International Journal of Agricultural and Natural Sciences
E-ISSN: 2651-3617 15(3): 346-354, 2022
Research Article

CHANGES IN BERRY COLORATION AND RESISTANCE OF TABLE GRAPE CULTIVARS (*Vitis vinifera* L.) IN RESPONSE TO DIFFERENT GROWTH CONDITIONS OF SOILLESS CULTURE AND VINEYARD CULTIVATION

İrem Türkoğlu[1], Ferhan K. Sabır[2], Ali Sabır[2]

[1]*Selcuk University Graduate School of Natural and Applied Science, Konya, Türkiye*
[2]*Selcuk University Agriculture Faculty Horticulture Department, Konya, Türkiye*

**Corresponding author:*
E-mail: asabir@selcuk.edu.tr

(Received 10th November 2022; accepted 24th December 2022)

ABSTRACT. Extreme climatic conditions resulting from global climate change became a challenging problem adversely affecting the sustainability of horticulture crops. Inconvenient climatic events seriously affect plant physiology and metabolisms. Poor coloration is one of such problems that frequently occurred in both table and wine grapes recently. Soilless culture in protected agriculture is one of the safest methodologies for coping with the negative effects of climate change on grapevines. Therefore, this study was performed to reveal the changes in berry quality, such as coloration and skin resistance of table grape cultivars Alphonse Lavallée', 'Italia' and 'Prima' (*Vitis vinifera* L.) in response to different growth conditions of soilless culture and vineyard cultivation. Bilateral cordon pruned grapevines of each cultivar were cultivated in two different conditions as soilless culture (solid medium of peat and perlite mixture) in the glasshouse and open area vineyard (1.2 x 2.7 m). The midday air temperatures in the glasshouse of soilless culture reached about 37°C for many days, while other lots of the study grapevines experienced a temperature not higher than 33°C, during the berry growth stages. Skin color features, such as lightness, chroma, and Hue angle values changed remarkably depending on the cultivars in response to growth conditions. But berry skin rupture force was higher in grapes from soilless culture than those of vineyard condition. Viticulturists should, thus, consider new production techniques under multiple stress conditions, such as soilless culture under protected agriculture to improve berry coloration and resistance because the skin features of grapes are among the pioneering agronomic features determining the visual or biochemical quality properties.

Keywords: *Climate change, soilless culture, table grapes, berry color, grape skin hardness*

INTRODUCTION

Grapes (*Vitis vinifera* L.) are among the most widely cultivated crops in the world with their functional properties as well as attractive cluster shapes and berry colors. The color, firmness, and other chemical features of grape berries are key parameters determining the market quality, as well as the postharvest life span of the table grapes. However, studies have shown that global climate change with its remarkable increase in air temperature has been believed to decrease the quality properties of grapes cultivated in temperate regions [1]. Physiologically, air temperature higher than the optimum level adversely affects the leaf functions [2], plant biochemical metabolism [3], and berry skin anthocyanin composition [4,5,6]. In a controlled environment, [7], studied the effects of high temperature on the physiology of 'Semillon' grapevines and concluded that temperatures above 40 °C impaired physiological functions such as berry growth and sugar accumulation with resultant costs on yield and quality attributes of grapes.

The optimum temperature for the anthocyanins biosynthesis and berry color formation is reported to be in the range of 17 and 26 °C [8], depending on the grape cultivar. Studies on various grape cultivars confirmed that exposure to high temperatures was detrimental to many aspects of berry growth in particular skin color [9], a prime feature determining the visual quality. Literature investigations indicated that the grape berry features appear to be a particular subject to climate change [10], as an increased frequency of grape berries with poor coloration has been reported in recent years [11].

'Alphonse Lavallée' is a black-skinned high quality and fruitful table grape, which show frequently poor and heterogeneous skin color in many regions of Türkiye, resulting in low commercial value in markets. The grape cultivars with yellowish berries, like 'Italia', also display inconvenient skin coloration when subjected to improper climate conditions. Therefore, determining the relationship between air temperature and skin color would make it possible to predict skin color from estimated air temperatures of grape growing areas, under the effects of climate change in particular. Furthermore, a such relationship could be employed to assess the impact of future climate change on the market quality of table grapes. Many studies have already qualitatively investigated the relationship between air temperature and berry skin coloration of grapes in temperature manipulation studies [12,13]. The present study was conducted to investigate the berry coloration responses of internationally popular table grape cultivars 'Alphonse Lavallée', 'Italia' and 'Prima' (*Vitis vinifera* L.) in response to different growth conditions of soilless culture and vineyard cultivation.

