EFFECTS OF IRRIGATION ON SOIL AND CROP

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THE TEMPERATURE OF WATER released from large reservoirs is of concern to irrigated agriculture in California as well as other parts of the world, including Japan and northern Italy. Water is usually released from the bottom of the large, deep reservoirs, where the temperatures are low throughout the year At Shasta Dam in California, the temperature of reservoir water averages 45° F at the outflow. The completion of such large reservoirs can cause a major change in the water temperature of the rivers downstream.

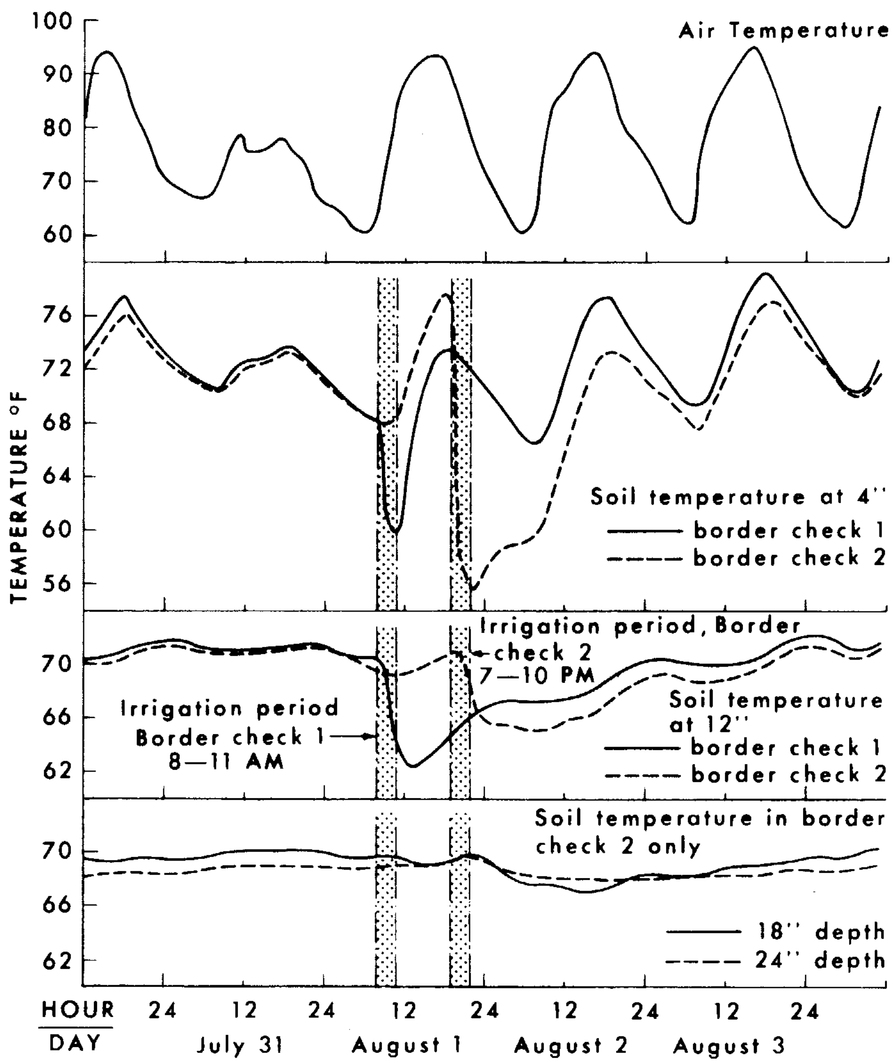
The effects of this colder water, as observed in recent years, have included a decrease in rice yields in the Sacramento Valley—primarily in fields directly irrigated from large irrigation canals. Cold water may also be beneficial, however, especially when used to cool soils planted to crops sensitive to high soil temperatures at certain stages of growth. Cold water can be detrimental to underground pipeline distribution systems, especially when used alternately with warmer water. Water sports are also adversely affected by cold water. Warm-water gamefish are less numerous, but salmon and other fish preferring cooler water may increase.

The influence of low water temperatures presently concerns agriculture along the Sacramento River downstream from Shasta Dam. Similar problems, perhaps on a more intensive basis, were predicted downstream from Oroville Dam on the Feather River. Possibly some portions of the area to be served by this water in the San Joaquin Valley will also be affected.

