Three Amigos Vineyard

2004

Cold Air Drain® units at Three Amigos Vineyard.

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Executive Summary

An initial study to evaluate the effectiveness of the Shur Farms Cold Air Drain® was conducted at Three Amigos Vineyard during the spring 2004 frost season. The accumulation of cold air in the lowest area of Three Amigos Vineyard contributed substantially to approximately 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 3°C. No frost damage at Three Amigos Vineyard was reported at the end of the spring 2004 frost season.

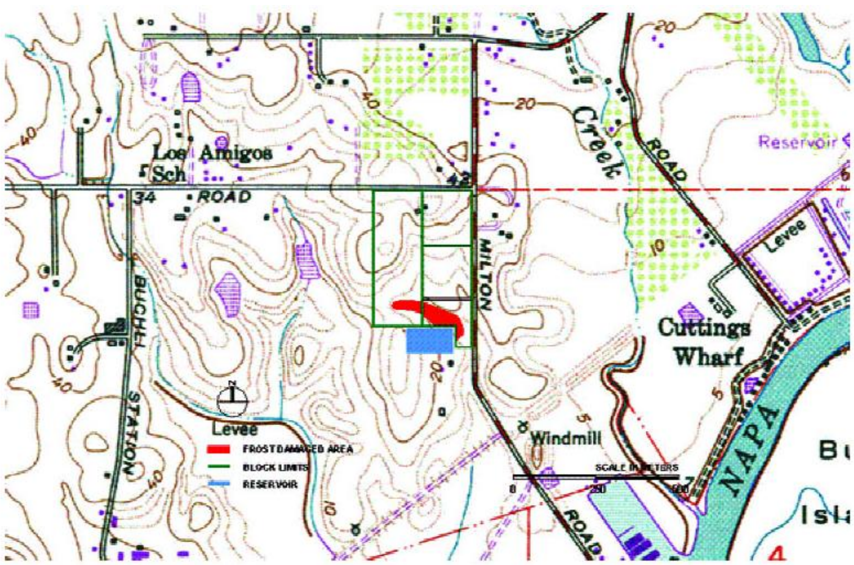
Introduction

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

Frost Problem at Three Amigos Vineyard

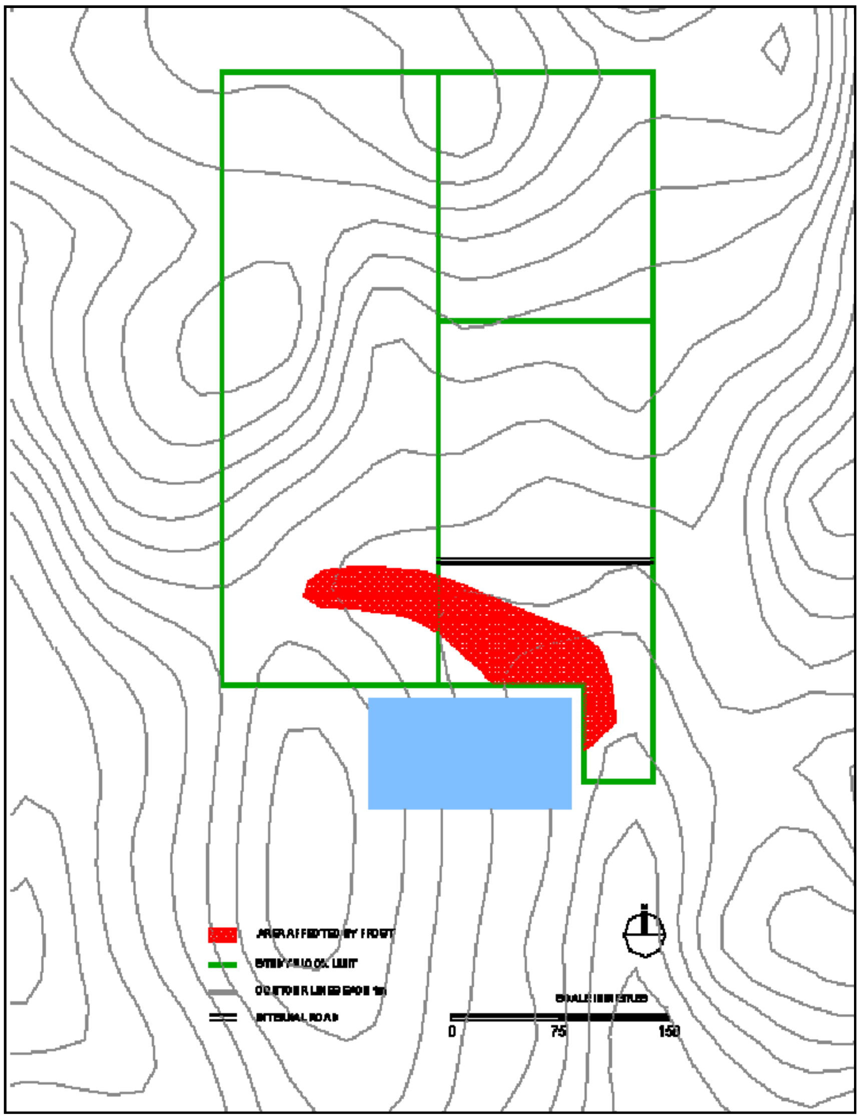
Three Amigos Vineyard is located in the USGS Cuttings Wharf quadrant in Napa, California (Figure 1). The property boundary is outlined in green and frost damage is indicated by the red area.

