12TH ANNUAL ALMOND RESEARCH CONFERENCE, DECEMBER 4, 1984, SACRAMENTO

Project No. 84-04 - Tree and Crop Research
Freeze Protection - Irrigation

Project Leader: Dr. Richard L. Snyder (916) 752-1130
Land, Air and Water Resources Department
University of California
Davis, CA 95616

Personnel: J. Connell, S. Lindow, R. Shaw, J. Carroll, W. Micke, W. Asai, J. Meyer

Objectives: (1) To evaluate and improve the practice of under-tree irrigation for freeze protection in almonds by determing optimum application rates, starting and stopping conditions, and optimum spray characteristics. (2) To study the interactions of freeze protection combining under-tree sprinklers and control of ice-nucleating bacteria.

Interpretive Summary:

A model of the energy budget in an almond orchard during frost conditions is being formulated to study the effects of under-tree irrigation. Energy (heat) fluxes during a typical frost night expressed in Watts per square meter (W/sq m) are on the order of -85, +28 and +39 for net radiation, soil heat flux, and sensible heat flux, respectively. These fluxes result in a net balance of -18 W/sq m on a typical night. When water is sprinkled onto an orchard floor, additional heat is supplied through the cooling and freezing processes. Evaporation of sprinkled water, however, removes energy from the orchard and the amount of heat removed by evaporation must be less than that supplied by cooling and freezing for sprinkling to be beneficial. Whether or not the heat lost through evaporation exceeds that gained from cooling and freezing depends mainly on wind speed, humidity, and sprinkler application rates.

It is generally known that water sprinkled for frost protection cools to 0° C (32° F) by the time it travels from a nozzle to the ground. In our model, we assume that the heat for this cooling process comes from the water and, hence, the process does not take heat from the air. We also assume that the energy that would have been supplied to the orchard from cooling the water to 0° C is not available to raise the temperature of the orchard. Heat supplied to warm the orchard then comes from the freezing process, which occurs mainly on the soil surface. The amount of heat supplied is approximately 235 W/sq m per 0.1 inch of water applied. Other assumptions in the model are that (1) the orchard floor temperature remains at 0° C after commencing sprinkling unless the energy balance becomes negative, (2) air at the wet soil surface is saturated with water vapor, and (3) the wind profile is logarithmic from the surface to 2 meters.

The initial objective of this modeling effort is to be able to estimate the temperature of a small depth of soil during a frost night starting with some initial environmental conditions without the sprinklers operating. This objective was selected because the air temperature in a frost situation closely parallels the soil surface temperature and the surface temperature is simpler to model. This model includes the determination of (1) soil heat flux, which depends on soil thermal diffusivity and volume heat capacity, (2) net radiation, which can be estimated from temperature and humidity, and (3) turbulent heat transfer, which depends on wind speed and atmospheric stability.

After successful modeling of an unsprinkled orchard, the heat effects of sprinkling will be introduced to determine its effects on the temperature of the small depth of soil at the orchard floor. Determination of the evaporation rate is difficult to accomplish, and, hence, verification of evaporation section of the model is the main objective during the next frost season. The energy lost to evaporation of water from the soil surface is approximately -170 W/sq m for a sprinkler application rate of 0.08 inch/hour if the night is typical and the evaporation rate just balances the effects of net radiation, soil heat flux, turbulent heat transfer and heat from freezing water on the surface. For atypical situations, the adequacy of various application rates can be studied once the model proves accurate.