MATERIAL AND METHODS

Study Description

These investigations were performed in the research and implementation glasshouse and vineyard (38°01.814N, 032°30.546E, 1158m altitude) of Selcuk University, Konya, Türkiye. Four years old 'Alphonse Lavallée', 'Italia', and 'Prima' cultivars grafted on 41 B rootstock were included in the study as internationally widespread table grape cultivars with different colors and/or ripening dates. The main features of the grape cultivars included in the study have been presented in Table 1.

Table 1. *Certain agronomic and cultivation features of grape cultivars used in the study*

Cultivar*	Main use	Berry color	Ripening	Growing regions
'Alphonse Lavallée'	Table	Black	Midseason	Mediterranean, Aegean, Marmara, Central Anatolia
'Italia'	Table	White	Midseason/late	Mediterranean, Aegean, Marmara, Central Anatolia
'Prima'	Table	Black	Very early	Mediterranean

* [14,15]

In the vineyard study, the grapevine rows were east–west oriented with the spacing between vines and between rows were 1.5 and 3.0 m, respectively. Experimental vines were trained to a common bilateral with thin vertical summer shoot-positioned canopy. According to the winter bud fruitfulness of the studied cultivars, the vines were cane pruned by providing three spur canes (2 buds) for each of two arms per vine. Shoot thinning was performed at the beginning of the vegetation period (May and June, for the glasshouse and vineyard, respectively) to leave an average of 10 and 12 shoots per vine. Cultivation practices in the vineyard were common for Turkish grape production with the trellising system. The summer shoots were tied with thread to wires 2.3m above the pots to provide vines develop on a perpendicular design for similarly benefiting from the sunlight. The grapevines received the same cultivation applications and were drip irrigated using one line per plant row, single pressure-compensated emitter per vine. Irrigations were programmed according to soil water matrix potential. The cluster zone of the overall grapevines in both conditions was covered with the same bird nets near the ripening period to prevent the berries from damage. The general growth systems of the grapevines have been illustrated in Fig. 1.

In the soilless culture, four years old grapevines of each cultivar were grown individually in about 70 L (solid volume) black pots filled with a solid growth medium consisted of an equal mixture of sterile peat 1.034% N, 0.94% P_2O_5, 0.64% K_2O, Klassman®) and perlite in climate controlled glasshouse. The study grapevines were placed in south and north oriented rows with a distance of 0.5×1 m.

Fig. 1. *A picture showing the soilless culture (left) and vineyard cultivation (right) of grapevines (example of 'Prima' cultivar)*

Measurements and Analyses

Midday air temperatures inside the glasshouse conditions were recorded with a datalogger, while daily records of the Turkish State Meteorological Service were used for vineyard conditions. Grape cluster samples have been collected at the commercial ripening stage (at around 15-16 °Brix). For berry measurements, fifteen clusters per cultivation technique for each cultivar were used. Sixty berries were collected from the middle of the clusters as indicated in [16], OIV (1983) to measure berry skin color coordinates using a colorimeter (Minolta® CR-400). Equatorial points of the berries were used to obtain the following color variables: L* (lightness), C (chroma), and h° (hue). Lightness values range between 0 (black) and 100 (white). Chroma represents the intensity or purity of color, the distance from gray (achromatic) toward a pure chromatic color, and is obtained from the a* and b* values of the CIE Lab scale system, starts from zero for a completely neutral color and does not have an arbitrary end, but intensity increases with magnitude. Hue angle value refers to the color wheel and is calculated in angles; green, yellow and red correspond to 180, 90, and 0°, respectively [17,18]. For skin rupture force (SRF) values of the same berries were calculated as follows; a berry was cradled in a jig attached to a force gauge (DPS-11; Imada, Northbrook, IL) and the gauge was gently pulled away from the berry so that the berry skin punctures. The force required to puncture the berry skin was recorded as the SRF in Newton [19].

Data Analysis

Numerical row data were subjected to one-way ANOVA. Statistical differences were considered significant at $P < 0.05$, and analyses means were compared with Student's test LSD (least significant difference) test using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA). Each cultivar was separately evaluated for parameters as the cultivars have different colors.

