257

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Sprinkler-Induced Soil Temperature Changes Under Plant Cover

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ABSTRACT

An experiment was conducted to determine the amount of soil temperature reduction to be expected from irrigating potatoes (*Solanum tuberosum*) at various intervals. Soil temperatures were measured at the 10-cm depth under potato ridges with various amounts of plant cover. The mean daily soil temperature at the 10-cm depth in a silt loam soil after 7 days following irrigation increased as much as 2 C above the daily irrigated plot with full cover and 4 C above the daily irrigated plot without cover. Similar soil temperature increases occurred in a loamy fine sand soil irrigated after 5 days which is the normal irrigation intervals for these soils.

Additional index words: **Frequent irrigations, Potatoes.**

SPRINKLER irrigation has been shown to reduce soil temperatures for both bare soil (5, 7) and soil beneath growing crops (4, 6). Depending on the crop grown and existing climatic conditions, sprinkler irrigation could benefit or hinder crop production by reducing soil temperatures. However, the extent of soil cooling induced by different irrigation intervals has not been established.

An experiment was conducted to determine the amount of soil temperature reduction to be expected from irrigating potatoes (*Solanum tuberosum*) at various intervals.

Soil temperatures were measured at the 10-cm depth. A total energy balance at the soil-air boundary was not possible because the energy stored in the soil on a daily basis was less than 5% of the net radiation and less than the error involved in predicting the partitioning of the available energy.

MATERIALS AND METHODS

The experimental sites were located on the Snake River Plain at an elevation of about 1,200 m. The mean minimum, mean maximum, and mean air temperatures at the 1.5-m height and soil temperature at the 10-cm depth for 12 to 14-day periods during data collection (Table 1) were near normal for the area and illustrate the large diurnal air temperature fluctuations typical of mountain climates. In 1970, 'Russett Burbank' potatoes were planted on April 30 on Portneuf silt loam, and in 1971 on May 3 and 25 on both Portneuf silt loam and Minidoka loamy fine sand. Rows were spaced 76 cm apart in a north-south direction and ridged or hilled about 12 cm above the furrow bottom. Temperature sensors were placed 10 cm below the ridge center. Standard cultural practices were followed except for irrigation intervals. All water was applied by solid set sprinklers on a 9.5 × 9.5 m spacing. In 1971, each planted plot was adjoined by a ridged, bare plot to compare the effects of plant cover with bare soil.

The irrigation treatments imposed were: 1) daily irrigation to maintain the soil moisture tension at the 30-cm depth near 0.4 bar on the silt loam soil and 0.2 bar on the loamy fine sand; and 2) irrigation at 10 to 14 days on the silt loam soil, and 9 to 10 days on the loamy fine sand to evaluate soil temperature changes over extended irrigation intervals. Exploratory measurements indicated that the 10-cm soil temperature 1 day after irrigation returned to values very close to that of plots receiving daily irrigations. Therefore, the daily irrigation treatment was used as the base temperature to which the soil would be cooled by sprinkler irrigation on any day. The rise in temperature of a plot with time after an irrigation above the daily irrigated plot indicated the temperature drop to be expected by an irrigation on a given day. Irrigating at 10 to 14-day intervals resulted in higher soil moisture tensions than desired for good potato production; therefore, yield data were not collected. Initially, cross-sectional soil temperature patterns were measured but were not found to add appreciably to temperature differentiation between plots beyond that obtained from measurements at the 10-cm depth below the surface of the ridge center, which is in the tuber development zone. Both recording thermographs and multipoint recorders with thermocouples were used to monitor soil temperatures. Data from 3 to 12 locations per treatment were averaged for analysis. The standard deviation of the temperature increase above the mean for the daily irrigated plots ranged from 0.22 to 0.91 C with an average of 0.60 C for the thermocouples. The average standard deviation for the thermographs was 0.62 C. Percent crop cover was estimated from photographs taken at weekly intervals.

RESULTS AND DISCUSSION

Irrigation intervals of 9 to 14 days returned the mean soil temperature at the 10-cm depth on the day following irrigation to that of the daily irrigated

Table 1. Average air and 10-cm depth soil temperatures with plant cover at Kimberly, Idaho during 1970 and 1971.

