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# Effect of Altitude on Cold Damage and Phenophase Durations in cv. Karaerik

## Karaerik Üzüm Çeşidinde Rakımın Soğuk Zararı ve Fenofaz Üzerine Etkisi

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## ABSTRACT

Karaerik, the only standard table grape variety of Erzincan, distinguishes itself from other grape varieties with its training system and unique taste. This variety, which has a high commercial value, is also a natural heritage and is an important example of Türkiye in terms of sustainable viticulture. In Erzincan Üzümlü district, where Karaerik grape cultivation is widespread, the vineyards are located between 1150 m and 1650 m altitude. In this study, the damage levels caused by low winter frosts in vineyards at different altitudes and the effectiveness of the methods used to determine these damage levels were investigated. In addition, the phenophase stages of the grapevines that occur between the pruning and harvest periods depending on the altitude were determined. Within the scope of the study, frost damage in Karaerik vineyards located at 1200 m, 1300 m, 1400 m and 1500 m altitudes throughout the district was determined by cross sectioning, shooting and real-time shooting methods and tests, and it was revealed to what extent the sectioning and shooting methods and damage detection confirmed real-time shooting. In all of the methods used, it was determined that the most frost damage occurred in the bottom buds (first 3 buds) of the vineyard at an altitude of 1200 m, and in terms of bud type, the damage in the primary buds was greater than the secondary and tertiary buds. The cross sectioning method confirmed 83.02% of real-time shooting test, while the shooting method confirmed 93.06%. The number of days between pruning-bud break, bud break-full bloom, full bloom-veraison, veraison and beginning of harvest increased from 1200 m altitude to 1500 m altitude. Taking the altitude factor into account in cultural processes in Karaerik vineyards will both increase the sustainability of local viticulture and carry a genetic heritage to future generations.

**Keywords:** Altitude, Cold damage, Karaerik, Phenophase

## ÖZ

Erzincan'ın tek standart sofralık üzüm çeşidi olan Karaerik; terbiye sistemi ve eşsiz tadı ile diğer üzüm çeşitlerinden ayrılmaktadır. Ticari değeri yüksek olan bu çeşit aynı zamanda doğal bir miras niteliğinde olup sürdürülebilir bağcılık açısından Türkiye'nin önemli örneklerindendir. Karaerik üzüm yetiştiriciliğinin yaygın olarak yapıldığı Erzincan'ın Üzümlü ilçesinde bağlar 1150 m ile 1650 m rakımları arasında yer almaktadır. Bu çalışmada, farklı rakımlarda kış donlarının bağlarda meydana getirdiği hasar düzeyleri ve bu hasar düzeylerini belirlerken kullanılan yöntemlerin etkinliği incelenmiştir. Ayrıca asmaların budama ile hasat dönemleri arasında rakıma bağlı olarak gerçekleşen fenofaz evreleri tespit edilmiştir. Çalışma kapsamında İlçe genelinde 1200 m, 1300 m, 1400 m ve 1500 m rakımda bulunan Karaerik üzüm bağlarındaki don zararı kesit alma, sürdürme ve gerçek zamanlı sürme yöntem ve testleri ile belirlenmiş, kesit alma ve sürdürme yöntemleri ile hasar tespitinin gerçek zamanlı sürmeyi hangi oranda doğruladığı ortaya koyulmuştur. Kullanılan yöntemlerin tamamında en fazla don zararının 1200 m rakımdaki bağın dip gözlerinde (ilk 3 göz) gerçekleştiği ayrıca tomurcuk tipi bakımından primer tomurcuklarda meydana gelen zararın sekonder ve tersiyer tomurcuklardan daha fazla olduğu tespit edilmiştir. Kesit alma yöntemi %83,02, sürdürme yöntemi ise %93,06 oranında gerçek zamanlı sürme sayımını doğrulamıştır. Budama-gözlerin uyanması, uyanma-tam çiçeklenme, tam çiçeklenme-ben düşme, ben düşme ve hasat başlangıcı arasında geçen gün sayısı 1200 m rakımdan 1500 m rakıma doğru artış göstermiştir. Karaerik üzüm bağlarında kültürel işlemlerde rakım faktörünün dikkate alınması, hem yöre bağcılığının sürdürülebilirliğini artıracak hemde genetik bir mirası gelecek nesillere taşıyacaktır.

