SHuR FARMS®

Frost Protection

Division of Recovery P.T. Inc.

Simpkins Family Vineyard

2004

Cold Air Drain® unit at Simpkins Family Vineyard.

Executive Summary

An initial study to evaluate the effectiveness of the Shur Farms Cold Air Drain® was conducted at Simpkins Family Vineyard during the spring 2004 frost season. The accumulation of cold air in the lowest area of Simpkins Family Vineyard contributed substantially to annual frost damage. The Cold Air Drain® was expected to increase in the temperature in the lower elevation area, thereby reducing the natural temperature difference between the higher (non-accumulation) and lower (accumulation) areas. The net temperature increment achieved by the Cold Air Drain® was approximately 1°C. No frost damage at Simpkins Family Vineyard was reported at the end of the spring 2004 frost season.

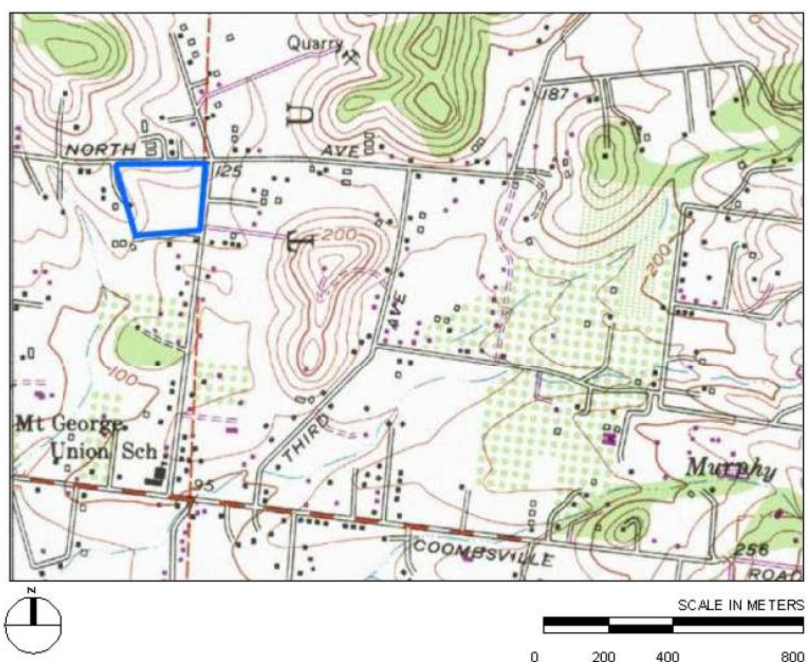
Introduction

An initial study to evaluate the effectiveness of the Shur Farms Cold Air Drain® was conducted at Simpkins Family Vineyard during the spring 2004 frost season. The main objective of this study was to observe the temperature effects from the operation of the Cold Air Drain® during radiation frost nights. This report presents: 1) a discussion of the frost problem at Simpkins Family Vineyard, 2) study methodology, and 3) results from the test of the Cold Air Drain®.

Frost Problem at Simpkins Family Vineyard

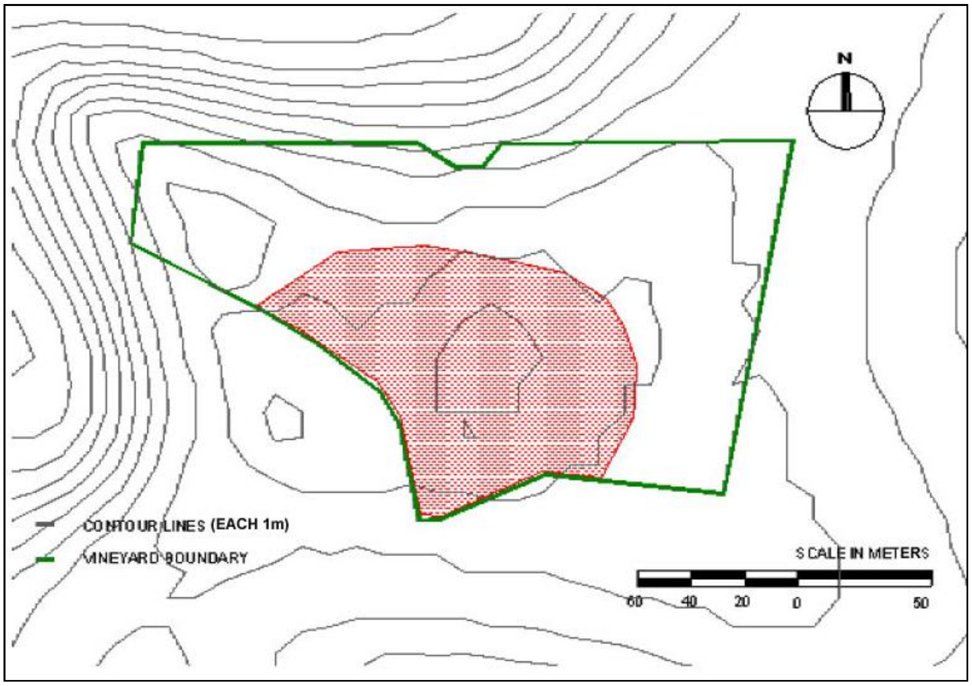
Simpkins Family Vineyard is located in the Mt. George USGS quadrant in Napa County (UTM Zone 10) (Figure 1). The property boundary is outlined in blue.