As the result of experience gained in the operation of Shasta Dam, plus measurements of water temperatures in the Feather River System and its service area, and information on possible detrimental effects from releasing cold water, the State Department of Water Resources is building a multi-level inlet structure for Oroville Dam. This will permit some control of the temperature of outflow water. For optimal use of this multi-level intake structure, more complete information on water temperature requirements for rice and other crops grown in the service area is needed. The possible extent and effects of delivering cooler irrigation water to areas of the San Joaquin Valley will also need more complete study. Investigation should also be made along the western part of the Sacramento Valley—which will receive relatively cold water from Shasta Dam through the Tehama-Colusa Canal. Information gained about water temperatures from reservoirs in the Sacramento Valley also raises the question of whether water discharged from reservoirs along the east side of the San Joaquin Valley may be cold enough to influence crop production there.

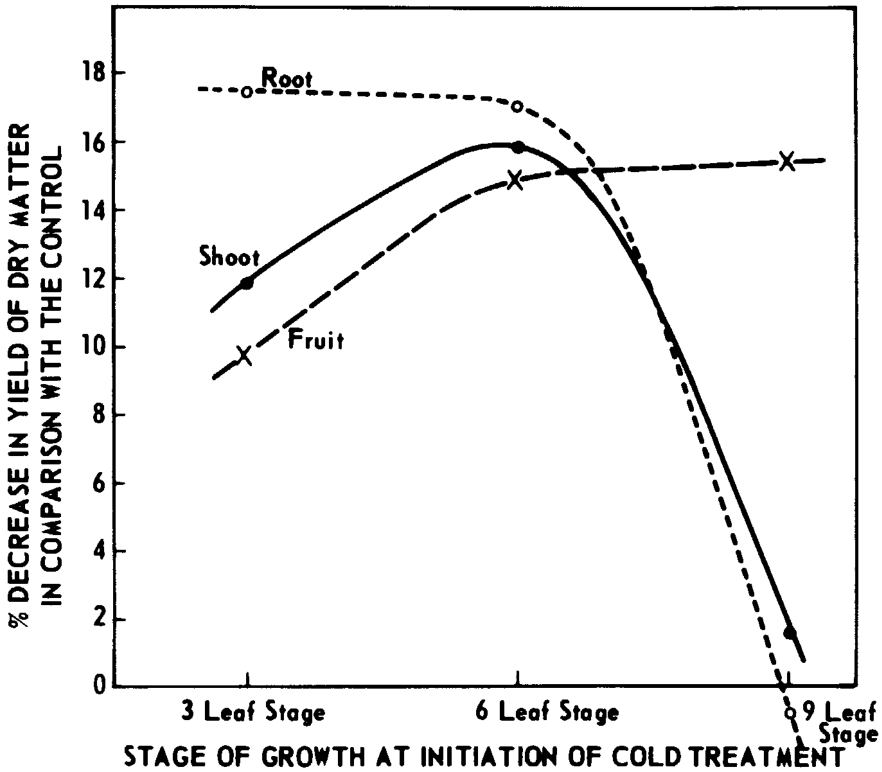
Since 1962, the Department of Water Science and Engineering at the Davis campus has cooperated with the State Department of Water Resources in their measurements of the water temperature in the Feather River, and in canals of the Feather River service area, using 12 thermograph stations along the principal distribution canals. Data now available show that daily maximum and minimum temperatures, when averaged over five-day periods, fluctuate for all stations in the service area. This is due apparently to changes in weather conditions and in the rate of flow of water in the canals. Although there is no well-defined relationship between the gain in water temperature in the district canals and the distance

Graph 1. Air and soil temperatures measured before, during, and after irrigation of alfalfa—at 40 ft from the intake in two parallel border checks. Temperature of irrigation water was 52°F during irrigation of border check 1 and 56°F during irrigation of border check 2.



COLD WATER TEMPERATURE GROWTH

Limited studies with water temperatures, as reported in this article, indicate soil temperatures are reduced for short periods of time with possible effects on yield where crops are irrigated frequently with cold water.



Graph 2. Per cent decrease in yield of Red Kidney beans given periodic cold treatments (50° F) for 72 hours, compared with control plants at a constant soil temperature of 77° F.

from the intake on the Feather River, the average monthly gain in different canals ranges from 0.05° F to 1.0° F per canal mile. Thus, the average increase in temperature of water flowing through district canals may be as low as 0.5° F per 10 miles of canal length or as high as 10° F per 10 miles of canal. These differences in temperature increases are caused mainly by differences in canal dimensions and flow rates.

Very little information has been available on changes in soil temperatures resulting from irrigation. To obtain such information, a soil temperature measurement program was set up in the Anderson Irrigation District south of Redding, where the irrigation water temperature averages a low 50° to 55° F the year around. Fields planted to alfalfa, mixed pasture, and corn were selected. Soil temperatures were measured and recorded at hourly intervals with thermocouples at 0, 4, 12, 18 and 24 inches below the soil surface and located 20, 40, 80, 160 and 320 feet from the head ditch.

