SHuR FARMS®

Frost Protection

Division of Recovery P.T. Inc.

Tablas Creek Vineyard

2003

Cold Air Drain® units at Tablas Creek Vineyard.

Executive Summary

An initial study to evaluate the effectiveness of the Shur Farms Cold Air Drain® was conducted at Tablas Creek Vineyard during the spring 2003 frost season. The accumulation of cold air in the lowest areas of Tablas Creek Vineyard contributed substantially to annual frost damage. The Cold Air Drain® was expected to increase the temperature in the lower elevation areas, thereby reducing the natural temperature difference between the higher (non-accumulation) and lower (accumulation) areas. The Cold Air Drain® reduced the natural temperature difference by approximately 2.5°C (4.5 °F). No frost damage at Tablas Creek Vineyard was reported at the end of the spring 2003 frost season.

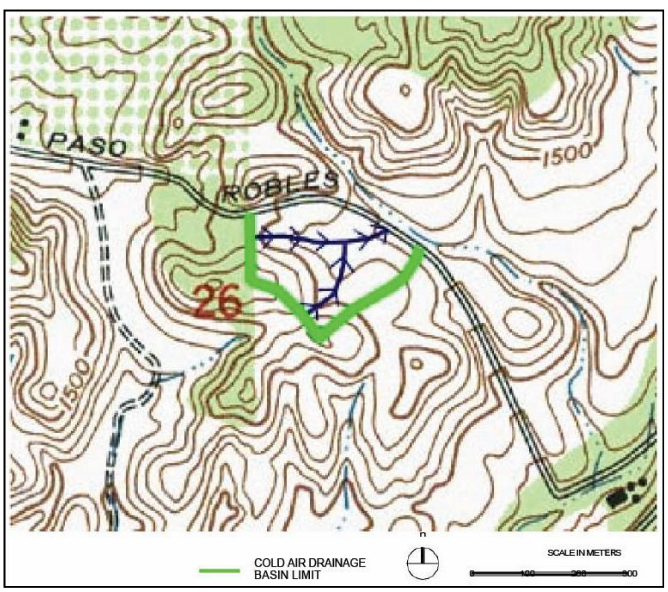
Introduction

An initial study to evaluate the effectiveness of the Shur Farms Cold Air Drain® was conducted at Tablas Creek Vineyard during the spring 2003 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 Tablas Creek Vineyard, 2) study methodology, and 3) results from the test of the Cold Air Drain®.

Frost Problem at Tablas Creek Vineyard

Tablas Creek Vineyard is located in the USGS Adelaida quadrant in Paso, Robles, CA (Figure 1). The property boundary is outlined in green. Maps were also prepared using the Lime Mountain, Cypress Mountain, and York Mountain USGS quadrants.

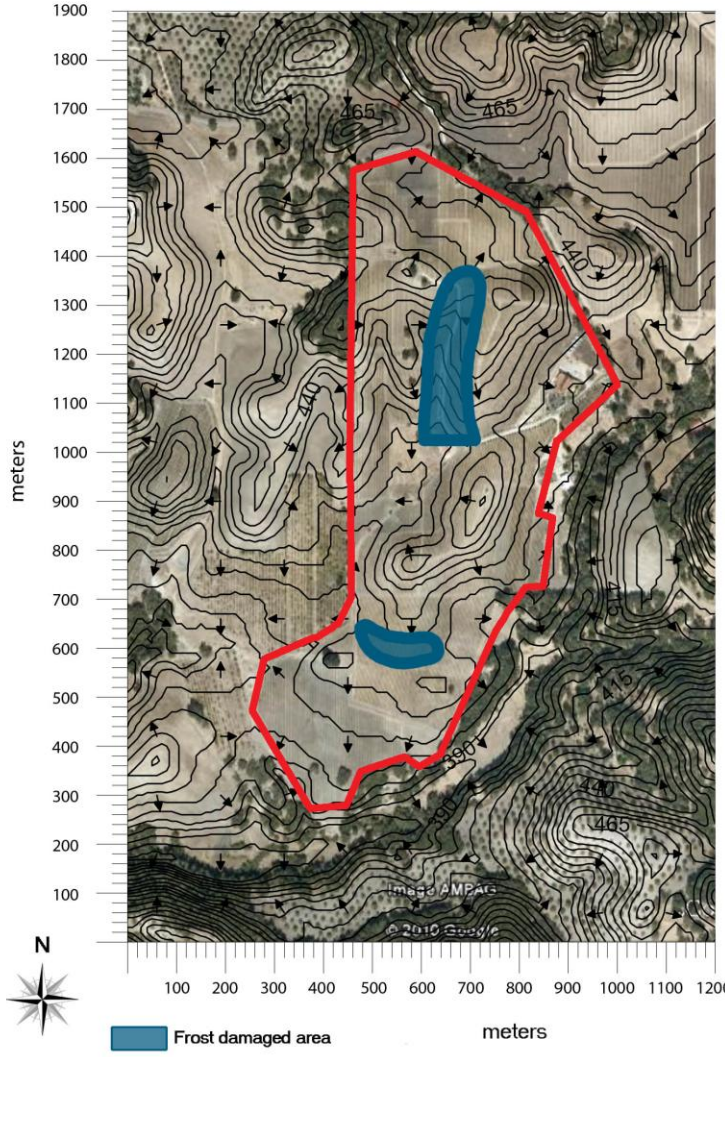
Figure 1: Tablas Creek Vineyard Location



