Water Temperature in Irrigation

cold water damage to rice can be controlled by use of small unshaded warming basins before water is applied to fields

Franklin C. Raney, Robert M. Hagan, and Dwight C. Finfrock

Rice yields have been reduced during recent years in northern California, because of cold water damage near field intake boxes.

Since the construction of Shasta Dam, water temperature in the Sacramento River approximately 13 river miles below the dam has dropped an average of 16°F, to approximately 51°F and at the city of Sacramento, 260 river miles south, reduced by 5°F, to about 66°F. As more dams are built to maintain high summer flow rates for irrigation in other areas of central and southern California, water temperatures may be expected to fall still farther. Construction of Oroville Dam can be expected to cause the Feather River—from which much rice is irrigated—as well as the Sacramento River to become colder during the growing season.

In past years cold water damage to rice has seriously affected about 5% of the planted area. Even this apparently small percentage represents a direct loss to growers who must bear the cost of land preparation, seeding and irrigation on the unproductive acreage. Plants are delayed in heading, heads do not fill, or maturity is not reached by the end of the normal growing season.

Cold water in the large rivers or canals warms up some, it is true, but only about 10°F during the growing season at any one place and about 1°F per 10 miles moved by the water. At the grower's headgate in northern California, water temperatures in the high fifties or low sixties are common during the season. After water enters the rice field it spreads out and warms up as it runs through successive checks. The mean water temperature may increase at least 7°F in going from the intake to the end of the third check. It continues to warm going down the field. Even during the last half of the summer—when the water is shaded by the maturing rice plants—some warming occurs as it passes across the rice field.

Such water warming in the field is reflected in higher rice yields. As intake water is warmed yields increase and after the first few checks they reach field average. In this way the first checks are serving as water warming basins, although inefficiently.

Field studies during the last three years have shown that small weed-free water warming basins can successfully raise the mean water temperature to 70°F or higher throughout the growing season. A temperature of 70°F is about the lowest that the present varieties endure without showing damage or seri-

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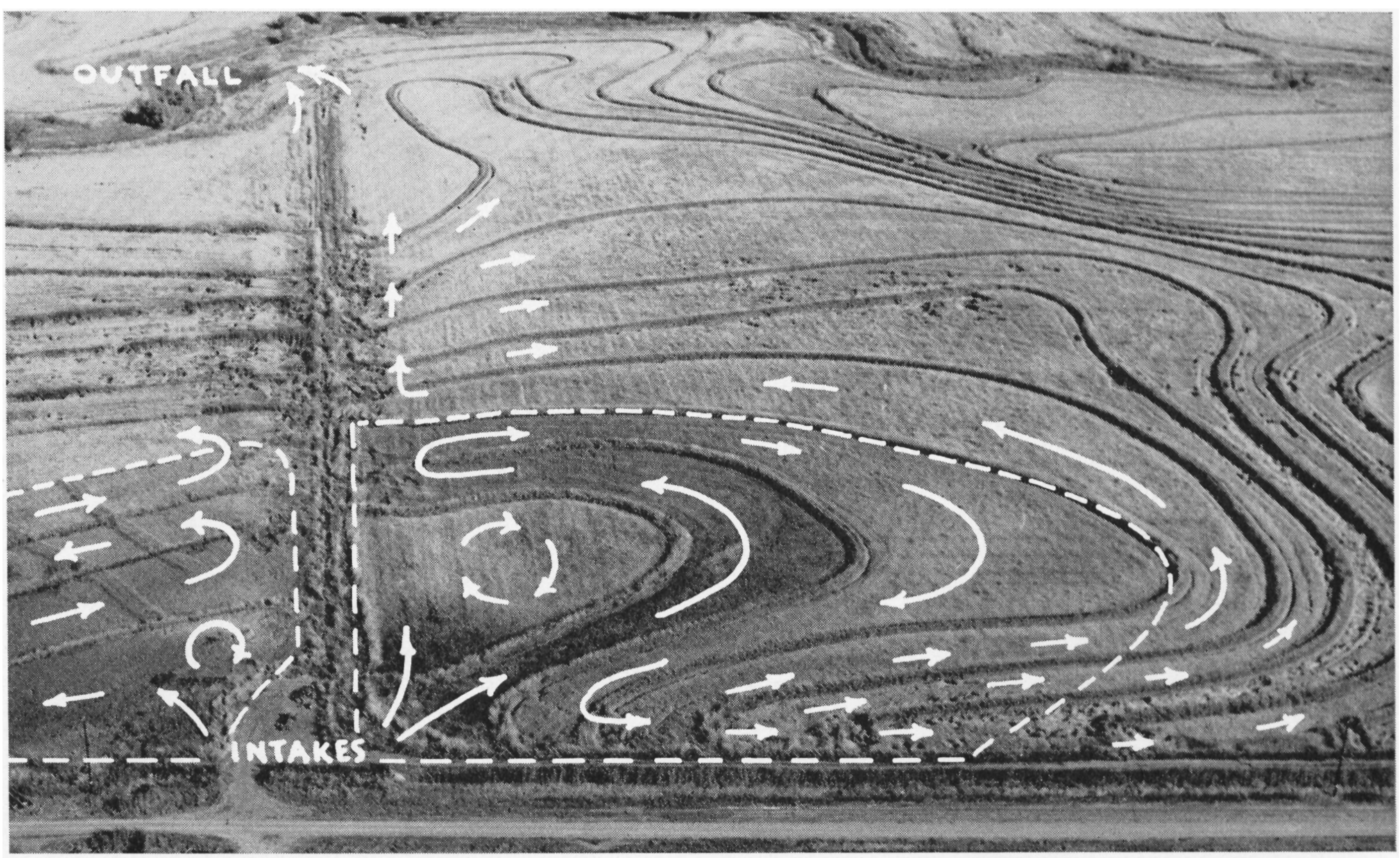
Rice field in Glenn County in October 1953, showing water circulation—white arrows—and plant immaturity in checks near intake. Damaged areas are dark colored in the photograph and enclosed by a dotted line. Note stagnant area with mature rice in first check.