Figure 1: Three Amigos Vineyard Location



The frost damage sustained at Three Amigos Vineyard was due to the flow of cold air down the hillside, which contributed to the accumulation of cold air in the lowest area of the vineyard. The cold air accumulation area borders the Three Amigos Vineyard irrigation reservoir to the north-east. Figure 2 shows the frost damaged area at Three Amigos Vineyard. The property boundary is outlined in green and the frost damage is represented by the red area. The affected areas were part of approximately 6.5 acres of organic and biodynamically grown Pinot Noir wine grapes.

Figure 2: Frost Damage at Three Amigos 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 Three Amigos Vineyard. The property boundary for Three Amigos Vineyard is outlined in red. As Figure 3 indicates, the cold air flows down the gulley in the northern area of the vineyard and accumulates in the lowest area in the vineyard bordering the reservoir.

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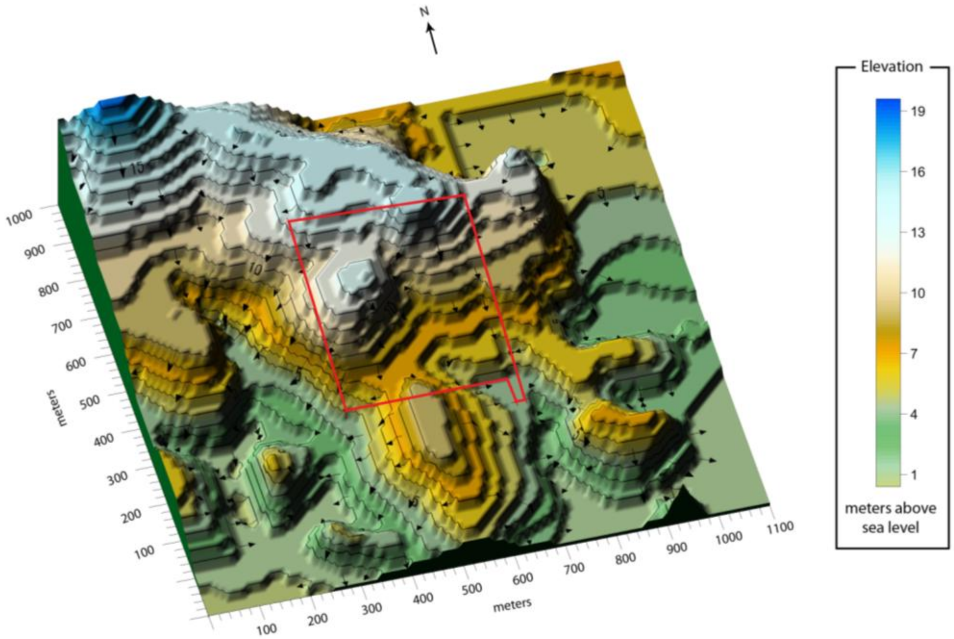
1 A radiation frost night is typically characterized by clear, cold nights, little moisture and little or no wind, fog, or cloud cover (e.g., Thompson 1986; Gudiksen, et al 1992). During a radiation frost, an inversion layer (i.e., stratified atmosphere) will be present.