RESULTS AND DISCUSSION

Air temperatures of different cultivation conditions recorded at midday are illustrated in Fig. 2. In the glasshouse condition, the inside temperature led to an increase of certain degrees above optimum levels for grapevines. On many dates of berry development stages, the air temperatures in the glasshouse reached about 37°C (for example, 30.07.2022, 06.08.2022) which were slightly higher than the recommended optimum levels of various researchers [8, 20]. On the other hand, the vineyard part of the study experienced a midday temperature not higher than 33°C (02.08.2022) during the berry growth stages of the cultivars. Air temperature, among the other environmental factors, has the most profound influence on anthocyanin coloration in grapes [1]. Studies on 'Emperor' grape cultivar already revealed that a high daily temperature regime (37°C) completely inhibited coloration in [21] and that high day temperature (35°C) strongly reduces anthocyanin concentration, while the effect of night temperature was not very high [22]. The color response of grape berries to climatic factors is also depending on the growth stages of the berries, as [6], suggests that the most sensitive stage for the grape berry to temperature treatment was one to three weeks after the véraison. Therefore, berry coloration of grapevine cultivars in the same ecology would probably exhibit alteration according to ripening dates, besides their genetic aptitudes, as they expose to different temperatures during the summer season. Furthermore, the cultivation of 'Alphonse Lavallée' cultivar in Türkiye as well as in Mediterranean Regions around Europe is located in ecologies characterized by warm climatic conditions. In these areas, high temperature may restrict the synthesis of anthocyanins color pigments [4], that inevitably results in poor and heterogeneous berry skin color. Viticulturists should, therefore, take measures in such regions for better berry coloration as the skin features of table or even wine grape cultivars are one of the most determinant aptitudes in visual or biochemical quality properties.

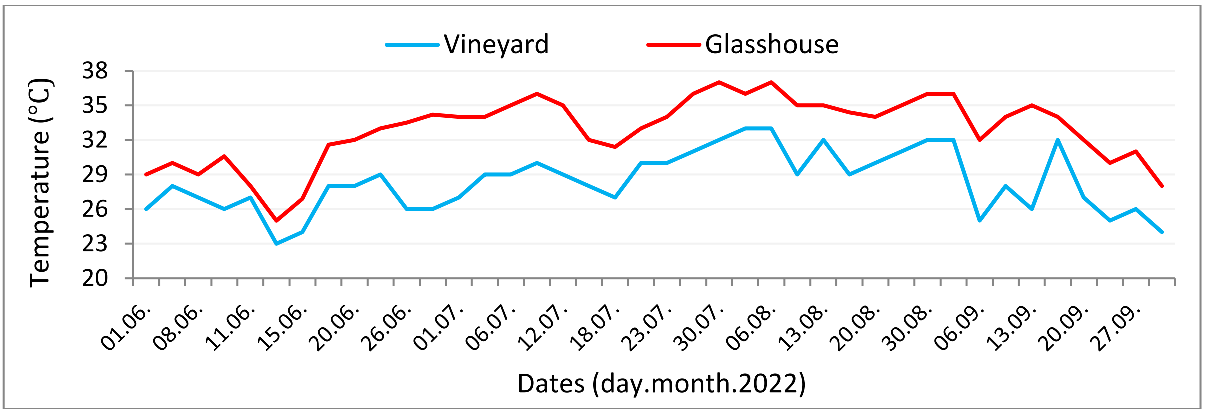

Fig. 2. *Air temperatures recorded in vineyard and glasshouse soilless culture during the berry development stages of the grapevines*

As depicted in Fig. 3, berry skin lightness (L) values of 'Alphonse Lavallée' and 'Italia' cultivars displayed significant variations in response to different environmental conditions. L values of these cultivars responded oppositely, probably because of their different berry colors. On the other hand, early ripening 'Prima' cultivar did not show significant variation in response to skin L value. Table grape cultivars are generally cultivated in ecologies with a warm temperatures and dry climates around the world. Although warm climates contribute to high yield and good quality, they also frequently result in the retention of the synthesis of skin color pigments of black and red grapes. Warmer condition of soilless culture in the glasshouse led to a slight decrease in black cultivar 'Alphonse Lavallée', and little increase in white cultivar 'Italia'. L value of 'Alphonse Lavallée' was closer to those of [23], when cultivated in soilless culture rather than a conventional vineyard.