TEMPERATURE

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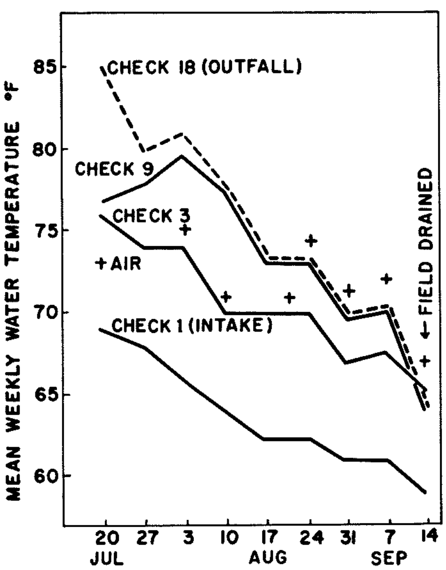
ously delayed maturity. Approximately square basins, equal to about 2% of the planted area and 24″ deep raised the mean water temperature about 5°F; basins 12″ deep, about 7°F; 6″ deep, about 9°F above intake temperature.

The yield of rice was related to the degree of shading and depth of water in the warming basin serving the rice plot. If the warming basin were kept weed-free, even the checks near the intake produced a nearly normal yield. On the other hand, plots served from warming ponds shaded by weeds—or immature rice—consistently produced the lowest yields. In two years out of three, yields in plots served from unshaded ponds 12″ and 24″ deep were lower than those from unshaded ponds 6″ deep. During the third year, however, yields below the 6″ weed-free ponds were lower than those below the deeper ponds, presumably because of a different combination of meteorological factors. The relationships involved are receiving further study.

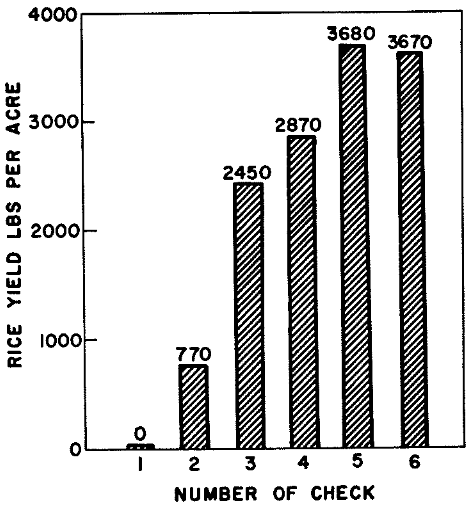
Warming of water in passing through a rice field during the latter half of the season when the water is shaded by rice plants. Checks are numbered successively downfield from the intake check.