Date	Air temperature			Soil temperature		
	Min	Max	Mean	Min	Max	Mean
	°C					
Aug 1 to 15, 1970	11.7	30.0	20.8	15.5	23.4	19.5
Aug 15 to 31, 1970	12.1	30.6	21.3	15.6	22.4	19.0
Jul 15 to 31, 1971	14.6	32.5	23.6	16.9	21.2	19.0
Aug 1 to 12, 1971	15.1	33.2	24.1	17.5	23.2	20.4

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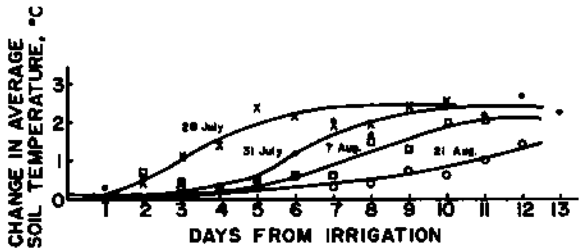

Fig. 1. The rise in the average soil temperature at the 10-cm depth of the biweekly irrigated plots above that of the daily irrigated plots on Portneuf silt loam, 1970.

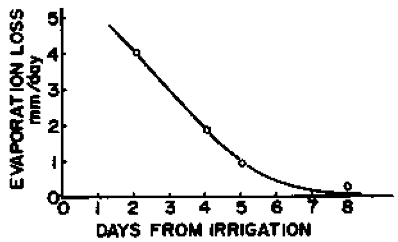

Fig. 3. Evaporation loss of water from a bare, level plots of Minidoka loamy fine sand irrigated on August 23, 1971.

plots. The soil temperature difference between these two irrigation treatments at this depth, instead of the absolute temperatures, was considered as the primary dependent variable because it represented the manageable change in temperature that could be achieved by irrigation. This difference was plotted as a function of days since the start of an irrigation on treatment 2 (Fig. 1 and 2). The curves were fitted by eye. The different curves in Fig. 1 represent data for plots irrigated as designated. Very slow crop cover establishment in 1970 permitted comparisons during periods of relatively warm air temperatures with only partial crop cover (Table 1). Fifty percent cover was achieved by July 27, and full cover was achieved by August 18. With partial cover (Fig. 1), the soil temperature of the plot irrigated on July 28 increased more rapidly above that of the daily irrigated plot than did plots irrigated bi-weekly later in the season. The maximum cooling attributed to daily irrigation amounted to only 2.5 C at the 10-cm depth.

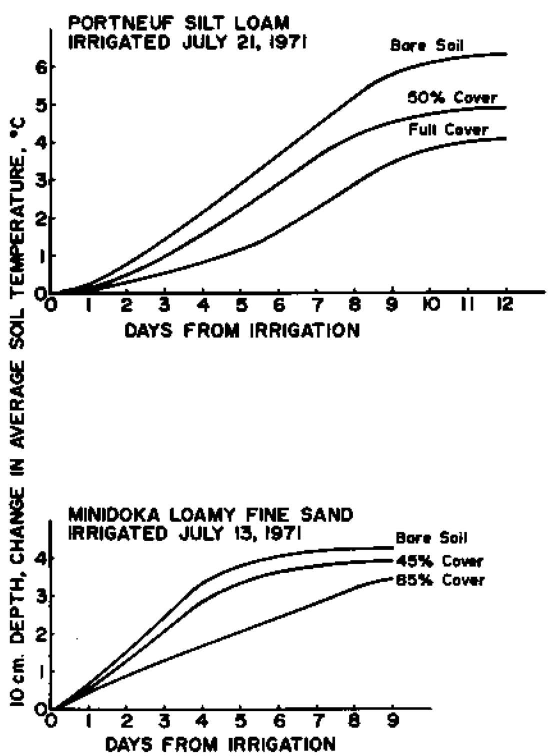

Fig. 2. The rise in the average soil temperature at the 10-cm depth of the biweekly irrigated plots above that of the daily irrigated plots on Portneuf silt loam, and on Minidoka loamy fine sand, 1971.

The temperature difference between the two treatments was greater in 1971 than in 1970. The mean air temperature was 2.8 C warmer in 1971 than in 1970 and the relative humidity was lower, 21 vs 38%. Whether or not the 1971 conditions could produce enough additional evaporative cooling to lower the daily irrigated soil temperature and increase the biweekly irrigated soil temperature enough to cause greater temperature differences in 1971 is difficult to determine.

As expected, the temperature difference was greatest for bare soil and intermediate with partial cover. The temperature difference increased more rapidly for the loamy sand than for the silt loam and appeared to be associated with the conductance of soil moisture to the soil surface and drying of the surface. The evaporation rate curve for the bare loamy sand following an irrigation (Fig. 3) decreases almost proportionally to the increase in the bare soil temperature rise curve (Fig. 2). Because 59 cal are consumed in the evaporation of 1 mm of water cm^{-2}, significant quantities of energy are converted to latent heat in the vaporization of water from a moist soil. The withdrawal of this amount of energy from soil heat storage would lower the 10-cm soil temperature almost 4 C, which is the difference between the wet and dry plots. Although more than 1 mm day^{-1} was evaporating from the freshly irrigated soil, the additional energy must have been supplied by radiant energy exchange and convective heat transfer from the air.