The frost damage sustained at Tablas Creek Vineyard was due to the accumulation of cold air in the lowest area of the vineyard. Figure 2 shows the frost damaged area at Tablas Creek Vineyard. The property boundary is outlined in red and the frost damage is indicated by the blue area. The typical severe frost risk period for Tablas Creek Vineyard is from early April to late May.

The basin affected by frost damage is planted with Rousanne and Marsanne Vionier (French varieties) in the higher elevation areas; the lowest areas are planted with rootstock. The soil is rocky and chalky with limited topsoil, which absorbs and retains more heat than sandy or silty soil. The rows are densely planted (1,600-1,800 vines per acre) and trellised low to the ground.

Figure 2: Frost Damage at Tablas Creek Vineyard



Cold Air River

Cold air flowing down the hillside, like a river, is a concentrated streamline of cold air that is created when cold air flows into a gulley or swale from the surrounding higher elevation areas. The cold air continues downhill due to gravity. This is a dynamic (i.e., moving) mass of cold air that is contained within swale boundaries and the mass of cold air can get wider and deeper as it flows downhill. The increase in the mass of cold air downstream is due to the addition of cold air that enters the gully from the surrounding area. There will be a difference in temperature between the air inside of the swale and the air outside. The air inside the swale can be several degrees colder because the coldest and densest (i.e., heaviest) molecules will flow into the gully, displacing the warmer air layers. Frost damage that "snakes" its way through an orchard is an indication of a concentrated streamline of cold air.

Cold Air Lake

The frost-prone basin may be characterized as a cold air "lake". Cold air lakes exist where there is a static mass of air that builds up or pools in a specific area due to an obstruction to air flow. As cold air enters a basin from higher elevations during a radiation frost night[1] and builds up, the warmer air in the basin is displaced upwards. Cold air can build up to several times the height of the obstruction and back into the orchard. The lower the slope angle of approach to the obstruction, the deeper cold air can build up in relation to the height of the barrier before finally flowing over.

Significant frost damage is seen primarily in the lower elevation areas, since the cold air flows downhill into the basin, where the cold air collects. Figure 3 illustrates the cold air streamlines[2] in Tablas Creek Vineyard. The property boundary for Tablas Creek Vineyard is outlined in red. As Figure 3 indicates, the cold air flows down the gullies and accumulates in the lowest areas in the vineyard.

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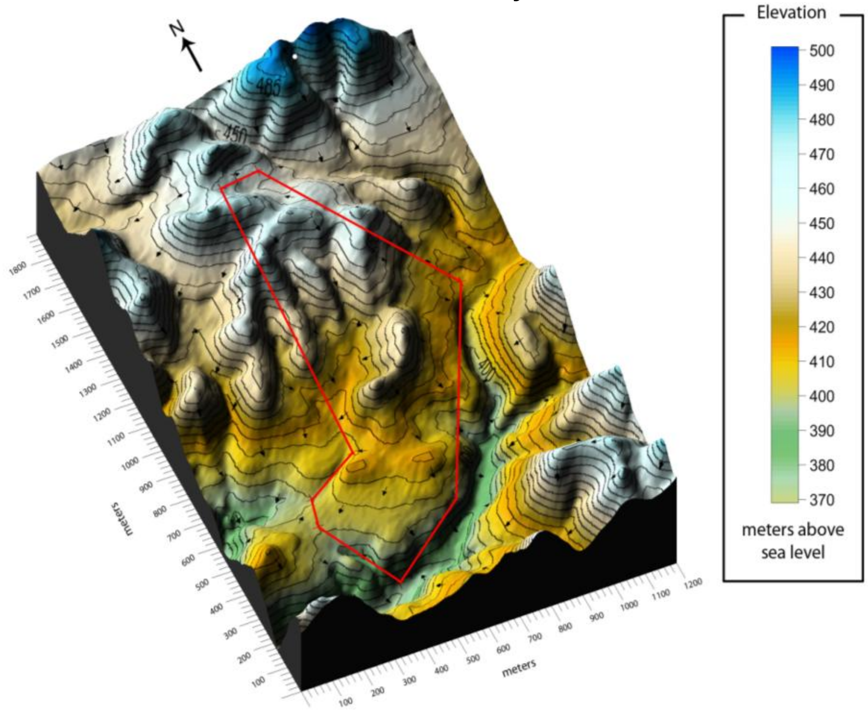
1 A radiation frost night is typically characterized by clear, cold nights, little moisture and no wind, fog, or cloud cover (e.g., Thompson 1986; Gudiksen, et al 1992). During a radiation frost, an inversion layer (i.e., stratified atmosphere) will be present.