**Anahtar Kelimeler:** Rakım, Soğuk zararı, Karaerik, Fenofaz

*This study is derived from the Master's Thesis of Üzeyir ÖZOĞUL.*

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## Introduction

Grapes one of the oldest fruits that have existed since prehistoric times and have survived to the present day (Ekhvaia & Akhalkatsi 2010; Naqinezhad et al., 2018; Zohary & Spiegel-Roy, 1975). Vine and wine are frequently mentioned in the holy books of monotheistic religions such as the Torah and the Bible. From the mythological period to the present, grapes and grape by-products have always been included in artistic works. As a matter of fact, the archaeological excavations carried out to date have been the greatest proof of the importance societies give to grapes (Deliorman et al., 2011). It is thought that the vine began to be cultivated in the Neolithic period (6000-5000 BC) in the region known as Transcaucasia in the eastern part of the Black Sea. Türkiye, which is located in the world's most suitable climate zone for viticulture, has a very old and deep-rooted viticulture culture. Grapevine, which was first cultivated in Anatolia, has been one of the most important agricultural products for all civilizations that made this geography their home (Candar et al., 2021; Doğan, 1996).

Grape, one of the most diverse fruit species in the world, is still facing the negative effects of the climate in some regions, even though it has survived to the present day. Especially in regions where the continental climate prevails, winter cold is one of the most important abiotic factors that limits economic viticulture. Therefore, producers face serious problems when they aim to obtain high quality grapes in areas where short vegetation and cold climate prevail (Fennel, 2004). Although Türkiye has a significant advantage for viticulture due to its climate, low temperatures and frost events cause yield loss and economic losses in vineyards (Küpe, 2019). Especially in the Eastern Anatolia Region, viticulture is faced with many negative effects of the continental climate. For *Vitis vinifera* L. varieties, low temperatures in winter cause damage at -12$^{o}$C in winter buds, -16$^{o}$C in shoots and -20$^{o}$C in branches (Köse & Güleryüz, 2009). The threshold values of this damage vary depending on factors such as altitude, location of the vineyard, rootstock, variety, dormancy period temperatures, pruning time and method, training method, cultural control, product load, genetic factors, and adaptability of the variety. In fact, according to research, it is estimated that approximately 5-15% of world grape production is lost each year due to frost damage (Evans, 2000).

One of the regions most affected by winter frosts in terms of viticulture in Türkiye is the Üzümlü District of Erzincan. Although the grape microclimate is a suitable region for viticulture, the short vegetation period and winter frosts in the region cause economic losses in grapes. The Karaerik grape variety, which is thought to be one of the grape varieties with the high commercial value in Türkiye. Karaerik grown in Üzümlü as the only standard table grape variety of Erzincan and is marketed at a high demand (Köse, 2002). The vineyard areas in Üzümlü start from 1150 m altitude and go up to 1650 m altitude. In a study conducted by Köse and Güleryüz (2009) in Karaerik vineyards, it was reported that there were significant differences between the damage levels occurring at different altitudes. Another factor that changes with altitude is phenological periods. It has been reported that altitude drives phytophenological stages through a temperature decrease of about 0.6°C per 100 m (Barry, 1981; Koch et al., 2007; Ziello et al., 2009).Phenological stages includes processes such as the growth, development, and fruiting of a vine throughout the year (Nasirovic, 2024). Monitoring phenological periods is important for quality grape and wine production. In a study conducted by Alikadic et al. (2019) on the phenological periods of altitude in grapevines, it was reported that bud burst was delayed by 0.85 to 2.88 days and harvest was delayed by 6.27 to 7.16 days for every 100 m increase in altitude, thus the increase in altitude on a global scale caused a delay in phenological stages and the main effect of the increase in altitude was seen in bud burst and the beginning of harvest. Agricultural science uses phenological data for the timing of agricultural work and the selection of suitable products and varieties. Nowadays phenological data are usually used in providing valuable input data for crop yield modelling, they provide important support to frost warnings and are essential for pest control measures (Koch et al., 2007).

Within the scope of this study, the level of damage caused by low winter temperatures on the Karaerik grape variety in Erzincan Province Üzümlü District, where the continental climate prevails but exhibits microclimate characteristics, was examined in laboratory, greenhouse and field conditions in vineyards at 4 different altitudes (1200 m, 1300 m, 1400 m and 1500 m). It was tried to detected by cross-sectioning, shooting and real-time shoot counting tests. In addition to determining the level of damage that occurs depending on altitude, the study also tried to reveal the difference between the methods used to determine these damage levels and the effect of altitude on the time between phenological stages of grapevine was evaluated.