Because an irrigation returned the mean soil temperature at the 10-cm depth to that of the daily irrigated plots, the data allow an estimation of the amount of cooling to be expected by irrigating at different time intervals. During the period of high water use in July and August, it is usually necessary to irrigate potatoes at 5 to 7-day intervals on Portneuf silt loam. An irrigation after 5 to 7 days might reduce soil temperature 1 to 2 C under full cover during warm weather and less during a cooler period. A temperature reduction of 4 C or more could be experienced for bare soil. Solid set sprinkler irrigation often allows more frequent irrigations, which would result in a smaller temperature rise between irrigations and a 1 to 2 C lower average soil temperature.

On Minidoka loamy fine sand, irrigation intervals are usually 3 to 5 days during midseason in southern Idaho. Because of the rapid temperature rise after an irrigation, regular irrrigation intervals would also result in a 1 to 2 C soil temperature reduction when water is applied with full crop cover. A greater temperature response would be expected with partial cover or bare soil. The cooling effect of sprinkler irriga-

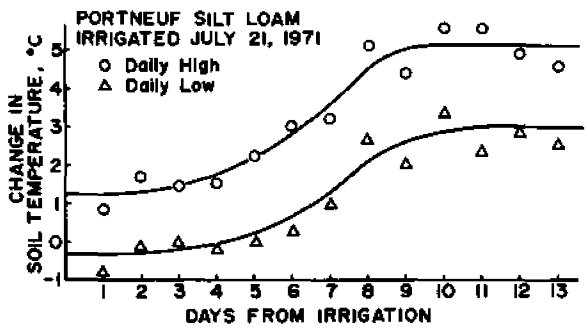

Fig. 4. The rise in the daily high and daily low soil temperatures at the 10-cm depth of the early planted Portneuf silt loam plots irrigated on July 21, 1971 above those of the daily irrigated plots.

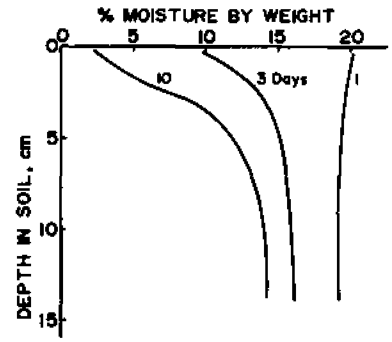

Fig. 5. Soil moisture profiles under a bare soil surface of Minidoka loamy fine sand on different days after irrigation.

tion could be more significant on this sandy soil than on the silt loam soil.

The cooling from irrigation reduced both the daily high and low soil temperatures for Portneuf silt loam (Fig. 4). If a lower soil temperature would be beneficial to a particular crop, then frequent irrigations would reduce the daily high soil temperature. Conversely, if higher soil temperatures would be beneficial, less frequent irrigations may be desired.

The importance of soil temperature reduction by irrigation depends on the sensitivity of the crop to changes in soil temperature. This plant response may change at different locations and different stages of growth. For example, it may be desirable to maintain long irrigation intervals between planting and emergence of potatoes to encourage rapid sprout growth and reduce rhizoctonia damage (8). More frequent irrigations would be desirable during tuber initiation and growth to encourage a larger set and yield in a moderately warm climate (1, 3) where a large set is desirable. This would not be the case in cooler, high mountain valleys where soil temperatures are often suboptimal.

The surface of Minidoka loamy fine sand dried quickly and the rate of evaporation loss decreased rapidly after an irrigation (Fig. 3). This left a few centimeters of dry sand on the surface with relatively moist sand below 5 cm (Fig. 5). Field capacity was determined by measuring the soil moisture content with time in a plastic covered plot after saturation and found to be near 17% moisture by weight for the plow layer. Figure 5 suggests that over winter precipitation or an irrigation at planting may provide sufficient soil water for potatoes through emergence. This would allow the soil to warm after the initial irrigation and encourage more rapid emergence and reduced rhizoctonia susceptibility.

Steep moisture gradients can exist near roots in sandy soil (2) because of the soil's low unsaturated hydraulic conductivity. Therefore, an irrigation may be required soon after emergence depending on the rates of root extension and leaf area development.

The availability of sprinkler equipment from handlines and wheel moves to circular center pivots and solid set systems allows the irrigator to select irrigation intervals from long periods dependent on the soil water holding capacity to daily or more frequent irrigations dependent on equipment capability. Where soil temperatures can become important to crop production, the effect of irrigations on soil temperature should be considered both in the selection of appropriate sprinkler equipment and in the management of that equipment. However, where an average of only 2 to 3 C represents the decrease in soil temperature resulting from irrigation, and if this difference has little effect on plant growth, selecting and managing irrigation equipment for frequent irrigations for soil cooling may incur unnecessary production costs.

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