Figure 1: Simpkins Family Vineyard Location



The frost damage sustained at Simpkins Family Vineyard was due to the accumulation of cold air in the lowest area of the vineyard. Figure 2 shows the frost damaged area at Simpkins Family Vineyard. The property boundary is outlined in green and the frost damage is represented by the red area. Cabernet Sauvignon grapes are grown in the frost damaged area.

Figure 2: Frost Damage at Simpkins Family Vineyard



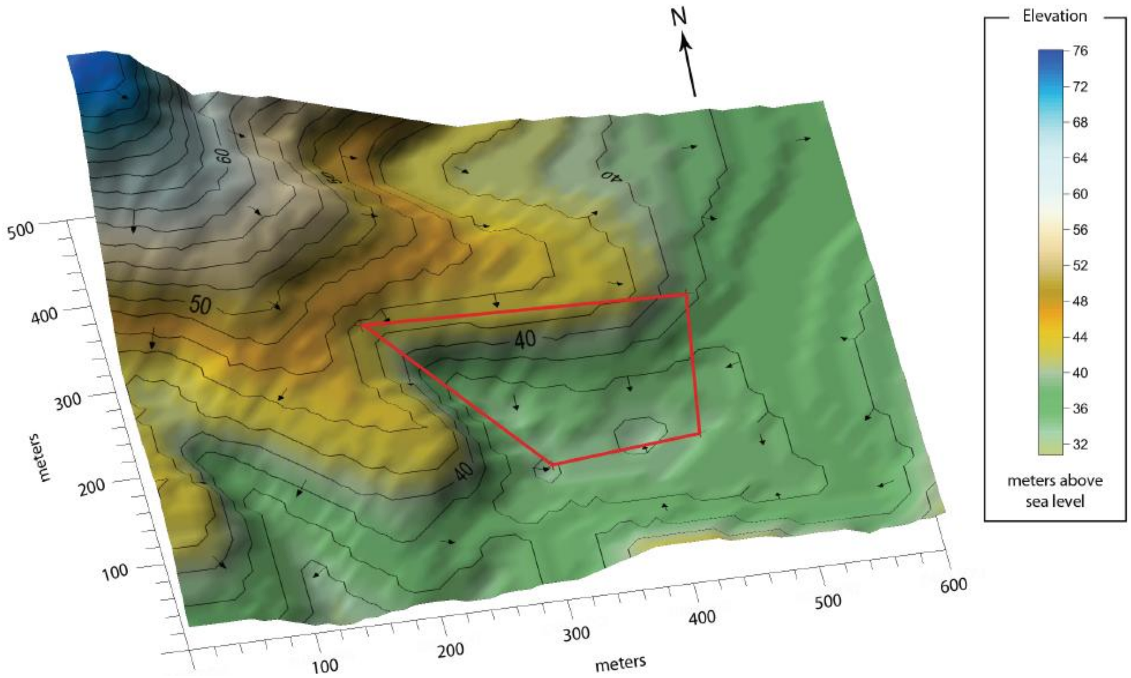
Cold Air Accumulation

This low, frost-prone, and bowl-shaped area is a cold air accumulation area. During a radiation frost night[1], the denser (i.e., heavier) cold air flows downhill from higher elevation areas (e.g., hillsides) due to gravity, filling the lowest area like a bowl or a lake. When there is not adequate drainage of the cold air in the lowest area, the cold air builds up, thereby contributing to frost damage. Cold air accumulation often occurs in valleys, in which higher elevation areas are generally several degrees warmer than lower elevation areas (e.g., Gustavsson, et al 1998).