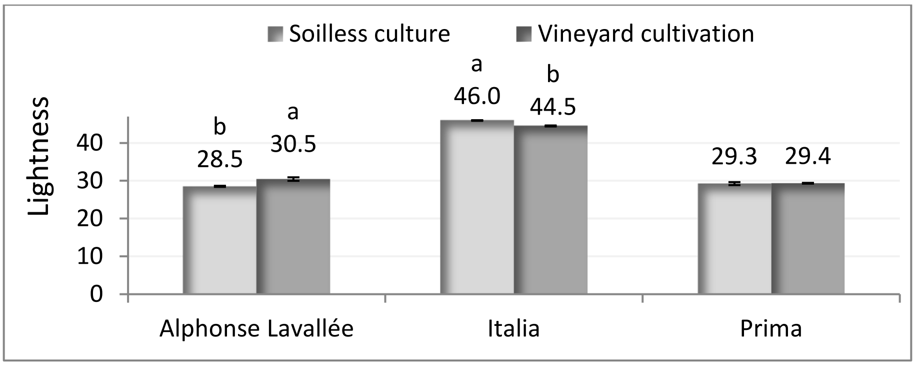

Fig. 3. *Changes in berry lightness (L) values of table grape cultivars (Vitis vinifera L.) in response to different growth conditions*

Values of bars indicated by different letters identify significantly different means (P< 0.05, LSD)

Chroma (C) values of the berries among the grape cultivars displayed just similar changes to those of L values (Fig. 4). A two fold increase in C value of the 'Alphonse Lavallée' grape berries was found in vineyard condition in comparison to soilless culture in the glasshouse. Whereas a slight but statistically significant decrease in C value of 'Italia' berries was detected in vineyard conditions when compared with soilless culture. Disparate responses of these cultivars to the growth conditions might be most probably due to the differences in their berry colors. As an indicator of color purity, saturation, and intensity of the berry, C value directly influence the appearance of the grapes in markets. C value of 'Prima' cultivar did not significantly respond to these environmental conditions. Such responsiveness of 'Prima' cultivar might be attributed to very early ripening metabolism of this cultivar in comparison to others. Because, in the previous studies [24,25] suggested that the temperature sensitive period for skin coloration of grape berries begins from soon after véraison. Véraison and the subsequent ripening stages of 'Prima' occurred mostly just before high temperature events for both conditions.

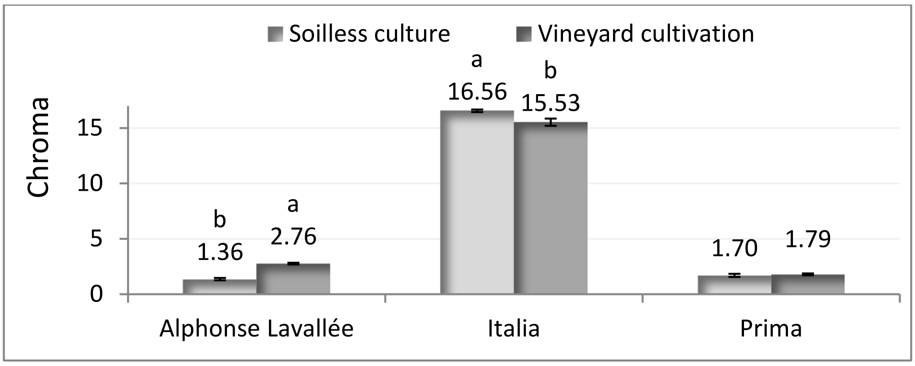

Fig. 4. *Changes in berry chroma (C) values of table grape cultivars (Vitis vinifera L.) in response to different growth conditions*

Values of bars indicated by different letters identify significantly different means (P< 0.05, LSD)

The Hue angle values of the cultivars significantly changed in 'Alphonse Lavallée' and 'Prima' cultivars, although there was no significant variation in 'Italia' berries in response to the cultivation conditions (Fig. 5). Hue angle value of the 'Alphonse Lavallée' grapes obtained from soilless culture was very close to general findings of the previous studies on this cultivar [26]. The greatest change, from 295.0 to 321.7 (with 8.3% increase), was detected in 'Prima' cultivar for Hue value.