[2] The cold air streamlines shown in Figure 3 assume that no obstacles prohibit the free flow of the cold air.

Figure 3: Cold Air Streamlines in Tablas Creek 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 (91.44 meters), 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 areas, making them 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 Tablas Creek Vineyard

Shur Farms Frost Protection's calculations of the volume of cold air to be removed from the low, frost-prone areas resulted in six Cold Air Drain® #925 units placed in the lowest areas in the vineyard to drain the accumulated cold air. Six artificial barriers of 1.5m x 40m were also placed perpendicularly to each Cold Air Drain® #925 unit approximately 8m downstream from each unit to help block further cold air flows.

Hypotheses

By removing the coldest air layer using the Cold Air Drain®, the temperature in the lowest elevation areas should *increase*, thus minimizing the natural temperature difference between the lower (accumulation) areas 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® units are in operation (as compared to when the Cold Air Drain® units are *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® units are in operation (as compared to when they are not in operation) during a given radiation frost night. We expect that the null hypothesis will be rejected.

Methods & Data

Tablas Creek Vineyard was selected to evaluate the effectiveness of the Cold Air Drain® because the vineyard had annual frost damage. Information about frost damage locations, patterns, and extent was provided by the Tablas Creek Vineyard manager. 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.[3] 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 as "higher elevation" or "lower elevation".[4]

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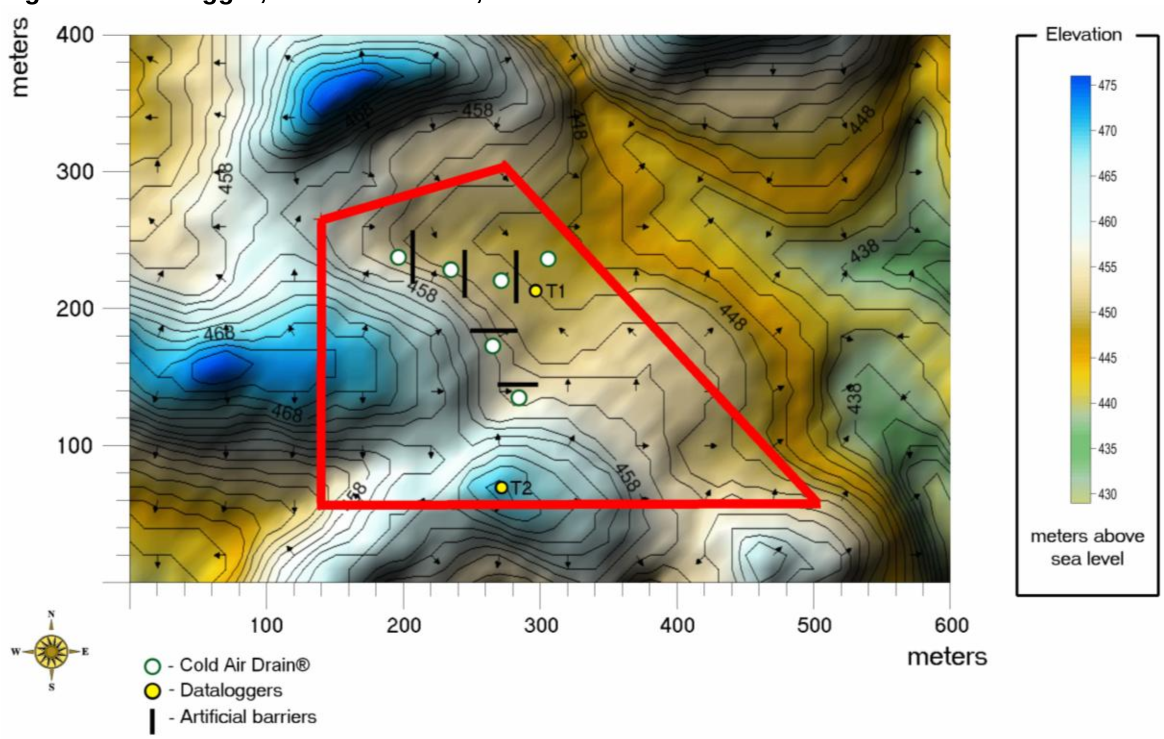
3 Frost protection methods to protect against advective frosts are limited.

4 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.

