Micro Sprinkler Irrigation using SCADA and sensor network for freeze protection.

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Abstract

Freeze damage to crops occur when water within the crop freezes and ruptures the cell membranes, which is not limited to only the fruit but also the leaves, twigs and wood. Citrus and some vegetable crops unlike deciduous trees cannot protect it self by shedding their leaves in the fall, but continue to grow year around. The overall objective of this research is to investigate the potential of Supervisory Control and Data Acquisition (SCADA) systems with a combination of soil moisture sensors and micro sprinklers as an efficient irrigation system during freeze condition. As 1 gram of water is applied using micro sprinklers and controlled by a SCADA system and monitored via soil moisture, temperature and wind speed sensors, it will freeze releasing 80 calories of heat energy to protect the plant. If not properly managed/controlled water being applied to freeze will rather evaporate, thereby 600 calories will be absorbed and further lower the temperature around the plant canopy.

Introduction

Freeze damage occurs in crops occur when water within the crop freezes and ruptures the cell membranes, this is not limited to only the fruit but also the leaves, twigs and wood (Boorse et. al 1998). The damage at times is limited not only to the leaves and fruits but can be so severe as to destroy the whole orchard.

California's San Joaquin Valley which is situated in the heart of the state is the top agricultural production region, also sometimes referred as "the nation's salad bowl" for the range of fruits and vegetables grown in its fertile soil. But this region is plagued with the problem of salinity (approximately 1.82 million hectares)(Jacobsen and Basinal 2004;Ayars 2005) and now this year we have the added burden of "freeze damage" to the crops. The freeze damage to citrus alone in this region has been estimated at $ 1 billion (Mercury News 2007). Freeze damage to crops occur when water within the crop freezes and ruptures the cell membranes, which is not limited to only the fruit but also the leaves, twigs and wood. Unlike deciduous trees, that protect it by shedding their leaves in fall, Citrus and some vegetable crops continue to grow year and are prone to freeze damage due to the presence of heavy vegetative mass like leaves. This year's sudden drop in temperature has affected citrus, avocado, strawberry, winter vegetables, spring vegetables, artichokes, olives and flowers. Damage has been reported from as far as Imperial Valley and San Diego among others and has turned this into a Federal disaster.

Traditionally *radiation and advection freeze* are encountered in California orchards. Both of these freeze events vary greatly from one another in terms of meteorological conditions and frequency of occurrence associated with them. Advection or horizontal movement of a cold air mass over land creates widespread cooling as cold air moves into a region or from the loss of heat due to radiation. If radiation heat loss becomes predominant form of cooling then it is called radiation freeze whereas advection freeze happens when cooling by advection is the predominant factor.

When a large mass of Arctic air moves in and covers the region resulting in drop of day and night temperature an advection freeze is said to have occurred. During advection freeze the weather condition may be clear or cloudy with strong winds that continue into the night. We may also see a lot of mixing and interaction at the lower layers of the atmosphere.

Unlike advection freeze, radiation freezes occur mostly on clear, calm nights after cold air has moved into the region, which results in heat being lost to the atmosphere throughout the night. The rate of heat loss by radiation into space is partly dictated by the amount of moisture present in the atmosphere. The heat loss is greater in dry air compared to moist air. During such freeze condition the coldest layer of air is normally found near the radiating surface as the air layers into various regions of air with varying temperature with relatively hotter air at the top. Normally, temperature decreases as height in the atmosphere increases. Thus, this meteorological condition is known as a temperature inversion (warm air layers over cool air layers).

Almost all spring freeze events in California vineyards are radiation freezes. Fortunately, a wide range of frost protection methods can be employed against radiation freezes. Advection freezes are relatively rare and normally occur only during the dormant season. The 1990, 1998 and 2007 freeze are examples of an advection freeze. Very little or no protection mechanism are available to protect the orchards from severe advection freeze. Therefore, the remainder of the paper will deal with the some concepts to deal with advection freeze.

In order to meet the food and fiber needs of existing population and also meet the demands of the future populations, the world's food supply must be made sustainable and renewable without putting undue pressure on the ecosystem. Therefore, sound resource management which emphasizes careful and efficient use of our agricultural production and our ecosystem is the key to achieving these objectives. The overall objective of this research is to investigate the potential of SCADA systems for the irrigation management during freeze condition, such that application of irrigation water as a means of protection will elevate the temperature around the crop canopy. By optimizing the irrigation delivery system with a SCADA system the irrigation age old technique of applying water during freeze can be perfected and made efficient.

Purpose

A more deliberate and scientific approach to the frost/freeze protection mechanism is needed in order to prevent frost/freeze damage. A currently available technology that could be utilized for this purpose is SCADA (Supervisory Control and Data Acquisition) systems. SCADA consist of a complex central computer system that can monitor and control an irrigation system spread out over a long distance. SCADA systems are capable of monitoring and controlling many parameters with the help of various sensors and feedback mechanisms. By properly monitoring the wind speed, evaporation rate, soil heat flux and rate of irrigation, *adequate irrigation* can be used as protection mechanism (NC Coop. Extension 2007). Additionally a combination of irrigation, wind machine and gas heaters can be deployed for best result under varying condition.

Significance

Historically over the last decade or so, freeze damage to crops in California in particular occurs every 8 years. The freeze damage that occurred in 1990 devastated most of the citrus crops and many orchards had to be replanted, leading to heavy financial losses to the grower and the economy. The crop damage during 1998 freeze was comparatively less, and this can be partially attributed to some of the advances in freeze prevention methods gained since 1990. In the wake of the recent (2007) crop damage all over California and other parts of the United States, unless drastic remedial measures are researched and implemented this might turn in to an epidemic in the years to come. This will not only affect the local economy but also the constant supply of fruits and vegetables for the masses.