## Methods

Meteorological data for Üzümlü District were obtained from Erzincan Meteorology Station. According to long-term (1929-2022) climate data, the annual average temperature in Erzincan is 10.9$^{o}$C, the annual average highest temperature is

17.4°C, the annual average lowest temperature is 4.8°C, the average number of rainy days is 102.1, and the annual average rainfall is 367.2 mm. According to the long-term temperature average, the temperature values in summer are between 20°C and 24.1°C, and in winter the temperature is between 1.2°C and -3°C. The number of cloudy days per year was determined as 197.9 and the number of sunny days as 105.4 (Anonymous, 2022a). As of 2022, there are 38,672 acres of planted land in Erzincan Province, 9478 acres of which are vineyards, and 58% of these vineyards are located in Üzümlü. In 2022, 4190 tons (67.5%) of the 6202 tons of grapes produced in the province were produced in Üzümlü (Anonymous, 2022 b).

**Material**

The Karaerik (*Vitis vinifera* L.) grape variety that we used as material in the study is the only standard table grape variety of Erzincan and is widely grown in Üzümlü (Cimin) District. Karaerik is a table grape variety with black color, flattened oval shape, an average weight of berries is 3-4 g, an average number of seeds of 1-4, medium skin thickness, plump density and an average cluster weight of 300 g-500 g (Köse,2002; Küpe,2013; Özoğul, 2024). It has a unique mist on its berries and aroma that is not seen in other grape varieties, meeting at a very fine point between tart and sweet in taste (Karadeniz & Altınbilek, 2016).

The training method for the Karaerik grape variety is the baran system, which is a method specific to the region. The Baran system can be described as a system in which the grape trunk is taken underground, the branches and rods are left above the soil, and the soil is raised from the ground in a herringbone shape.  In recent years, due to global warming, the decrease in snow cover in the region and climate changes, the Karaerik grape variety has been seriously affected by winter frosts (Köse & Güleryüz, 2009; Küpe, 2012).

**Determination of Frost Damage**

The level of frost damage was determined using 3 different methods: cross sectioning, shooting and real-time shoot counting tests in greenhouse, laboratory and field conditions. As a matter of fact, carrying out frost damage detection studies in viticulture comparatively in the laboratory, greenhouse and field triangle will increase the accuracy of the studies.

*Cross-Sectioning Test*

In this method, a total of 72 number 1-year-old healthy branches with 9 buds were taken from 4 different altitudes in January and February. The samples were brought to the laboratory on the same day and kept at room temperature for 1 day to allow enzymatic browning to occur and to more clearly determine the level of damage. In this method, the damage level in primary, secondary and tertiary buds was examined according to the positions of the buds (bottom, middle, end) on January and February 24, a total of 648 number of buds, according to their positions and altitude. Then, the winter buds on 1-year-old branches were cut with a scalpel and the vitality of the primary, secondary and tertiary buds was determined (Çelik et al., 2008; Köse & Güleryüz, 2009; Küpe, 2013; Odneal, 1984). Primary, secondary and tertiary buds with green tissue were considered alive and brown ones were considered dead (Küpe, 2013) (Figure 1).

**Figure 1.**
*Determination of vitality in buds by cross sectioning method*

*Shooting Test*

In the shooting test, a total of 72 number 1-year-old healthy branches with 9 buds were taken from 4 different altitudes in 2 different periods in January and February. Branches brought to the laboratory were grouped according to their altitude and position, and the 1st, 2nd, and 3rd buds of the 9-bud branches were accepted as bottom buds; the 4th, 5th, and 6th buds were accepted as middle buds; and the 7th, 8th, and 9th buds were accepted as end buds. After the branches were cut into 1-bud cuttings and kept in room temperature water for 24 hours, they were planted in shooting boxes prepared from a 1:1:1 mixture of sand, perlite and soil in a greenhouse environment according to the bud position and altitude (Özgür et al., 2021). In this method, a total  324 number of 1-bud cuttings were used from 4 different altitudes, including 27 bottom, 27 middle and 27 end buds for each period. Cuttings with buds were considered as living and cuttings without buds were considered as dead (Figure 2).

**Figure 2.**
*Determination of vitality in buds by shooting method*

*Real-Time Shoot Counting Tests*

In Karaerik vineyards located at altitudes of 1200 m, 1300 m, 1400 m and 1500 m, buds that have completed their blooming were counted on different vines in the vineyard on May 20. The number of shoots on all the remaining 3- bud branches after pruning on the 3 number of vines detected at each altitude was counted directly in real time. In this method, the buds that have completed their bud burst stage and formed leaves and green shoots are considered alive, and the buds that have not formed are considered dead. Because of only 3 number of buds are usually left during pruning of the Karaerik grape variety in the region, the damage level was determined at the bottom buds according to the bud position (Figure 3).