Studies were made at Davis in outdoor plots during the last two years to determine water temperature requirements of Caloro rice grown under continuous flooding with water 6″ deep.

Ten water temperature treatments with four replications were used. In Treatments *1–4*, water temperature—day and night, from sowing until the water was drained prior to harvest—was constant at 65°F, 70°F, 80°F, and 90°F. In Treatment *5*, water temperature cycled with days at 80°F and nights at 70°F. In Treatment *6*, days were 70°F and nights 80°F. In Treatments *7–10*, water temperature was constant at 70°F day and night, except that the temperature was held at 90°F during one of the four growth stages and then returned to 70°F until water was drained prior to harvest. The four growth stages during which the temperature was elevated were: germination to emergence in Treatment *7;* emergence to tillering in Treatment *8;* tillering to heading in Treatment *9;* and, in Treatment *10*, from heading to maturity.

Rice yields in successive checks downfield from intake in the same field.



The higher the constant water temperature the earlier was the maturity date. The two cyclic treatments—*5* and *6*—matured on the same date. Of the plants held at 70°F, application of 90°F water from tillering to heading resulted in earliest maturity. In the constant temperature treatments, grain yields diminished in the following order: 80°F, 90°F, 70°F and 65°F. Both day-night cyclic treatments outyielded all other treatments. Elevating the temperature to 90°F from emergence to tillering resulted in a higher yield than by the same elevation of temperature during other growth stages.

Thus, it appears that the commercial rice variety Caloro shows two effects from water temperature: it matures only when water temperatures average above a minimum threshold of about 70°F, and yield is increased by applying warmed water at certain growth stages.

Warming Pond Materials

The possibilities of minimizing rice yield losses from cold water by use of warming ponds point to the importance of finding ways to increase the warming efficiency of the ponds.

During most days of the growing season about 40% of the incoming solar energy is lost from a water basin through evaporation. This loss can be much greater on windy days.

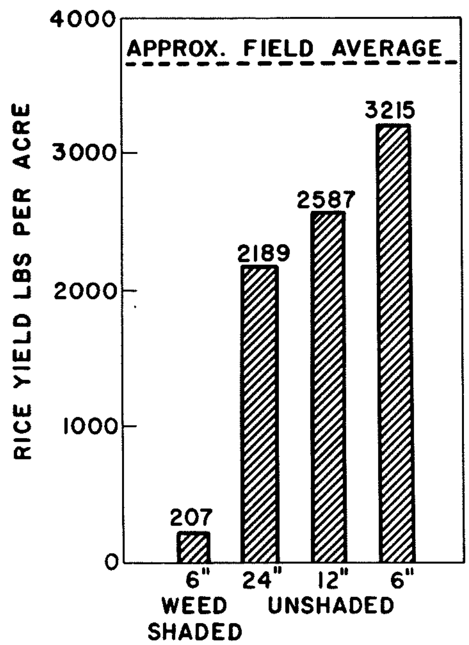
A combination of membranes or films which sharply curtail evaporation could result in higher water temperatures. The required area of warming basins might be considerably reduced.

Recent trials were made at the Rice Experiment Station at Biggs with polyethylene floating membranes 2–4 mils—thousandths of an inch—thick.

A transparent membrane permitted light to pass and at first produced higher water temperatures. However, weeds flourished beneath and tended to lift the membrane. Algae and diatoms coated the under side of the membrane while dust deposits on the top increased the reflectivity of the surface. As a consequence the water temperature gains later fell sharply.

A floating black, opaque membrane completely eliminated weeds. However, even with baffled, turbulent flow in the basin, the energy saved by reducing evaporation was approximately offset by the energy lost because of the opacity of the film. Accordingly water temperature gains were small.

Effect of water depth and shading in warming ponds on rice yield in basins directly served from ponds. 1953–1956.



A proposed combination of membranes may be more successful. A black, opaque membrane covering the basin floor would eliminate weeds. Baffles placed to minimize thermal stratification would ballast the bottom membrane. Use of a flexible surface film of a long chain carbon compound would permit dust to fall through, reduce evaporation, permit free light passage, and result in large water temperature gains. Installation and maintenance costs appear reasonable.

