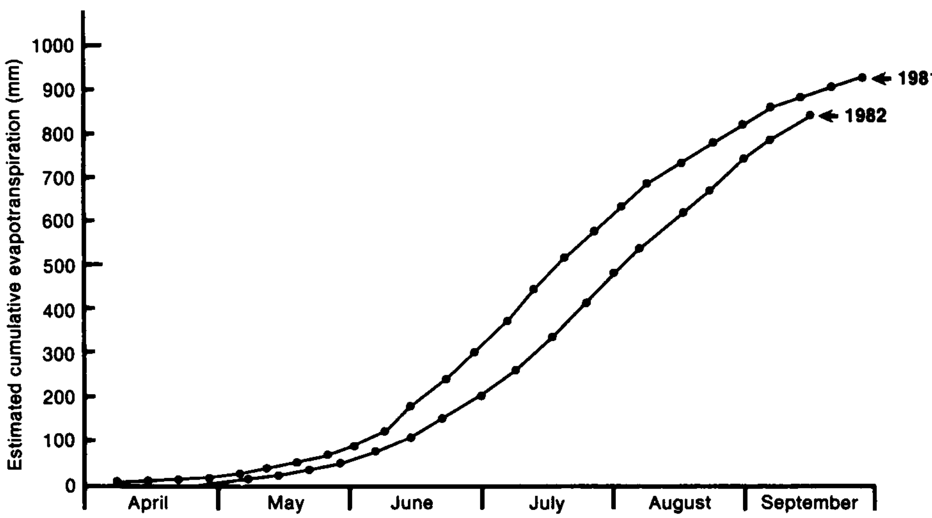
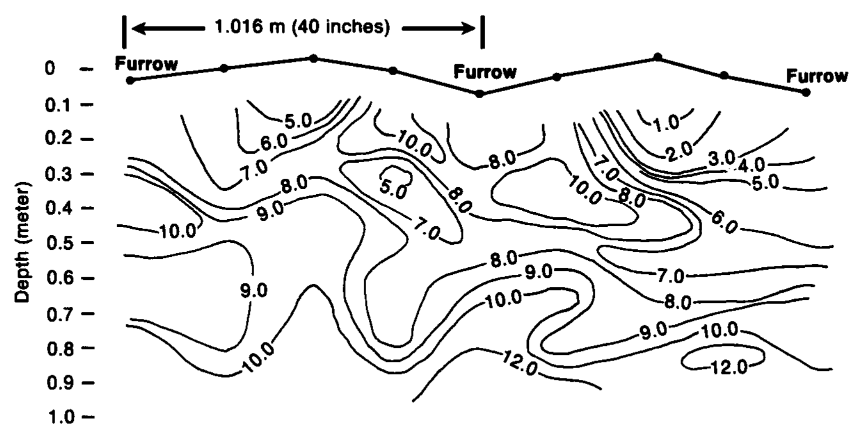


Fig. 2. Differences in cumulative potential evapotranspiration between the two years were not large.



Soil salinity (electrical conductivity of saturated extract) at project site increased from 1 to 5 dS/m near the surface to 10 to 12 dS/m at greater depths (1 dS/m = 640 ppm).

Leaf water potential four to six days after an irrigation (1982)

Date	Leaf water potential
	kPa
August 2	−1260
August 17	−1290
August 30	−1240

wet spring of 1982 forced the grower to delay planting until May 1, a month later than the 1981 planting.

Significant differences in cumulative maximum evapotranspiration between 1981 and 1982 existed early in the season, but the difference in seasonal evapotranspiration between the two years was only about 8 percent of the total 1981 evapotranspiration (fig. 2). During the peak evapotranspiration period of July and August, daily rates were about the same in both years.

An evaluation of water content data of both years showed that the increase in irrigation interval resulted in greater soil moisture depletion. The average depletion in 1982 was about 94 mm (3.7 inches) whereas in 1981 it was about 71 mm (2.8 inches). Thus, even though differences in planting days and seasonal evapotranspiration occurred, soil moisture depletion was greater when the pressure chamber was used for irrigation scheduling.