**Figure 3.**
*Real-time viability detection in buds*

*Differences Between Methods in Determining Frost Damage*

In frost damage determinations made by sectioning method, the situation in which all three primary, secondary and tertiary buds within the winter bud were dead at the same time was evaluated as final death. As a matter of fact, in the shooting and real time shooting methods, in cases where none of the buds in the eyes erupt, the eye is considered dead and the damage rate is determined accordingly. Therefore, final mortality rates were taken into account when comparing frost damage between methods. However, since the frost damage detection with the ploughing method is done after pruning and generally 3 buds are left in the traditional pruning carried out in the region, the damage difference comparison was made on the bottom buds.

**Phenophase Durations**

*Bud Burst*

In spring, as the daily average air temperature rises above 10°C and the soil temperature increases, the buds begin to swell, internal development accelerates, the protective scales on the bud separate from the tip, and first the brown woolly bud hairs, then the green shoot tip, begin to appear, and the bud completes its bud burst process (Ağaoğlu, 2002; Coombe, 1995; Eichhorn & Lorenz, 1977; Lorenz et al., 1994). This period was recorded as the period when the buds burst.

*Full Bloom*

The period when 50% of the caliper was shed was taken as basis (Ağaoğlu, 2002; Coombe, 1995; Eichhorn & Lorenz, 1977; Lorenz et al., 1994).

*Veraison*

In order to determine the veraison date, the vines in the vineyard were visited one by one and the bunches were examined, and the date when the coloration was first observed was determined as the veraison (Coombe, 1995; Eichhorn & Lorenz, 1977; Lorenz et al., 1994;).

*Harvest*

The harvest date is based on the variety's unique appearance and taste are formed and the first product is brought to the market (Coombe, 1995; Eichhorn & Lorenz, 1977; Lorenz et al., 1994).

*Yield (kg/da)*

Yield was calculated as kg/decare by multiplying the number of clusters on the vine by the average weight of 3 clusters representing the vine and by 200 (it is assumed that there are 200 vines on average in the vineyard).

## Results and Discussion

As a result of cross sectioning and shooting tests made in January, it was determined that the air temperatures in this period did not drop significantly below the critical limit (Figure 4), and in parallel, frost damage was not significant ($p$>.05) (Table 1, Table 2).

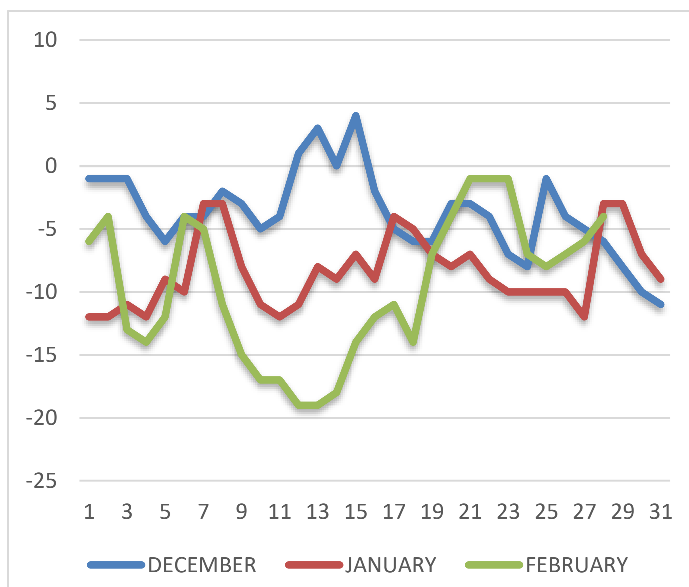


**Figure 4.**
*Minimum temperatures for the cold damage in study period (Anonymous, 2023)*

In the February period, frost damage determinations were made by taking into account the positions of the buds using the sectioning method, and among the bottom, middle and top buds. The highest damage occurred in the primary buds in the bottom buds of the vineyard at an altitude of 1200 m with 63%. This was followed by the primary bud of the middle buds of the vineyard at 1200 m altitude with 62%, and then by the primary bud of the end buds with 55.6%. The total damage rate in the bottom buds was found to be statistically significant ($p$<.05) according to altitude. After 1200 m altitude, the highest damage was detected in the primary buds of the middle buds of the vineyard at 1300 m altitude with 40.7%. Among all groups and bud positions, the most damage was detected in primary buds. Among all vineyards where damage was determined by the cross sectioning method, the highest average damage was determined in the vineyard at 1200 m altitude with 31.98%, followed by the vineyard at 1300 m altitude with 12.7% and at 1400 m and 1500 m altitude with 7.4% (Table 1).