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 Three Amigos 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 basin, 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 Three Amigos Vineyard
Shur Farms Frost Protection's calculations of the volume of cold air to be removed from the lower elevation, frost-prone areas resulted in two #925 Cold Air Drain® units (each unit covers approximately 2-3 acres) placed in the cold air accumulation areas to drain the cold air. Artificial barriers of 1.5m x 30m and 1.5m x 64m were also recommended to be placed according to the system design to strategically block the cold air to assist with the drainage of the 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® 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

Three Amigos Vineyard was selected to evaluate the effectiveness of the Cold Air Drain® because the area had approximately annual frost damage. Information about frost damage locations, patterns, and extent was provided by the Three Amigos 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.[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]

To measure the temperature difference, battery-powered HOBO H8 Pro (Onset

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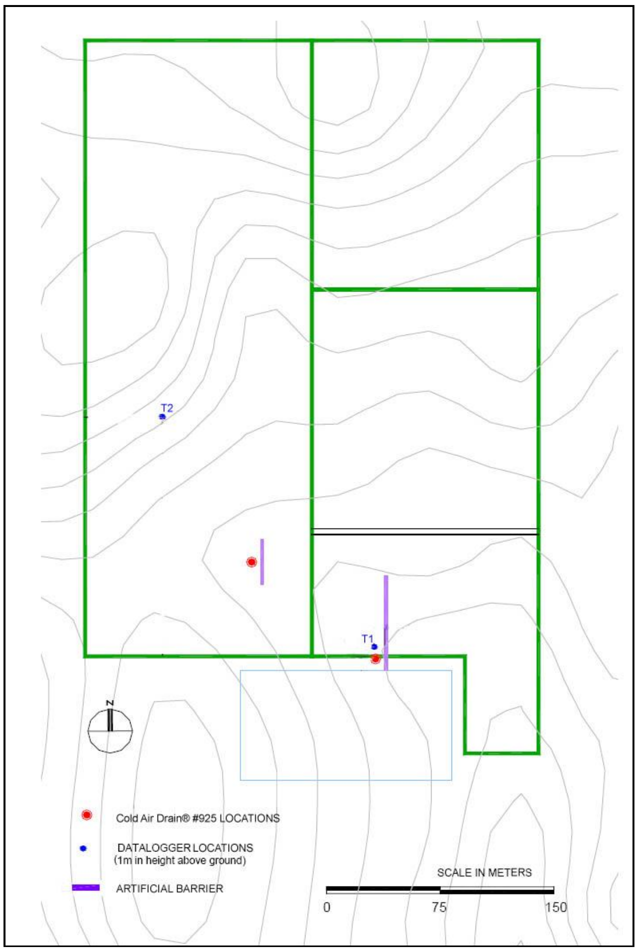
3 Frost protection methods to protect against advective frosts are limited.

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.

Computer Corporation) dataloggers[5] were placed in the higher elevation area (T2) and near the lowest point of cold air accumulation (T1). 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® units. The Cold Air Drain® units are located in the cold air accumulation 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°C (approximately 36°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
April 15, 2004	Yes
April 16, 2004	Yes
April 17, 2004	Yes
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

Figure 6 represents 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 the 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 light blue line and the temperature at the lower elevation

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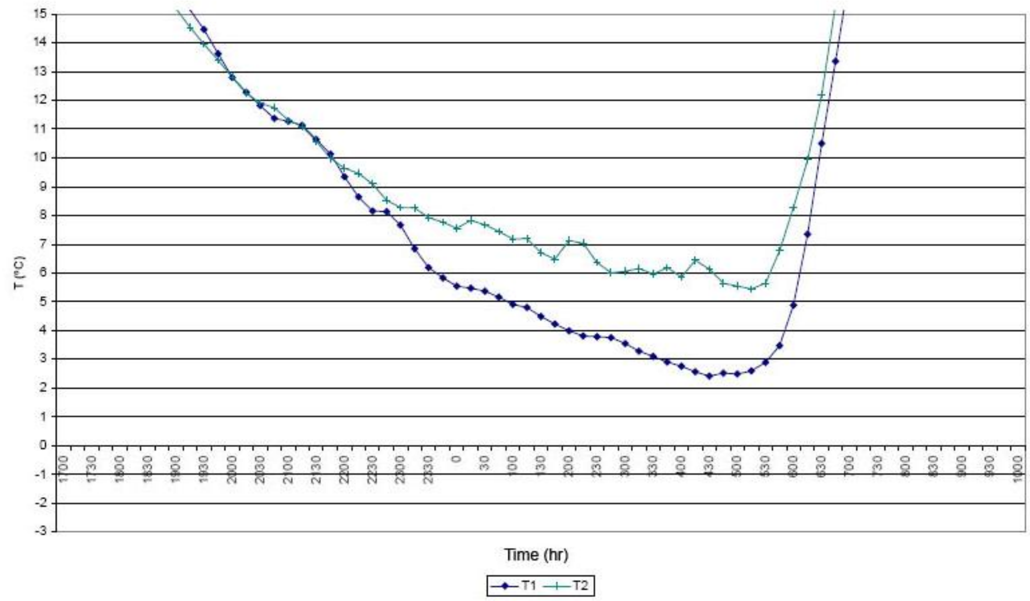
6 Growers are instructed to turn on the Cold Air Drain® when the temperature reaches approximately 2.22°C (approximately 36°F) to protect against frost damage.

area (T1) is represented by the dark blue line. As this graph shows, the temperature in the lower area remained below the temperature in the upper area until sunrise (approximately 6:30AM). This graph demonstrates the natural temperature difference between the lower and higher elevation areas.