1 A radiation frost night is typically characterized by clear, cold nights, little moisture and little or no wind, fog, or cloud cover (e.g., Thompson 1986; Gudiksen, et al 1992). During a radiation frost, an inversion layer (i.e., stratified atmosphere) will be present.

Frost damage is seen in the lower elevation area, but not in the higher elevation area, since the cold air flows down the slope into the lower area, where the cold air collects. Figure 3 illustrates the cold air streamlines (assuming that no obstacles prohibit the free flow of the cold air) in Simpkins Family Vineyard. The property boundary for Simpkins Family Vineyard is outlined in red. As Figure 3 indicates, cold air is flowing from all directions into the lowest area in the vineyard.

Figure 3: Cold Air Streamlines in Simpkins Family Vineyard



Shur Farms Cold Air Drain®

The Cold Air Drain® pulls the coldest layer of air along the ground using a horizontally-positioned, three-blade, aluminum, vibration resistant propeller. The Cold Air Drain® thrusts the cold air upward to a height of nearly 300ft (91.44m), allowing the warmer air from above to settle downward. As the cold air is sent upward, it mixes with the above warmer, less dense air layer until it is dispersed into the upper inversion layer. This process is known as “selective extraction”.

The Cold Air Drain® effect changes the microclimate in the lower, frost-prone area, making it consistent with the higher, non-frost areas. The grower can expect similar yields in all areas of the vineyard.

Shur Farms Cold Air Drain® at Simpkins Family Vineyard
Shur Farms Frost Protection's calculations of the volume of cold air to be removed from the low, frost-prone area resulted in a #1550 Cold Air Drain® unit (covers approximately 6-9 acres) placed at the lowest point in the vineyard to drain the accumulated cold air.

Hypotheses
By removing the coldest air layer using the Cold Air Drain®, the temperature in the lowest elevation area should *increase*, thus minimizing the natural temperature difference between the lower (accumulation) area and the higher (non-accumulation) areas. A smaller temperature difference between the higher and lower elevation areas should be observed when the Cold Air Drain® is in operation (as compared to when the Cold Air Drain® is *not* in operation) during a given radiation frost night. The magnitude of the reduction in the temperature difference depends on the initial (i.e., naturally occurring) temperature difference between the higher and lower elevation areas. The null hypothesis states that there will be no change in the temperature difference between the higher and lower elevation areas when the Cold Air Drain® is in operation (as compared to when it is not in operation) during a given radiation frost night. We expect that the null hypothesis will be rejected.

Methods & Data
Simpkins Family Vineyard was selected to evaluate the effectiveness of the Cold Air Drain® because the area had annual frost damage. Information about frost damage locations, patterns, and extent was provided by the Simpkins Family Vineyard management. Shur Farms Frost Protection® identified the GPS coordinates (UTM NAD-27) of the frost damaged areas. USGS topographical maps of the vineyard and surrounding regions were used to examine cold air flows in the vineyard. Additionally, “kill” temperatures for the wine grape varieties in the frost damaged area were obtained.