**Table 1.**
*Vitality rate of buds according to cross sectioning method (%)*

| Period | Position | bud type | 1200 m | 1300 m | 1400 m | 1500 m | $X^2$ Test |
|---|---|---|---|---|---|---|---|
| January (n=108) | Bottom | Primary | 96.3 | 100.0 | 96.3 | 100.0 | 0.565 |
| | | Secondary | 100.0 | 100.0 | 100.0 | 100.0 | |
| | | Tertiary | 100.0 | 100.0 | 100.0 | 100.0 | |
| | Middle | Primary | 100.0 | 100.0 | 96.3 | 100.0 | 0.387 |
| | | Secondary | 96.3 | 100.0 | 100.0 | 100.0 | 0.387 |
| | | Tertiary | 100.0 | 100.0 | 100.0 | 100.0 | |
| | End | Primary | 96.3 | 100.0 | 100.0 | 100.0 | 0.387 |
| | | Secondary | 96.3 | 100.0 | 100.0 | 100.0 | 0.387 |
| | | Tertiary | 96.3 | 100.0 | 100.0 | 100.0 | 0.387 |
| February (n=108) | Bottom | Primary | 37.0 | 59.3 | 81.5 | 74.1 | 0.004 |
| | | Secondary | 66.7 | 96.3 | 92.6 | 92.6 | 0.004 |
| | | Tertiary | 85.2 | 100.0 | 100.0 | 100.0 | 0.006 |
| | Middle | Primary | 38.0 | 55.6 | 81.5 | 77.8 | 0.002 |
| | | Secondary | 66.7 | 85.2 | 92.6 | 96.3 | 0.011 |
| | | Tertiary | 100.0 | 96.3 | 100.0 | 100.0 | 0.387 |
| | End | Primary | 44.4 | 96.3 | 85.2 | 96.3 | 0.000 |
| | | Secondary | 77.8 | 96.3 | 100.0 | 96.3 | 0.008 |
| | | Tertiary | 96.3 | 100.0 | 100.0 | 100.0 | 0.387 |

In the determination of frost damage made by taking into account the positions of the buds with the shooting method in the February period, the highest damage occurred in the bottom buds of the vineyard at 1200 m altitude with 38.9%, followed by the middle buds of the same vineyard with 33.3%. In four different altitudes examined with the shooting method, the average damage was detected to be the highest at 1200 m altitude with 28.6%, followed by 16.1% at 1300 m altitude, 6.6% at 1400 m altitude and 5.9% at 1500 m altitude (Table 2).

**Table 2.**
*Vitality rate according to bud position with shooting method*

| Period | Altitude | N | Bottom | Middle | End | $X^2$ *Test* |
|---|---|---|---|---|---|---|
| January | 1200 m | 96 | 93.90% | 97.00% | 90.00% | 0.521 |
| | 1300 m | 126 | 95.20% | 95.20% | 95.20% | 1.000 |
| | 1400 m | 93 | 97.00% | 96.80% | 96.60% | 0.996 |
| | 1500 m | 101 | 97.00% | 94.10% | 97.10% | 0.780 |
| February | 1200 m | 123 | 61.10% | 66.70% | 86.30% | 0.019 |
| | 1300 m | 158 | 71.40% | 91.80% | 88.30% | 0.012 |
| | 1400 m | 117 | 91.90% | 97.10% | 93.30% | 0.624 |
| | 1500 m | 151 | 82.00% | 100.0% | 98.10% | 0.000 |

When the results obtained from the determinations made with the real-time shoot counting method in the vineyard were examined, it was determined that the highest damage occurred at 1200 m altitude with 34.2%, at 1300 m altitude with 20.12%, at 1500 m altitude with 10.71% and at 1400 m altitude with 5.71%, respectively. Thus, it was determined that the most frost damage in the real-time shoot counting method, as in the cross sectioning and shooting methods, occurred in the bottom buds of the 1-year-old shoots of the vineyard at an altitude of 1200 m.