Figure 6: May 18, 2004



Cold Air Drain® Operation Nights

Figures 7-9 show the temperature difference during the radiation frost nights when the Cold Air Drain® units were in operation between approximately 2:00AM and sunrise. The largest temperature difference was at approximately 2:00AM, as the Cold Drain® units were turned on *after* the temperature in the lower area had fallen below -1 degree Celsius. As the graphs indicate, even though the Cold Air Drain® units were turned on late, the temperature difference between the higher and lower elevation areas was significantly reduced. The temperature difference between the higher and lower elevation areas was significantly reduced while the Cold Air Drain® units were running.

Figure 7: April 15, 2004

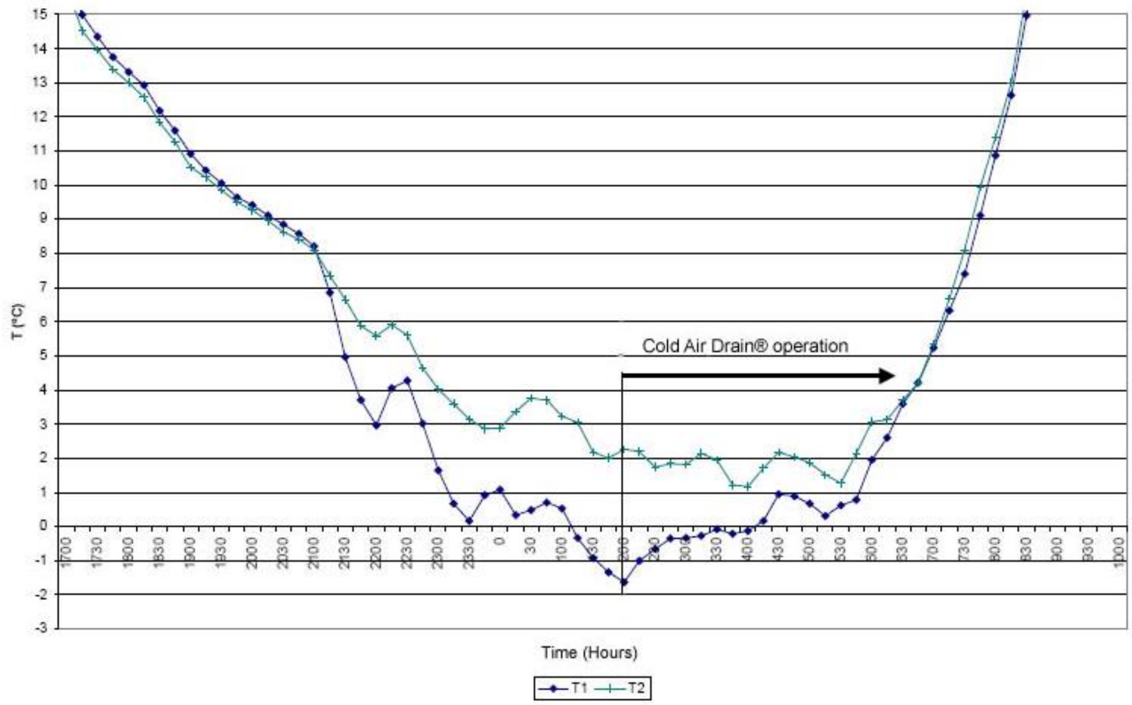


Figure 8: April 16, 2004

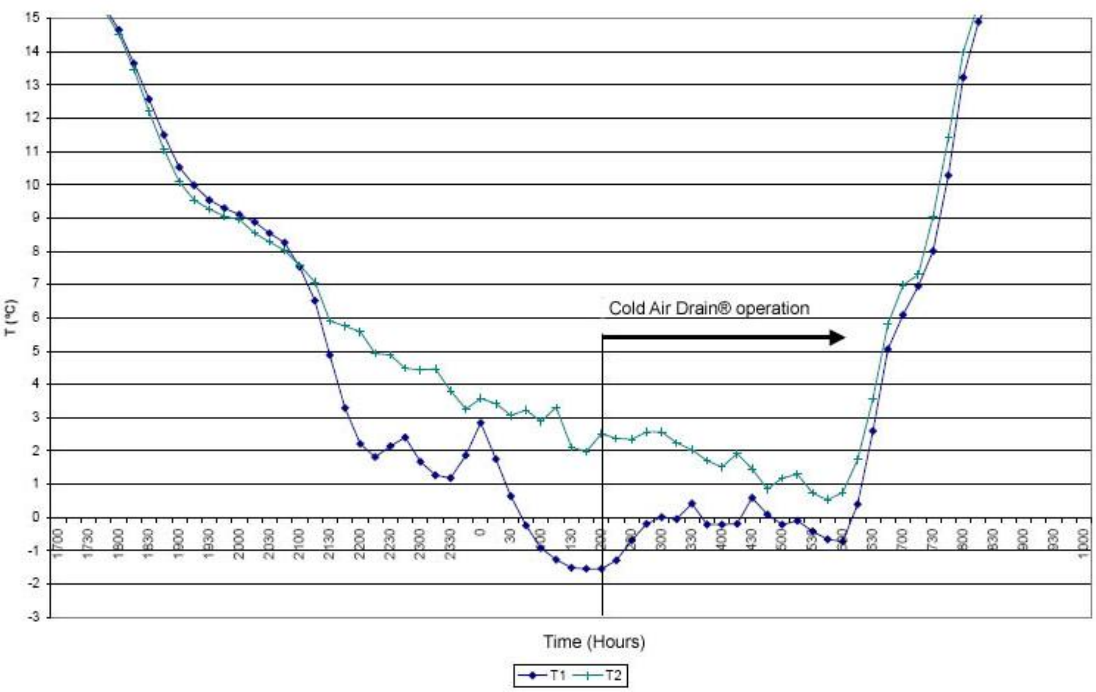