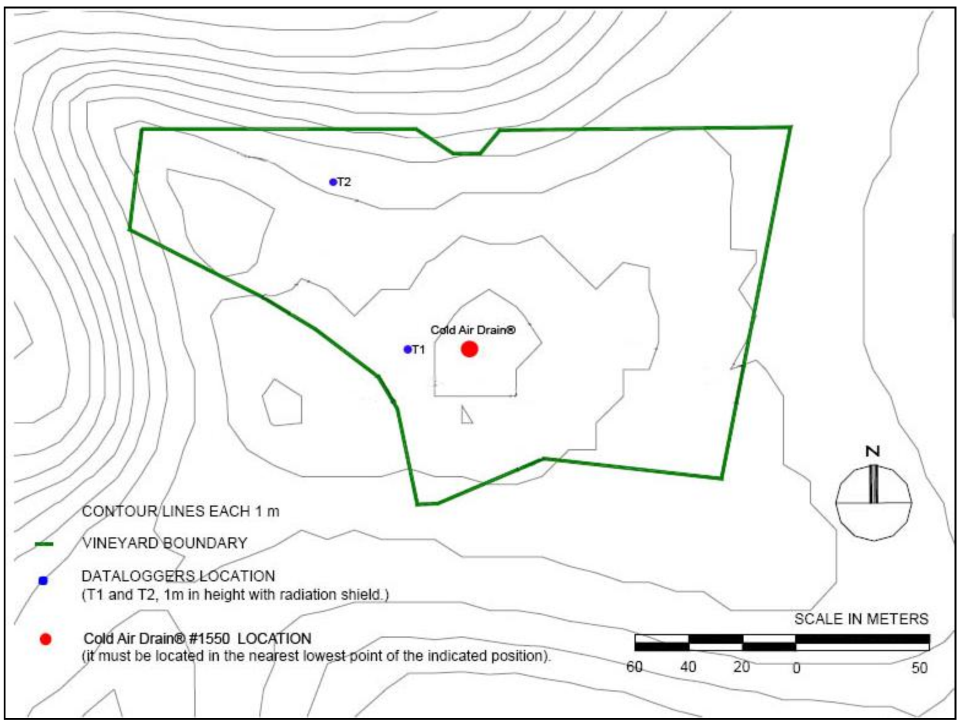
Operation of the Cold Air Drain® is the key independent variable of interest. Operation of the Cold Air Drain® was coded as “yes” or “no” during radiation frost nights. The dependent variable, *temperature difference*, is used as the measure of effectiveness of the Cold Air Drain® for this initial study. The temperature difference is calculated as the temperature of the higher elevation area minus the temperature at the lower elevation area. *Radiation frost night* was recorded, since the Cold Air Drain® was designed primarily to protect against radiation frosts.[2] The variable, radiation frost nights, was coded as “radiation frost night” or “non-radiation frost night”. *Topography* was also noted, in which an area was identified

2 Frost protection methods to protect against advective frosts are limited.

as “higher elevation” or “lower elevation”.[3]

To measure the temperature difference, battery-powered HOBO H8 Pro (Onset Computer Corporation) dataloggers[4] were placed in the higher elevation area (T2) and near the lowest point (T1) in the vineyard. The dataloggers were positioned approximately one meter off the ground (cordon height) to accurately measure the temperature of the coldest air layer. Each datalogger was placed on a stake made of non-heat-conductive material and was protected by a PVC radiation shield. Figure 4 indicates the locations of the dataloggers and the Cold Air Drain® unit. The Cold Air Drain® is located in the lowest area of the vineyard. Temperature differences between the higher and lower elevation areas were calculated from the actual temperatures measured by the dataloggers (T_2-T_1).

Figure 4: Datalogger and Cold Air Drain® Locations



3 Other variables (e.g., soil texture) contribute to the temperature difference; however, this initial study did not control for such variables, as such variables will consistently affect the temperature difference whether or not the Cold Air Drain® is in operation.

4 Testing of the HOBO H8 Pro dataloggers showed that the dataloggers were accurate within 0.26°C over the range from -5 to +50°C (Whiteman, et al 2000).

Nights selected for operating the Cold Air Drain® reached approximately 2.22°C (approximately 36°F)[5] and were expected to be radiation frost nights. Nights included in this analysis in which the Cold Air Drain® was not turned on were also expected to be radiation frost nights; however, the temperature did not reach 2.22°C at the control point (T1) during the non-operation nights. Figure 5 lists the radiation frost nights that the Cold Air Drain® was and was not operated. Radiation frost nights were identified using the actual temperatures measured by the dataloggers, weather reports, and grower observations. The grower recorded the dates and exact times (in hours and minutes) when the Cold Air Drain® was operated.

Figure 5: Radiation Frost Nights & Cold Air Drain® Operation

Date	Cold Air Drain® Operation
April 15, 2004	Yes
April 16, 2004	Yes
April 17, 2004	Yes
Apr 30, 2004	No
May 18, 2004	No

Reasonable care was taken to select only radiation frost nights to be included in this analysis; however, both operation and non-operation nights included in this analysis may not have all been actual radiation frost nights, as independent evidence of an inversion layer in the vineyard was not collected during this initial study. Thus, the Cold Air Drain® may have been more effective in increasing the temperature at the lower area of the vineyard than reported.