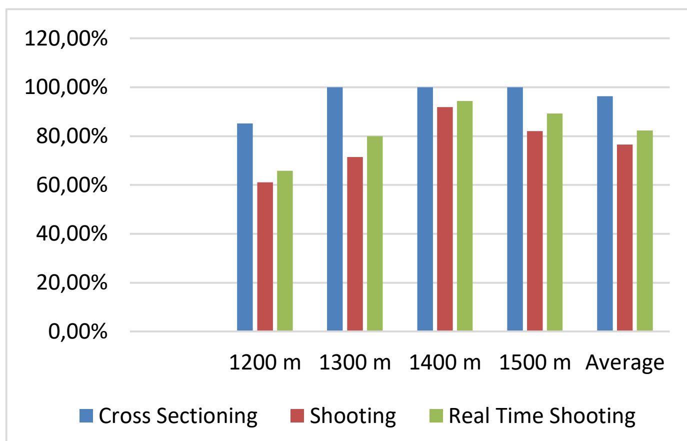


**Figure 5.**
*Vitality rate of buds according to different methods*

In this study, in which frost damage was determined with 3 different methods in vineyards at different altitudes, it was observed that although the frost damage level determined with the cross sectioning and shooting methods was generally parallel to the frost damage determined with the real-time shoot counting method, there were some differences between the methods. It was observed that the shooting test conducted under greenhouse conditions confirmed the real-time shoot counting in the vineyard to a higher extent compared to the sectioning method applied under laboratory conditions. When the altitudes were evaluated together, it was determined that the sectioning method was 83.02% similar to the real-time shoot counting test, while the shooting method was 93.06% similar (Figure 5). In fact, in a similar study conducted by Küpe and Köse (2019) low temperature damages occurring on winter buds of vines in the Karaerik grape variety were determined under vineyard (burst test) and laboratory conditions (sectioning method) and it was investigated whether there was a difference between the two methods. As a result of the study, the researchers reported that there were 7.9%, 14.56% and 0.1% differences in primary, secondary and tertiary buds between the sectioning method and the burst test, respectively. However, in a study conducted by Korkutal et al. (2023) investigating the productivity of buds growing in climate chamber and vineyard conditions, it was stated that there may be differences in terms of bud growth and bud productivity in climate chamber and vineyard conditions. These different results show that conducting bud productivity studies in viticulture in the triangle of greenhouse, vineyard and laboratory will increase the accuracy of the study and explain why three different techniques were used in this study. In this study, it was determined that the bottom buds were more sensitive than the middle and end buds in the damage detections made by sectioning and continuing methods (Table 1, Table 2). Köse and Güleryüz (2009) investigated frost damage in Karaerik vineyards located at 6 different altitudes (between 1197 m and 1650 m) using the cross-section method and found that the highest damage occurred at 1197 m and 1660 m altitudes, while the lowest damage occurred at 1360 m and 1460 m altitudes. In a study conducted by Khanizandeh et al. (2005) in a study conducted with 20 grape varieties at 3 different altitudes (43 m, 125 m and 205 m) in Quebec, Canada; It has been reported that winter cold damage is greater in the low-altitude C'Orpailleur and Dietrich-Joos regions compared to vineyards at higher altitudes, and this is due to the cold air draining and settling in low areas this study where cold damage was determined in vineyards. In this study where cold damage was determined in vineyards, it was determined that the highest cold damage occurred at 1200 m altitude, followed by 1300 m altitude in all of the cross sectioning, shooting and real-time shooting tests, and that there were differences in cold damage at 1400 m and 1500 m altitude depending on the applied method (Table 1, Table 2). These results are similar to previous cold damage studies conducted by taking altitude into account. It should not be overlooked that the vineyard, which is located at an altitude of 1200 m, is located at the bottom of the plain and that the cold air mass may accumulate here and cause more frost damage as a result of radiational cooling. In addition, the topographic structure of Üzümlü and the spread of vineyards from the hillsides to the bottom lands also support this situation. Indeed, Geiger et al. (1965) reported that under radiation cooling conditions, the Earth loses heat to space and cools the air mass, thanks to light winds and clear skies. Similarly, it has been reported that most of the winter frosts that cause damage in vineyards are usually caused by radiational frost, and that vineyards in frost lakes are more exposed to winter cold damage than vineyards at higher altitudes (Korkutal et al., 2012). In the frost damage determinations we made at different altitudes, another reason why the most damage occurs at the lowest altitude (1200 m). It should not be ignored that it may be related to the more limited protective effect of snow cover on vineyards in the bottom land. As a matter of fact, in Erzincan Üzümlü, our study was carried out, cultivation is carried out with the baran training system and it is known that one of the main advantages of the system is to benefit from the protective effect of the snow cover against low temperatures in the winter (Figure 6). However, the decrease in snowfall in recent years and the shortening of the duration of snow cover at low altitudes exposes the winter buds on 1-year-old branches directly to cold air on frost days and increases frost damage. Davenport et al. (2008) reported that although the Pacific Northwest has a mild climate, in addition to the small amount of snow cover and low temperatures, in some winter periods when snowfall is limited, this situation causes damage to grapevine buds and complete death of the grapevine, thus making the selection of suitable site and variety critical in viticultural activities.