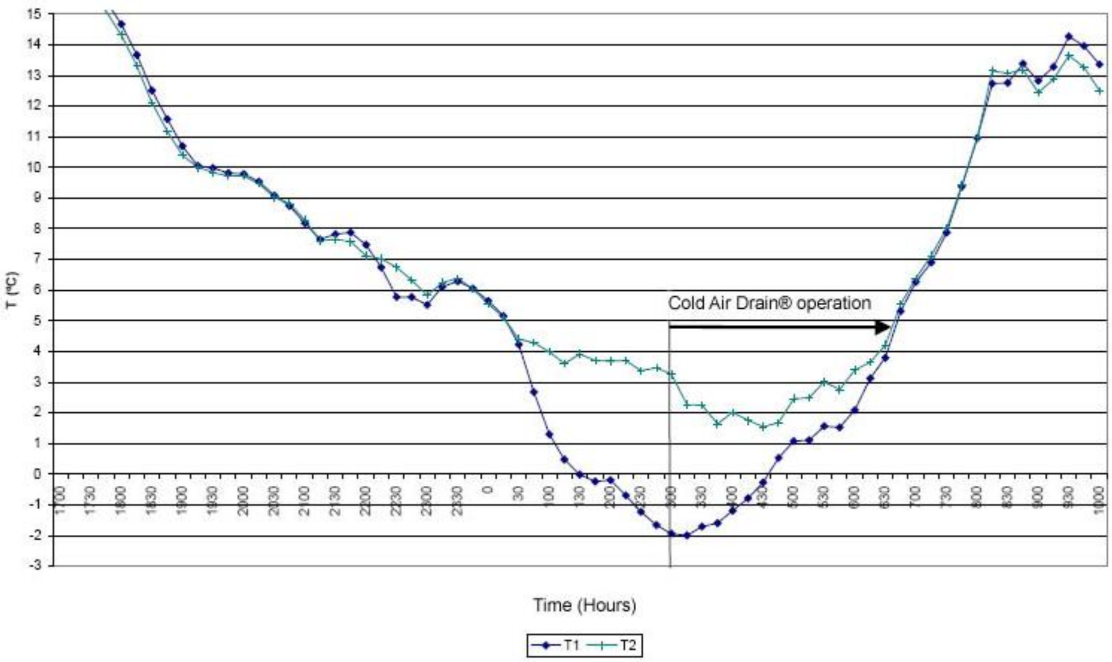


Figure 9: April 17, 2004



The temperature difference between the lower and higher elevation areas was significantly reduced during radiation frost nights when the Cold Air Drain® units were operating, despite the units being turned on after the temperature had already fallen below 2.22°C. The net temperature increment achieved when the Cold Air Drain® units were operating was approximately 3°C. No frost damage at Three Amigos 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® units were operating. The Cold Air Drain® significantly reduced the natural temperature difference between the higher and lower elevation areas of the vineyard (approximately 3°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

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Thank you for your participation.

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