Findings

Natural Nights

Figures 6 and 7 represent the temperature difference during radiation frost nights when the Cold Air Drain® was not in operation (i.e., naturally occurring temperature differences), since at no point during the night did the temperature at the control

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5 Growers are instructed to turn on the Cold Air Drain® when the temperature reaches approximately 2.22°C (approximately 36°F) to protect against frost damage.

point (T1) reach 2.22°C. The temperature at the higher elevation area (T2) is represented by the blue line and the temperature at the low elevation area (T1) is represented by the pink line. As these graphs show, the temperature in the lower area remained below the temperature in the upper area until sunrise (approximately 6:00AM). These graphs demonstrate the natural temperature difference between the lower and higher elevation areas.

Figure 6: April 30, 2004

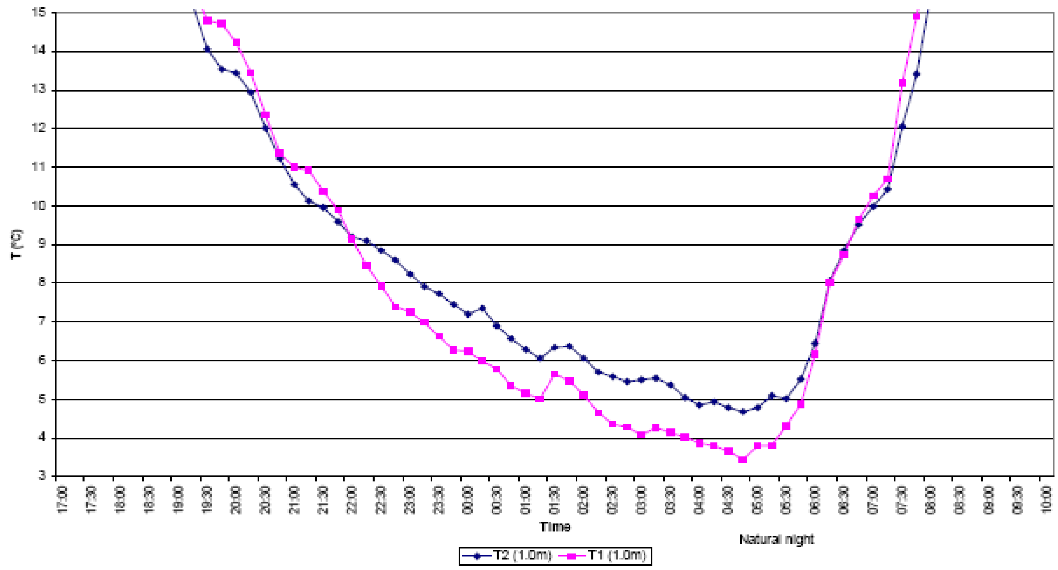
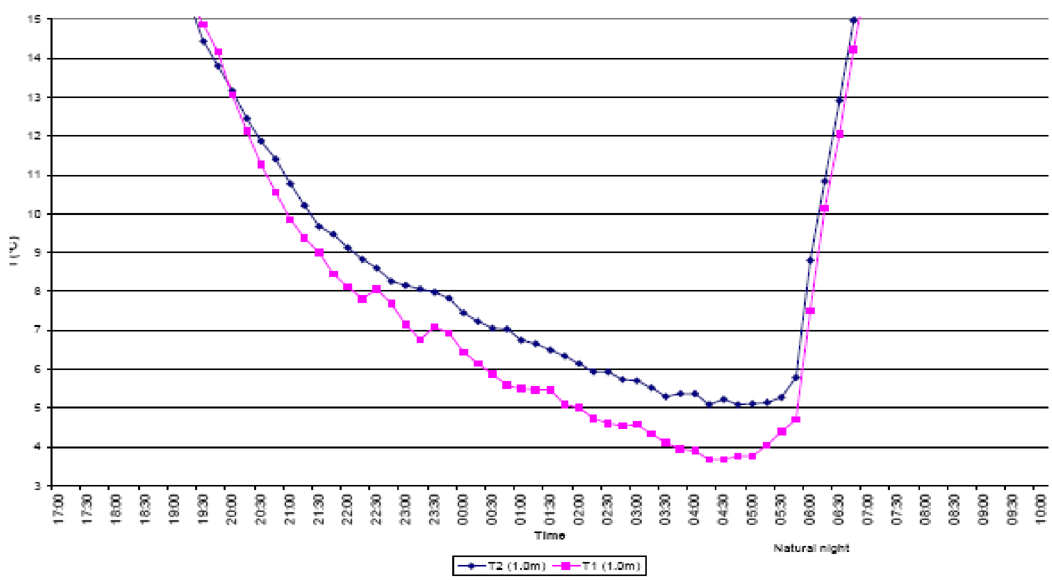