**Figure 6.**
*Baran training system under snow*

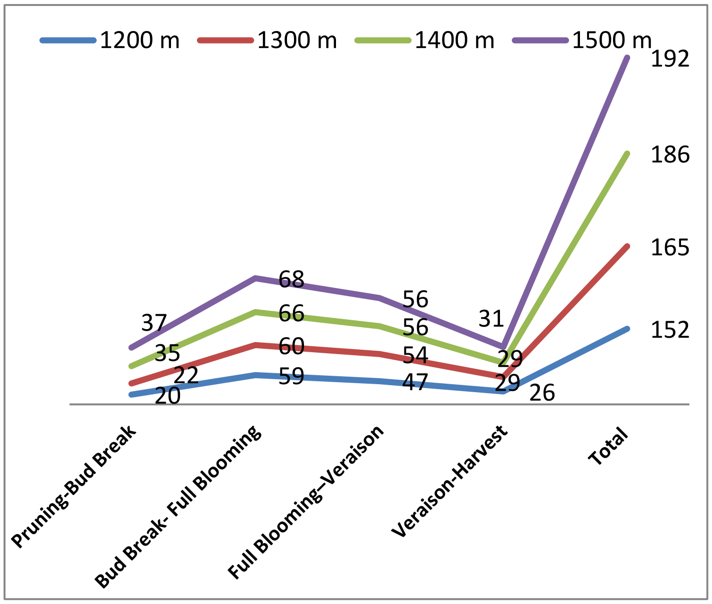


**Figure 7.**
*Change of phenophases depending on altitude*

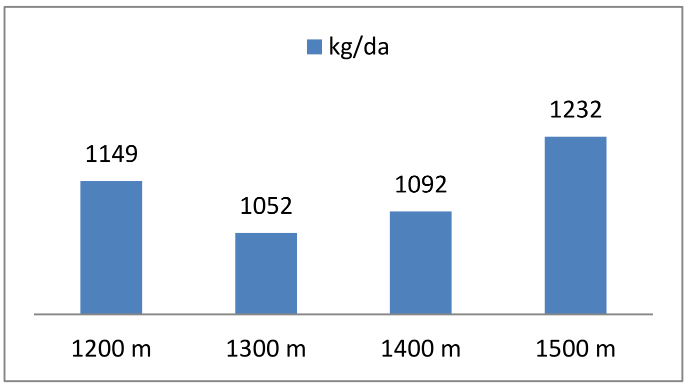


**Figure 8.**
*Yield change depending on altitude (kg/da)*

In the Karaerik vineyards examined at 4 different altitudes, it was observed that the shortest period between pruning and bud break was 20 days at 1200 m altitude and the longest period was 37 days at 1500 m altitude. From bud break to full bloom, 59 days passed at 1200 m altitude and 68 days at 1500 m altitude. After full blooming, veraison occurred in 47 days at 1200 m altitude and in 56 days at 1500 m altitude. After veraison in the vineyards, harvest started 26 days later at 1200 m altitude and 31 days later at 1500 m altitude (Figure 7). A 40-day difference was determined between 1200 m and 1500 m altitude from pruning to harvest. In terms of the duration of phenological stages, it was determined that the longest period at all altitudes was the phase from bud break to full blooming, and the shortest phase was the bud break phase after pruning. In Karaerik vineyards at 1200 m, 1300 m, 1400 m and 1500 m altitudes where phenological periods were examined, it was determined that the shortest number of days in phenological periods were at 1200 m altitude and the longest number of days were at 1500 m altitude (Figure 9).