A typical set of soil temperature data taken during irrigation of an alfalfa field is given in graph 1. From these, and other soil temperature data, it was found that at 4-inch soil depth the temperature drops to within 2 to 3° F above that of the applied irrigation water. Changes in soil temperature due to irrigation decreased at lower depths. At the 24-inch depth in most soils, these changes were minor—usually less than 3° F. However, in a dry, sandy-loam soil with a rapid infiltration rate and at a relatively high initial soil temperature, a drop of 9° F was recorded at the 24-inch depth (from about 82° F down to 73° F).

Changes in soil temperature were generally of short duration. Within 24 hours after irrigation, the soil temperature at the 4-inch depth tended to return to its pre-irrigation level. Temperature changes at greater depths persisted longer. At least 48 hours were required to regain the original temperature level at the 12-inch depth.

The warming of the irrigation water as it moved down the field caused the soil temperatures to drop less at 320 feet from the head ditch than close to the water intake on the field.

The extent of changes in soil temperature caused by irrigation was found to depend upon many factors in addition to the water temperature—including the amount of irrigation water applied, soil type, distance from the irrigation ditch, and time of day. The influences of these factors on resultant soil temperatures have not yet been evaluated. More detailed laboratory studies are underway to provide information that may allow prediction of changes in soil temperature.

These and earlier experiments were conducted using either thermographs, or thermocouples and a multipoint recorder for measuring soil temperatures. Thermographs must be properly installed and frequently calibrated, preferably in place. The thermocouple system proved to be very useful for field measurements and gave more reliable results than the thermographs.

The effects of lowered soil temperatures on plant growth were studied in greenhouse experiments set up to simulate the effects of irrigation with cold water under field conditions. Previous studies of Caloro rice showed that it matured only when water temperatures remained above 70°F. In later greenhouse experiments, it was reported that a drop in root temperatures from 77° to 59°F for a period of only five days had a depressing effect on yield of Caloro rice, particularly when the low temperature occurred during tillering and flowering. Some interaction between changes in soil temperature and rate of fertilization was also observed in these previous studies. Increased phosphate fertilization in some cases minimized the detrimental effects of a lowered soil temperature.

Studies with beans were started in the summer of 1964. Red Kidney and Sutter Pink beans were grown at constant soil temperatures of 59°, 68°, 77°, 86°, and 95°F. Yields of shoots and roots increased gradually with increasing soil temperature reaching a maximum of 86°F for shoots and 77°F for roots. Yields decreased sharply at root temperatures above the optimum values.

In a subsequent experiment, Red Kidney beans were grown at a constant soil temperature of 77°F. At various stages of the growth cycle, the temperature of the soil was lowered to 50°F for three days. The yield of shoot and root material was decreased by 17% when plants were given a single cold treatment early in the growing cycle (3-leaf stage) and by 14% when chilled at the 6-leaf stage (see graph 2). Lowering the soil temperature at the 9-leaf stage did not affect vegetative growth, but the yield of beans was 15% below that of the plants grown at a constant 77°F soil temperature. Repeated cold treatments—lowering root temperature for three days early in the growing cycle (3-leaf stage) and during two additional 3-day periods at 10-day intervals—caused the greatest yield reductions (25% less shoots, 28% less roots, and 34% less fruit).

Field plots

The effect of cold water on crop growth was also studied under field conditions. Plots of undisturbed soil 3 ft × 3 ft were insulated from the surrounding soil by rigid foam walls 2 inches thick and 20 inches deep. Red Kidney beans and pickling cucumbers were planted in two successive experiments. Treatments consisted of irrigating with water of 50°, 59°, 68°, and 77°F for beans and of 41°, 50°, 59°, and 68°F for cucumbers. Resulting differences in soil temperature patterns between treatments were minor, however, due to warming of the irrigation water on the soil surface before infiltration. No significant differences in growth or yield of shoots or fruit were found between treatments, indicating that possible shock effects of cold irrigation water may not be very important. Because of the slow infiltration of the irrigation water into the soil in this experiment, and the resultant warming of the water, extrapolation of these field plot data to predict effects on yield under field conditions must be done with caution.

These temperature studies were too limited to provide general conclusions. However, results indicate that yields of crops other than rice may also be reduced under field conditions, particularly if each of frequent irrigations with cold water causes an appreciable lowering of the soil temperature for several days. On the other hand, certain crops (including potatoes, lettuce and strawberries) have been reported to benefit from a decrease in soil temperature. Both detrimental and beneficial effects would presumably depend on type of crop, on the stage of growth at the time cold water is applied, and on what part of the plant is to be harvested.

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