Figure 7: May 18, 2004



Cold Air Drain® Operation Nights

Figures 8-10 show the temperature difference during the radiation frost nights when the Cold Air Drain® was in operation between approximately midnight and sunrise. As the graphs indicate, the temperature difference between the higher and lower elevation areas was significantly reduced. The temperature in the low area was more consistent with the temperature in the higher elevation area while the Cold Air Drain® was running!

Figure 8: April 15, 2004

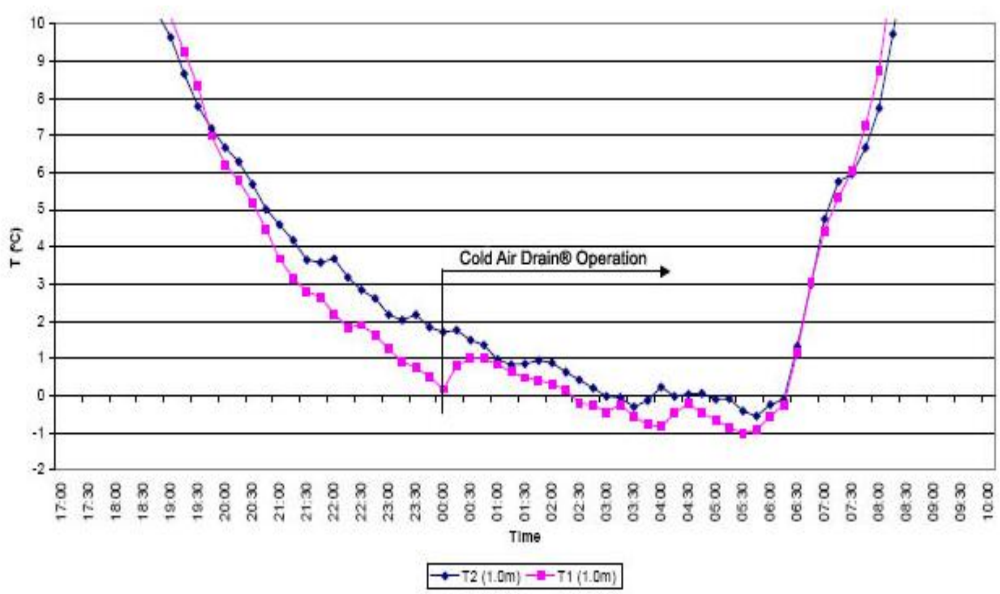


Figure 9: April 16, 2004

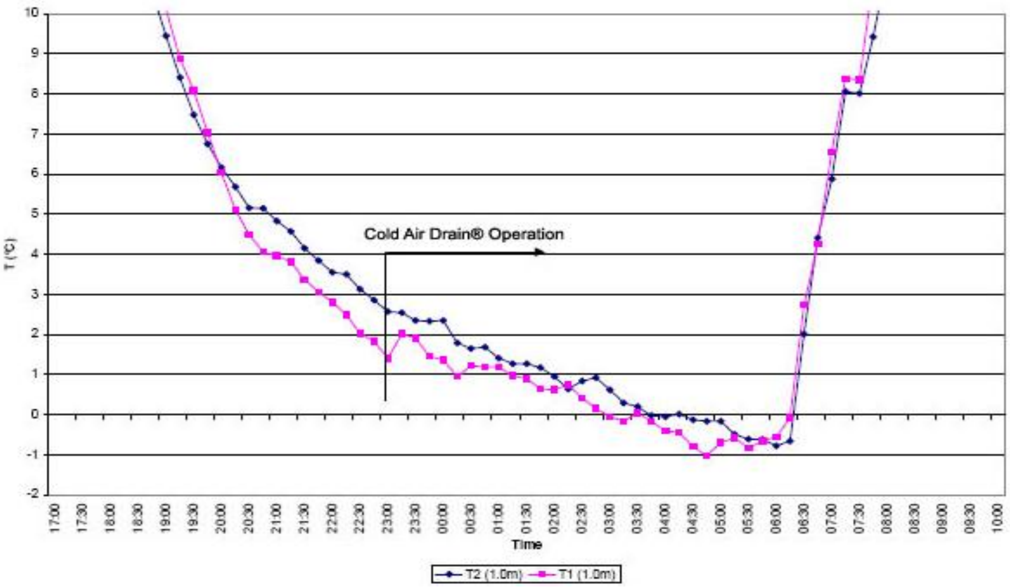
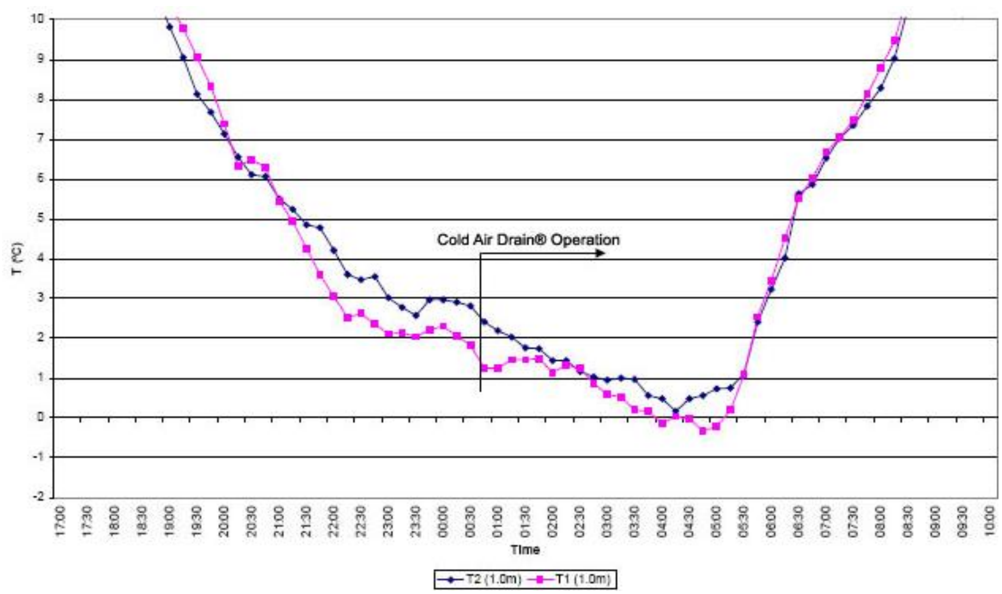


Figure 10: April 17, 2004



The temperature difference between the lower and higher elevation areas was reduced during radiation frost nights when the Cold Air Drain® was operating. The net temperature increment achieved when the Cold Air Drain® was operating was approximately 1°C. No frost damage at Simpkins Family Vineyard was reported at the end of the 2004 spring frost season.

Conclusion