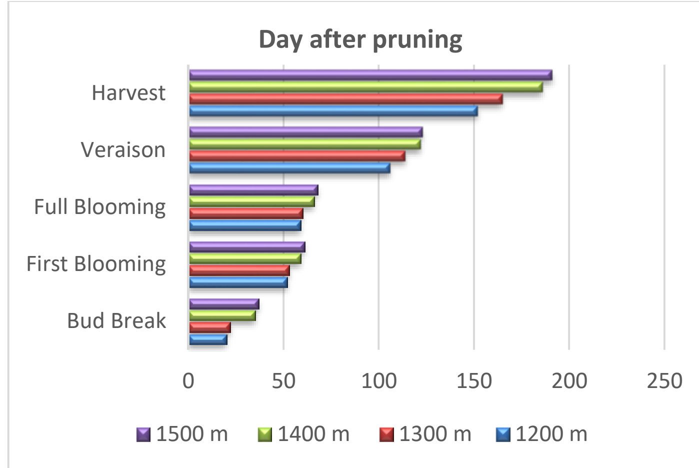


**Figure 9.**
*Difference between phenological stages according to altitude*

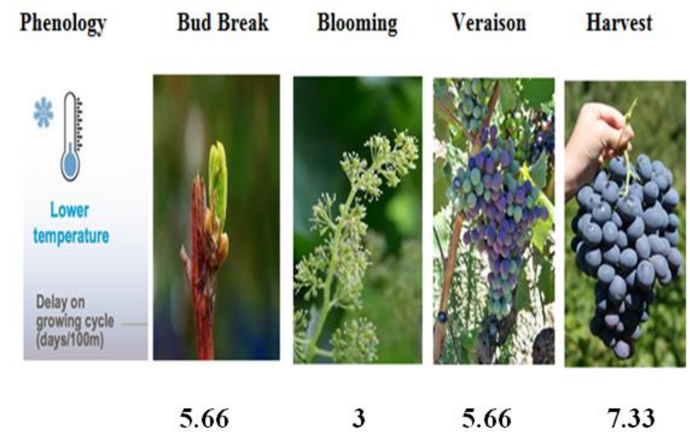


**Figure 10.**
*Average phenological delay per 100 m after bud burst stage (days) (Bud Break: After pruning)*

In this study carried out in Üzümlü, Erzincan, it was determined that for an average increase of 100 m in altitude, there was a delay of 5.66 days in bud burst, 3 days in flowering, 5.66 days in veraison and 7.33 days in harvest (Figure 10). It is considered that the sum of the decreasing air temperature and low effective heat summations (EHS) due to altitude increase is effective in this difference. In fact, the results of this study are similar to previous studies. For example, in a study conducted by Pellerin et al. (2012) to examine the phenology of grapevines in the Western Alps, it was investigated how air temperature, altitude and other topographic factors affect phenological processes. The study reported that altitude was the main determinant of bud burst dates with delays ranging from 2.4 to 3.4 days per 100 m as expected. Again, Cornelius et al. (2013) made phenological observations on grapes in 24 regions at an altitude of 680 to 1425 meters. The study found that the phenophases of the species were highly dependent on interannual temperature changes and altitude, with an average delay of 3.8 days reported for every 100 m increase in altitude. In a study conducted by Muniz et al. (2015) in the southern region of Brazil, it was reported that the air temperature of the vineyard at 1400 m altitude was 4.4ºC lower than the vineyard at 950 m altitude and received 12% higher total radiation, and that this altitude difference in the growing regions caused a 50-56 day delay in the harvest date and a 37 day delay from bud break to full bloom for both Merlot and Cabernet Sauvignon grape varieties, and that phenophases were significantly affected by altitude. Similarly, Ruml et al. (2016) examined the bud burst, flowering, veraison and harvest periods of 20 grape varieties, and as a result of the study, it was reported that an average 1ºC increase in these periods brought the harvest period 7.4 days earlier on average. In a study conducted by Alikadic et al. (2019) bud break and harvest periods of five varieties (Pinot Noir, Sauvignon Blanc, Chardonnay, Merlot, Pinot Gris) were examined in vineyards located at an altitude of 67 m above sea level and 950 m above sea level in the Trento Region of Italy. As a result of the research, it was reported that the beginning of harvest was significantly affected by altitude and that the harvest was delayed by 6.27 to 7.16 days for every 100 m increase in altitude, while the bud break period advanced by 0.85 to 2.88 days for every 100 m. All these results obtained from previous studies support our study and show that altitude is an important factor in phenological periods for Karaerik vineyards.

## Conclusion

As a result of the study, it was concluded that there are differences between the methods used to determine frost damage in buds, that the shooting method confirms a higher rate of real-time shooting than the cross sectioning method, and therefore it would be more accurate to evaluate the two methods together in frost damage determinations. In Üzümlü, where the continental climate prevails, it is considered that the possibility of the vines being damaged by winter frosts is quite high and that it would be more advantageous in the long term for producers to establish their vineyards on sloping lands in order to minimize frost damage. It is thought that in years where frost damage is experienced, the number of buds left on the branches during the pruning period can be increased and the negative effect of damage to the bottom buds on yield can be reduced. It has been observed that there are significant differences between the phenophase stages of vineyards located at different altitudes in the Üzümlü region. These differences occurring in phenological periods make the cultural processes that need to be carried out during the vegetation period (irrigation, fertilization, spraying, pruning, etc.) a necessity that pushes for periodic planning. For these reasons, it has been concluded that in grape cultivation carried out at different altitudes in the region, carrying out cultural processes such as the time and intensity of pruning, irrigation frequency, and fertilization within a periodic plan, taking into account the altitude factor, will allow producers to produce more economically with less input and will contribute to the sustainability of local viticulture.

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