To measure the temperature difference, battery-powered HOBO H8 Pro (Onset Computer Corporation) dataloggers[5] 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, barriers, and the Cold Air Drain® units. The Cold Air Drain® units are located in the lowest areas 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, Artificial Barrier, and Cold Air Drain® Locations



5 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 degrees Celsius (°C) (approximately 36 degrees Fahrenheit (°F))[6] and were expected to be radiation frost nights. Nights included in this analysis in which the Cold Air Drain® units were 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® units were and were 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® units were operated.

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

Date	Cold Air Drain® Operation
February 3, 2003	No
February 5, 2003	No
February 7, 2003	No
February 8, 2003	No
February 21, 2003	No
April 3, 2003	Yes
April 4, 2003	Yes
April 5, 2003	Yes

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.

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6 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.

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 6-10 represent the temperature difference during radiation frost nights when the Cold Air Drain® units were not in operation (i.e., naturally occurring temperature differences), since at no point during a given night did the temperature at the control 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 7:00AM). These graphs demonstrate the natural temperature difference between the lower and higher elevation areas.

Figure 6: February 3, 2003

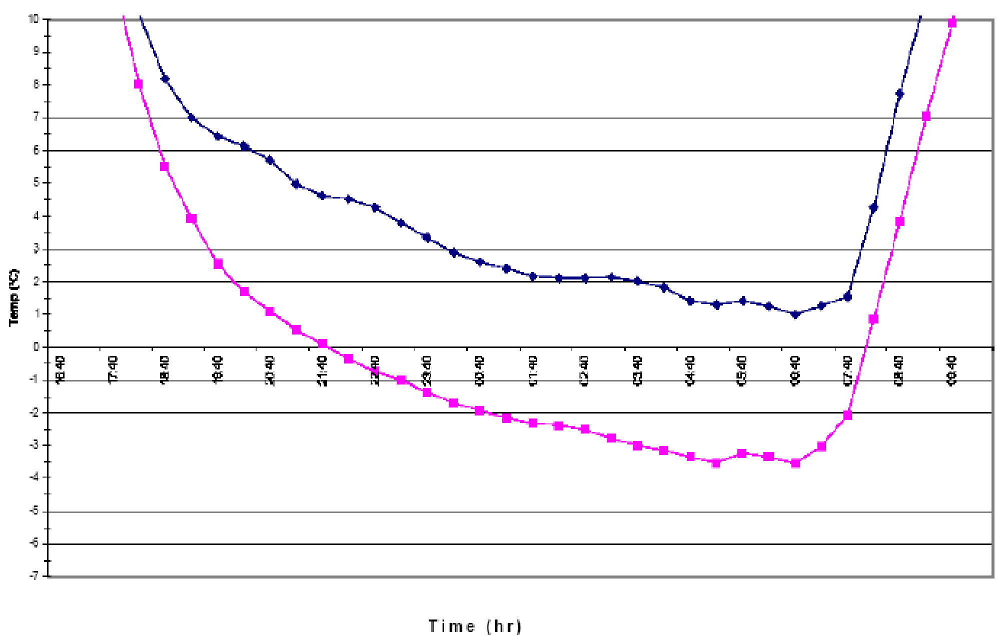


Figure 7: February 5, 2003

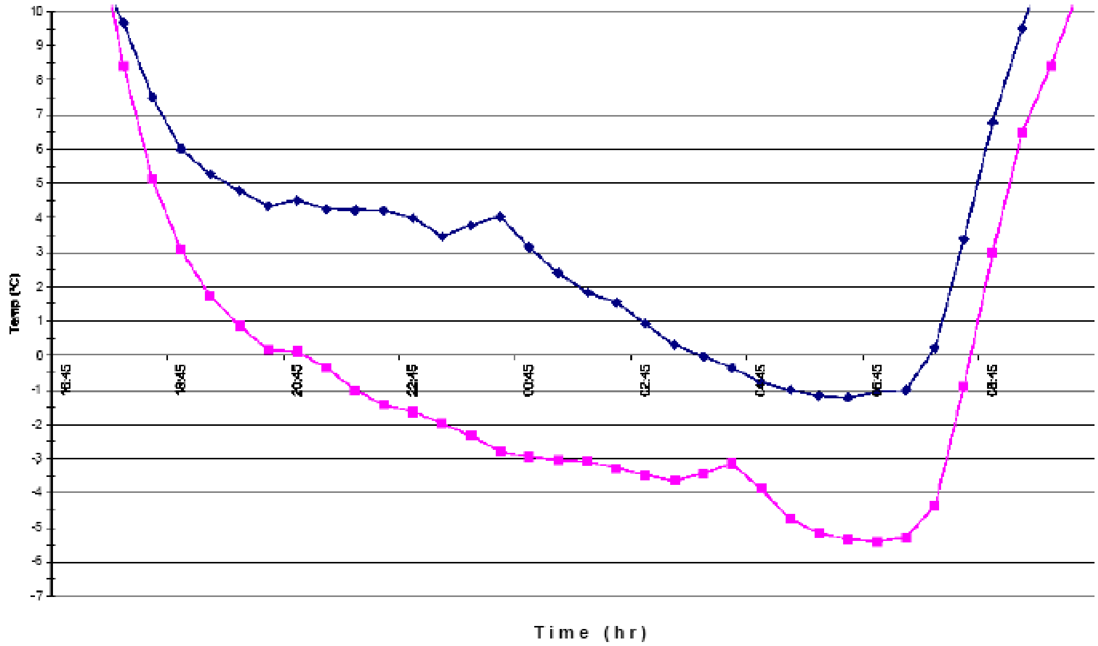


Figure 8: February 7, 2003

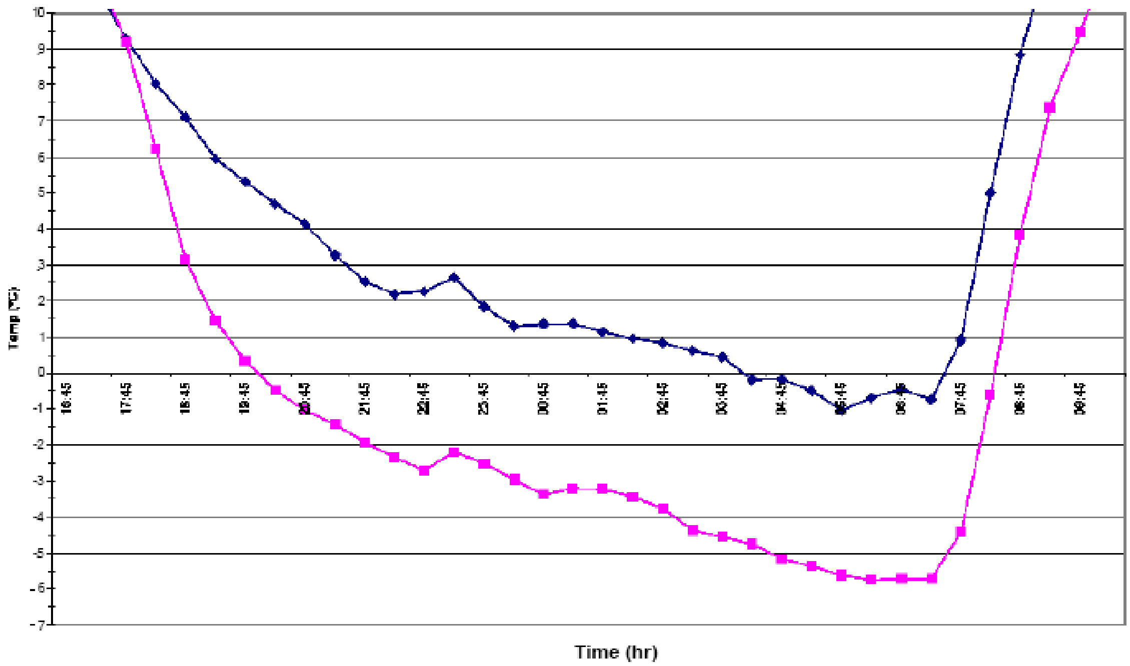


Figure 9: February 8, 2003

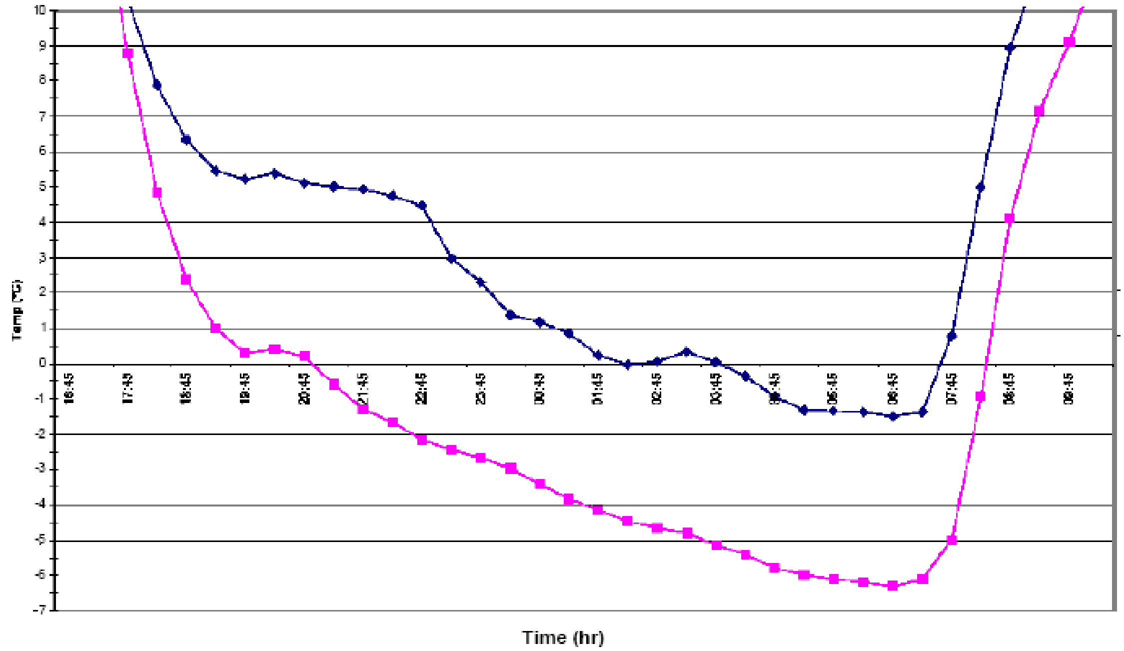
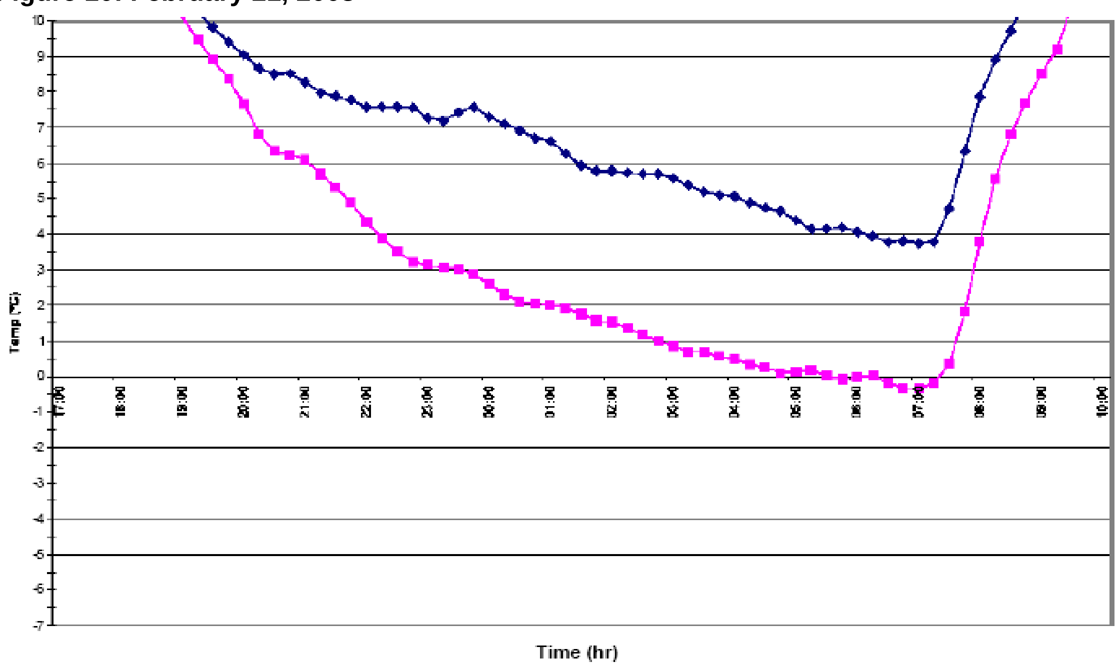


Figure 10: February 21, 2003



Cold Air Drain® Operation Nights

Figures 11-13 show the temperature difference during the radiation frost nights when the Cold Air Drain® units were 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® units were running!