The design of an efficient water warm-

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MOVEMENT

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phere suction value—about 75% of the available water has been removed from the Fallbrook soil and approximately 60% from the Holtville soil.

Further studies of moisture extraction from soils are being made under controlled conditions without using plants. Soil columns are positioned horizontally and brought to equilibrium with water at approximately 30 millibars. This is often a value read on tensiometers following an irrigation in the field. A constant suction is then applied at one end of a soil column, by applying a controlled vacuum to one side of a porous ceramic disc the other side of which is in direct contact with the soil. The lower left graph on page 24 shows the accumulated water extracted from soil columns when the suction of 900 millibars was maintained constant. The extracted water was measured in surface inches in relation to the area of the soil column.

In the same length of time, 80% more water was extracted from a column of soil 14″ long compared with the same column when it was cut down to 7″ in length. This would indicate that, for this Fallbrook sandy loam, root-free portions of the soil 7″ away from roots can make substantial contributions to water extracted by roots.

Soils vary greatly in their ability to conduct water. A comparison of three soil types shows that under the same controlled laboratory conditions the water extracted from a Ramona sandy loam soil was approximately twice as much as from a Fallbrook sandy loam and threefold that from a Yolo loam. The curves comparing various soils were all obtained using 14″ soil columns.

For these studies of soil moisture movement, fragmented soil samples were screened and compacted in the columns. Further studies will be made on undisturbed cores.

If only moisture flow rates are measured—to compare the ability of various soils to conduct water—the size and shape of the soil sample and suction equipment would need to be standardized. However, when continuous records of the moisture suction values are obtained at various locations along the soil column, as well as moisture extraction rates, computations can be made expressing the conductivity values of a soil as a function of the moisture suction. These values are characteristic of the soil and independent of the methods of measurement. They can be used to characterize different soils or study the effects of soil management practices on the same soil. Also, when suction values in the field are measured by tensiometers, flow rates can be estimated.

Studies of moisture movement in soils in the liquid phase are made under constant temperature conditions. Thermal gradients within the soil column, which result in water vapor diffusion, can cause significant disturbances to the measured liquid flow.

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In most cases not enough water can be stored in the soil to last throughout the season. Where water penetration is slow, more water can be applied by irrigating more frequently or by increasing the time the water is on the land surface at each irrigation. Both approaches have advantages and limitations. More frequent irrigation may be accomplished without any other change in the system or in practice, but has the disadvantage of higher labor costs. It may be an inadequate measure for the more difficult problems. Prolonged irrigation may require substantial changes such as converting from furrows to basins in which water can be ponded for long periods or using small furrows to insure better coverage of border strips with small streams. Irrigation of crops susceptible to injury or disease under prolonged irrigation can not be managed in this way, and the practice may encourage growth of water-loving weeds. However, such methods may be the only means of increasing the productivity of soils with very slow water penetration even though changes in cropping pattern or farming operations are required.

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ing facility must provide for maximum energy capture, discharge water at a temperature giving maximum rice yields, occupy a minimum land area, with reasonable installation and maintenance costs.

From experience in rice irrigation, water temperature may be expected to influence the growth of other crops. However, it is difficult to predict the influence of water temperature on yields because of its numerous direct and indirect effects on the plant. In addition to the cold water damage reported here, crop injury is sometimes associated with warm water.

As more is learned about its effects on irrigated crops, water temperature may become a factor of considerable importance in the selection of crops and their management for maximum yield and minimum unit cost.

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MEASUREMENT

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grove was on a two week irrigation schedule. The irrigation water applied July 19 and August 3 reached the 12″ soil depth but did not wet the soil at the 18″ depth to field capacity.

The time and place to use either tensiometers or blocks depends to a large extent on climatic conditions and soil types and to a lesser extent on the nature of the crop. In inland areas of southern California where high water losses may cause stress conditions in plants, timing of irrigations becomes very important. Tensiometers have proved to be valuable tools for timing irrigations in citrus and avocado groves. However, in the more humid areas where irrigations are intermittent, along with rainfall, resistance blocks are used with satisfactory results. Resistance blocks made of gypsum rather than fiberglass or nylon are generally preferred in agricultural soils.

The neutron method is still a research tool although it might be valuable on large agricultural acreages.

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QUALITY

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in the Imperial Valley. Here Colorado River water is used for irrigation and contains large quantities of sulfate, which produces this toxic symptom.

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