We estimated the contribution of the shallow groundwater to the seasonal crop water use by comparing changes in the soil moisture in the root zone between irrigations with the total evapotranspiration for the same period. The difference between the two is considered the volume of water supplied by upward movement into the root zone. With an assumed root depth of 0.68 meter (27 inches) (based on measurement of the tap root), we estimated that the average contribution from groundwater was about 19 percent in 1981 and 25 percent in 1982. However, we believe that these differences are insignificant.

One aspect to be considered in irrigating under a saline high water table is that of adequate leaching to prevent salt accumulation in the root zone. We believe that pressure chamber measurements made four to six days after an irrigation can be used to detect any increase in the salinity level of the root zone. In 1982, soil moisture in the root zone was approximately the same four to six days after each irrigation in July and August; thus, any significant increases in pressure chamber readings throughout the summer would be due to increases in salinity (excluding any effects of day-to-day variation of climate). Measurements made four to six days after an irrigation showed no significant change in leaf water potential (see table). This would be expected for the short time during which we collected data, if no appreciable increase in soil salinity had occurred.

Since day-to-day variation of the climate, as well as the root zone environment, can affect leaf water potential, we compared pressure chamber readings with solar radiation, maximum daily temperature, average wind speed, vapor pressure between noon and 3:00 p.m., and soil water content. We found little correlation between pressure chamber readings and the climate data, but good correlation between leaf water potential and soil water content. Thus, any day-to-day climatic variation had a negligible effect, but soil moisture changes had a significant effect on leaf water potential.

We believe that the pressure chamber, coupled with the information developed by the other UC researchers, provides a practical means for scheduling irrigations in areas with a saline high water table. In this study, the irrigation interval was increased by about four days during the peak evapotranspiration period and the number of irrigations reduced by one. However, yield at this site was 1,078 kg per hectare (1.9 bales per acre) in 1981 and 1,281 kg per hectare (2.2 bales per acre) in 1982. In our opinion, this yield difference is in part due to the differences in irrigation scheduling.

The need to increase the intervals between irrigations at this site was contrary to what we had expected. Normally, intervals between irrigations under saline conditions should be smaller than those under nonsaline situations to minimize yield reductions. Since we were able to increase the interval, soil moisture rather than soil salinity may have been the controlling factor for scheduling irrigations at that location. Nevertheless, under traditional methods of scheduling at this site, the influence of soil salinity could not have been as readily evaluated.

There is much interest in the feasibility of irrigating with subsurface drainage water. A number of projects are being conducted in California to address this matter. Their main objective is to look at the relationship between crop yield and irrigation water quality. This relationship, however, may depend not only on the water quality, but also on the irrigation schedule. Adjusting irrigation frequency according to measurements of leaf water potential could make a difference in the effects of a particular quality of water on crop yield.

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The medfly crisis:

Little research has been done on risk evaluation: how risks are perceived, what psychological and social factors influence perception, and how individuals interpret the impacts of events with uncertain consequences. The Mediterranean fruit fly eradication program provided an opportunity to assess public attitudes toward technological risks. This is a case study of 126 residents from a metropolitan area south of San Francisco, who, at the time, were undergoing exposure to aerial spraying with a pesticide.

The target pest, Mediterranean fruit fly *(Ceratitis capitata)*, infested a large portion of Santa Clara County, spreading into Alameda, San Mateo, Stanislaus, and San Joaquin counties. Using both attitude and behavioral assessments, we took the opportunity to study persons immediately exposed to a technological event of limited but unknown risk, which was generating considerable public debate.

Research on the perception of potentially hazardous technologies suggests that as the degree of exposure to, and experience with, specific hazards increases, risk perception decreases. These findings lead to the conclusion that for those living in hazard-prone areas, it is easier to change attitudes about living in potential risk situations than to change residences. Other data suggest that increased exposure to, or experience with, specific dangerous conditions may serve to reinforce indifference toward that condition, unless exposure has caused serious personal damage. Sex, age, and level of education have been valuable in predicting levels of risk perception. Generally women have a greater tendency toward risk avoidance than men. Younger subjects and those with higher education express greater concern over risk situations.

Acceptability of risks appears to be influenced by other factors, such as perceived benefit of technologies. High acceptability may also result when (1) one is better informed of the benefits of or has heard less about the risks of the event; (2) social traditions and norms