Figure 11: April 3, 2003

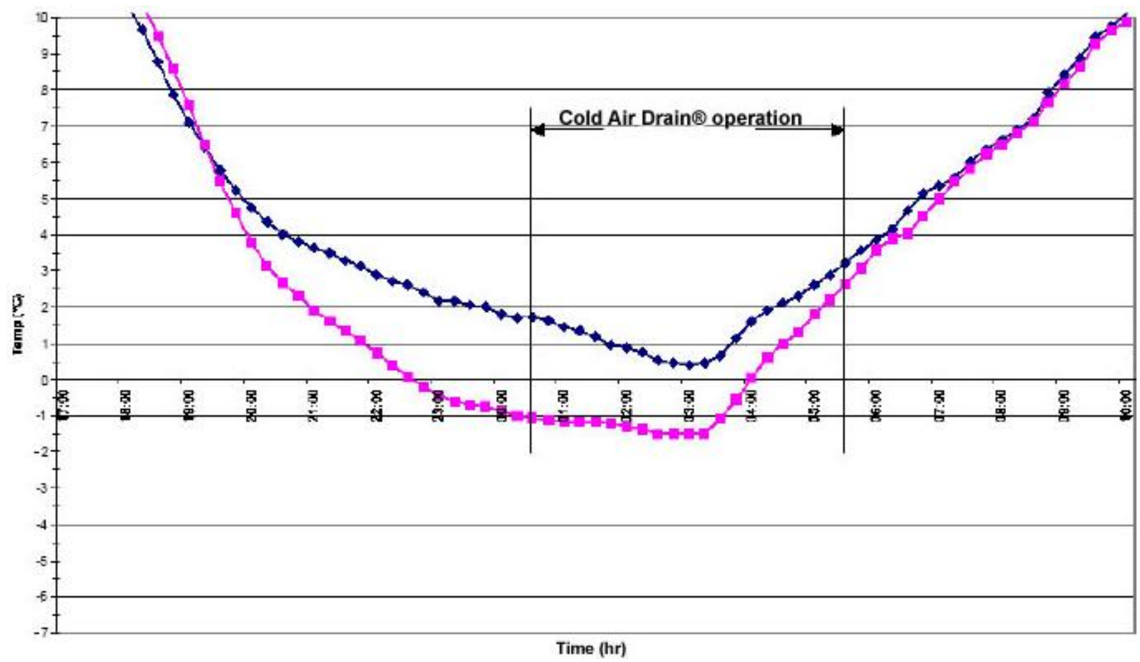


Figure 12: April 4, 2003

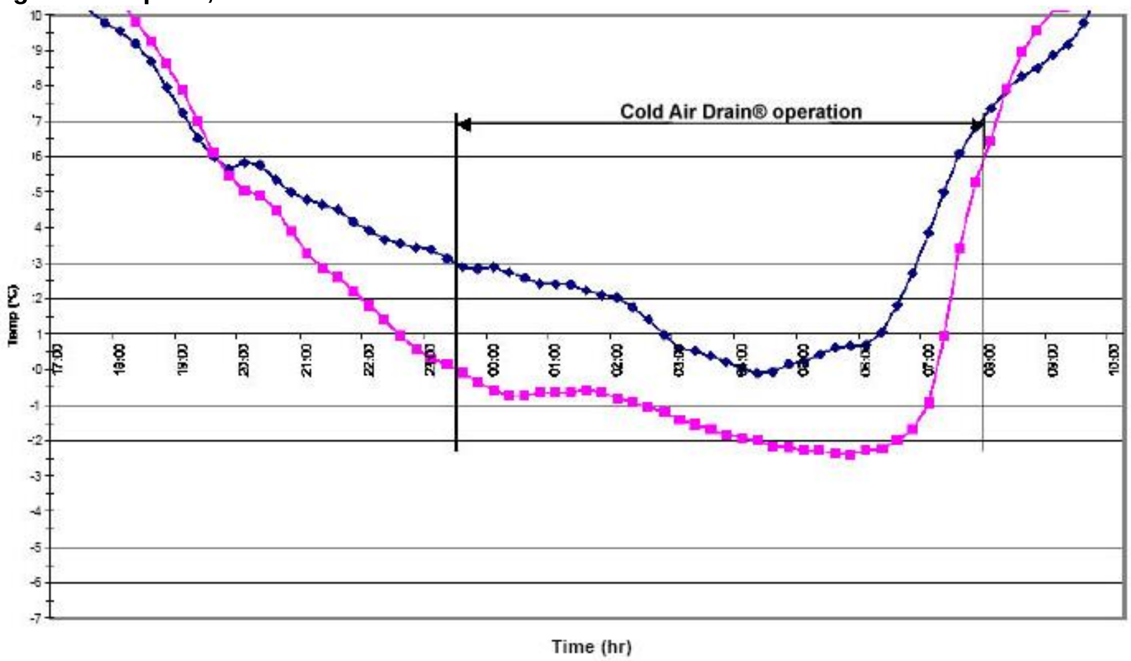
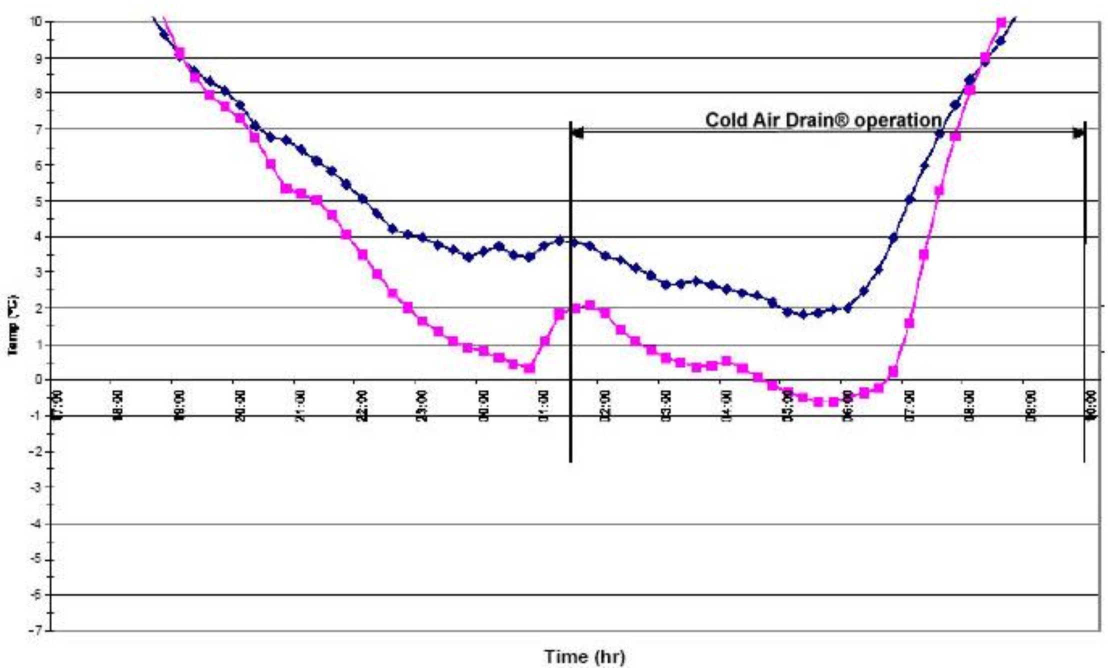
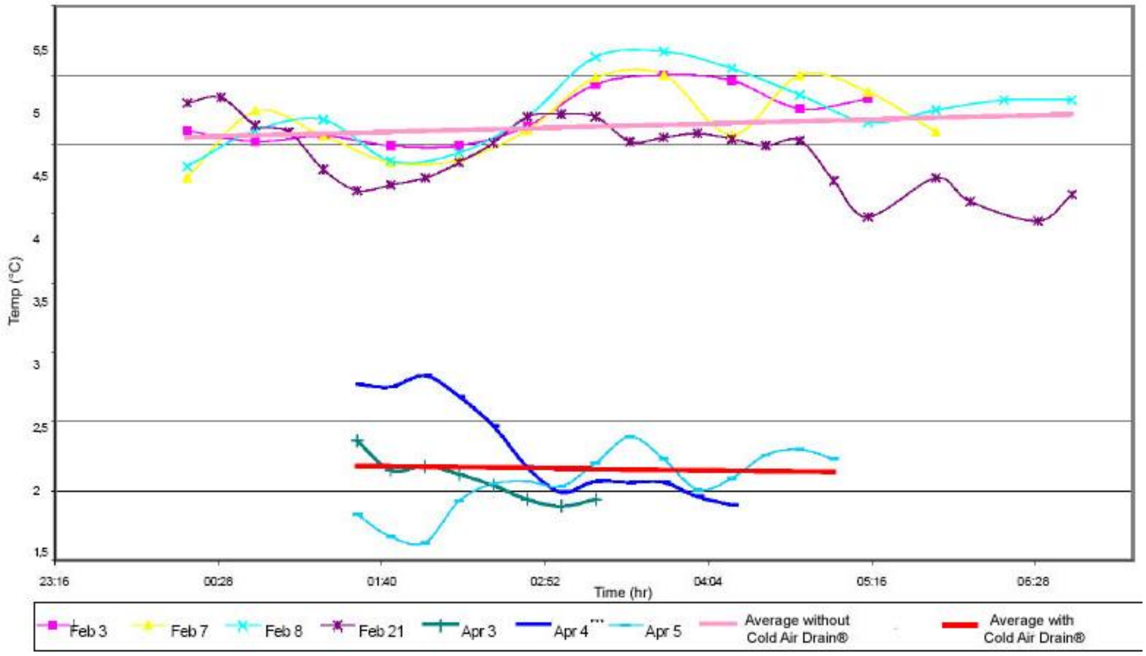


Figure 13: April 5, 2003



A simple regression model was used to calculate the net temperature increment due to the operation of the Cold Air Drain® (Figure 14). The average temperature difference between the upper and lower area during nights when the Cold Air Drain® units were not in operation was 4.7°C. The average temperature difference between the higher and lower elevation areas during nights when the Cold Air Drain® units were running was 2.2°C.

Figure 14: Higher & Lower Elevation Area Temperature Difference



The temperature difference between the lower and higher elevation areas was reduced during radiation frost nights when the Cold Air Drain® units were operating. The temperature difference was reduced by approximately 2.5°C (4.5°F) when the Cold Air Drain® units were operating. No frost damage at Tablas Creek Vineyard was reported at the end of the 2003 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® units were operating. The Cold Air Drain® significantly reduced the natural temperature difference between the higher and lower elevation areas of the vineyard by approximately 2.5°C (4.5°F). 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.

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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