The purpose of this initial study was to evaluate the effectiveness of the Cold Air Drain® by examining the temperature difference between the higher and lower elevation areas on radiation frost nights when the Cold Air Drain® was operating. The Cold Air Drain® significantly reduced the natural temperature difference between the higher and lower elevation areas of the vineyard (approximately 1°C). The increase in the temperature in the lower elevation area through the removal of the coldest air layer using the Cold Air Drain® protected the crops in this area from frost damage.

References

Gudiksen, P. H., Leone Jr., J. M., King, C. W., Ruffieux, D., and Neff, W. D. 1992. "Measurements and Modeling of the Effects of Ambient Meteorology on Nocturnal Drainage Flows." *Journal of Applied Meteorology* 31:1023–1032.

Gustavsson, Torbjörn, Karlsson, Maria, Bogrebm Jörgen, Lindqvist, Sven. 1998. "Development of Temperature Patterns during Clear Nights." *Journal of Applied Meteorology* 37: 559-571.

Thompson, B. W. 1986. "Small-Scale Katabatics and Cold Hollows." *Weather* 41:146–153.

Whiteman, C. D., Hubbe, J. M., and Shaw, W. J. 2000. "Evaluation of an Inexpensive Temperature Datalogger for Meteorological Applications". *Journal of Atmospheric and Oceanic Technology* 17: 77-81.

Thank you for your participation.

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