Project Statement

Hypothesis*:* Irrigation via micro-drips or spray heads in an efficient and scientific manner can reduce freeze damage. As 1 gram of water applied through irrigation freezes, 80 calories of heat energy is released, thereby providing latent heat as long as ice is formed. This method fails if the irrigation rate is not adequate, thereby resulting in more damage then cure. Insufficient irrigation rate results in inadequate water being applied to freeze, as 1 gram of water evaporates rather then freeze, 600 calories of heat energy are absorbed from the environment, which will take heat from the crop. The crop will freeze faster compared to no irrigation protection as evaporation is being promoted by wind speeds of 5 mph or higher in a typical frost/freeze condition there by limiting the success of this protection method (NC Coop. Extension 2007).

The overall objective of this research is to investigate the potential of SCADA systems as an efficient irrigation management system and also to investigate the potential of this system to deliver irrigation water via micro-sprinklers during freeze condition. This will not only result in comprehensive water management but also contribute to the reduction in fossil fuel wastage, as otherwise heaters and wind machines are used during freeze conditions.

With the goal of improved water efficiency and fuel management, we propose to refine the irrigation management techniques round the year using the SCADA system and also use this multi purpose system to prevent freeze damage via application of irrigation water during freeze condition. The usage will be electronically documented and compared with the net freeze damage if any. In order to achieve these objectives and quantify the positive attributes of this system, we take into account the following assumptions and limitations:

Assumptions:

- Water can prevent freeze damage
- Water is affordable and readily available
- Realtime feedback and sensor technology for the proposed measurements are available

Limitations:

- Climatic conditions
- Time period of the study
- Site selection
- Equipments
- Finance/Funding opportunity
- Available personal to carry out the technical and field work

Scope of research:

In order to achieve the project objectives rigorous lab testing in simulated environment will have to be performed, followed by site selection at a freeze prone location. With proper data acquisition and system fine tuning this model can be developed into an irrigation controller chip and added to the existing irrigation system. We understand that we will have to add minor adjustments to the current irrigation system, but if successful this research has endless benefits for areas prone to freeze.

Proposed Work and Statement of Methodology

With the goal of improved water efficiency and freeze management, we propose to refine the irrigation techniques used during frost/freeze condition, as well as electronic documentation of the characteristics of the applied water. In order to achieve these objectives we have identified three major components for the proposed work:

Component 1: Incorporation of a SCADA system in a farm during frost/freeze season

During this phase of the research, the focus will mainly be on adapting and incorporating the SCADA into the regular irrigation system which will also act as frost/freeze irrigation protection method during winter months.

<u>Component 2:</u> *Monitoring changes in the micro climate*

The proposed SCADA system will schedule irrigation water in a manner that leads to improved water usage during normal operation and deliver irrigation water in a manner so as to prevent freeze damage during frost/freeze condition. We will allocate a control area with traditional farmers practice and another area treated with our system and compare both micro climate.

<u>Component 3: Design the SCADA System</u>

The proposed SCADA system will have soil moisture sensors, pH sensors, wind speed sensors, soil heat flux plates, soil salinity sensors, pressure transducers for line pressure, flow-meters for monitoring the usage of Irrigation District water , flumes to check for flow and host of other sensors and controller. In addition to the sensors, the SCADA system will have its own hardware for the central processing unit, which is a low power usage embedded computer capable of withstanding harsh field conditions of heat, dust and humidity. Communication and monitoring with the SCADA system will be done remotely at times using wireless technology (WiFi). Specific attention will be paid while choosing the hardware to prevent conflict interfacing among different hardware's.
The SCADA system once built, will be designed or programmed according to the system variables and information collected during field study. The system will also be tested with ***supervisory*** controls to check the system performance to match user changing demands.

The final SCADA system will be tested under laboratory conditions using predetermined circumstances .Discrepancy of the system, if any, will be rectified by modifying the program.

Once the system is tested and corrected in the lab, the SCADA system will be made mobile and stationed at the field site and instrumented with all the sensors and the feedback system. The system will be programmed to run in an automatic mode and monitored for effective freeze protection. The system will be run at various freeze susceptible regions for 2secutive years.

Data collected during the field testing will be compared with the data obtained in the laboratory. Calibration curves, system performance and efficiency will be modeled using a computer generated simulation program. Salinity and hydraulic loading of the soil will be studied and curves will also be generated. Response curves and system performance will be generated on a weekly basis so that appropriate changes, if any, can be made in a timely fashion.

Definition of results and evaluation of the calibration curve with confidence limit will be made. If the range of the values defined by the confidence limits at a given reading is so great as to leave the blending decision unsupported, the system performance for those testing conditions will have to be revisited and re-programmed.

Summary and Conclusion

Nearly all orchards and vineyard regions of the world are subject to spring frost damage and finding an efficient frost protection mechanism especially for advection freeze is of paramount importance and a challenge for most commercial orchards. Avoidance of frost damage can be achieved through a combination of passive or active methods in a way, such that minimal damage occurs to the plant especially if the active method like application of irrigation water can be further automated and controlled. Active methods like wind machines, heaters combinations or sprinklers are more expensive but can provide 5-6°F of protection under ideal freeze conditions. Further work is underway to test our system and improve upon it as we move it out of the laboratory to the real field condition

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