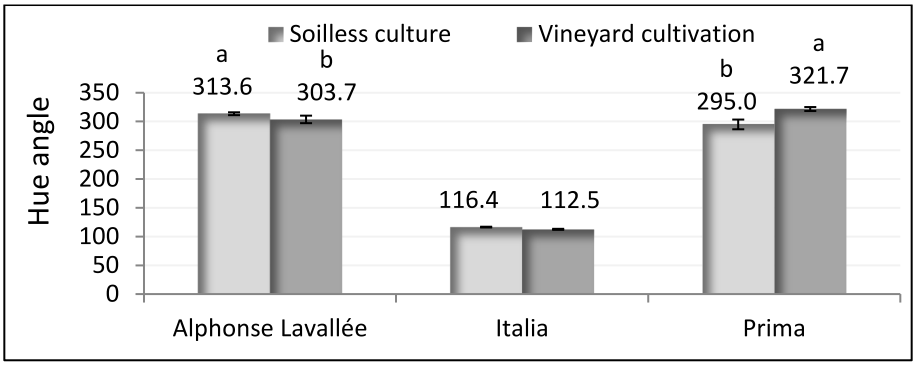

Fig. 5*. Changes in berry hue angle (Hue) values of table grape cultivars (Vitis vinifera L.) in response to different growth conditions*

Values of bars indicated by different letters identify significantly different means (P< 0.05, LSD)

Skin rupture force (SRF) significantly differed in response to the cultivation conditions across the studied cultivars (Fig. 6). There were remarkably higher values in SRF of the berries obtained from the soilless culture with 16.8, 10.9 and 11.6% improvements for 'Alphonse Lavallée', 'Italia' and 'Prima', respectively. Normally, postharvest berry skin consistency is inevitably decreased for all grape cultivars [27], although skin condition has a great impact on visual quality and consumer acceptance of table grapes. Furthermore, enhancing and extending the skin hardiness of table grapes is a prime consideration [28,26] because water loss and pathogen attacks are induced by hairline cracking on softening skin of the berry during postharvest handling or storage [29]. Therefore, improvements in berry skin hardness delay postharvest senescence and provide longer storage to remain in good physical conditions [7]. Findings imply that the soilless cultivation technique might improve the harvest quality and extend the postharvest storage duration with a positive effect on the improvement of the SRF.

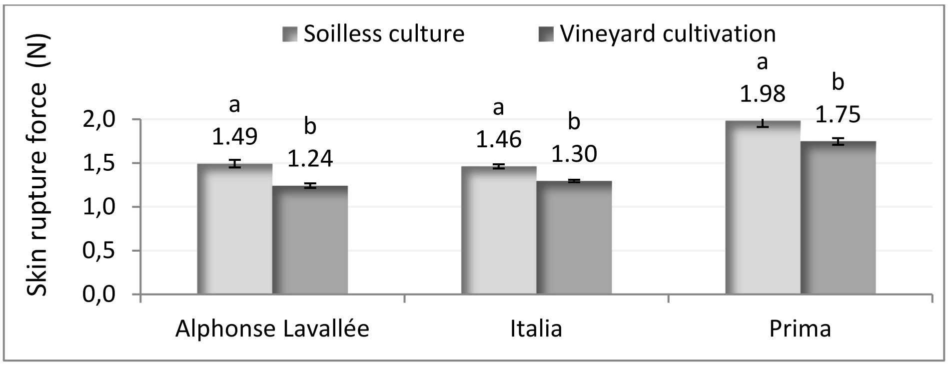

Fig. 6. *Changes in berry skin rupture force (SRF, Newton) values of table grape cultivars (Vitis vinifera L.) in response to different growth conditions*
Values of bars indicated by different letters identify significantly different means (P< 0.05, LSD)

CONCLUSION

Soilless culture in protected agriculture, as one of the safest methodologies for coping with the constrains of climate change, has been compared with the traditional vineyard cultivation technique for the effects of different environments on certain berry features of table grapes ('Alphonse Lavallée', 'Italia' and 'Prima' (*Vitis vinifera* L.) with different agronomic features. The findings revealed that the midday air temperatures in the glasshouse reached about 37°C for many days during the berry development stage, while other lots of the study grapevines experienced a temperature not higher than 33°C. Berry skin color parameters, such as lightness, chroma, and Hue angle values showed remarkable changes in response to different growth conditions. Cultivars differently responded to cultivation conditions in terms of berry coloration. However, berry resistance measured as skin rupture force was persistently higher in grapes from soilless culture than those of vineyard condition. Viticulturists should, therefore, consider new production techniques under multiple stress conditions, such as soilless culture under protected conditions for better berry coloration and resistance as the skin features of grapes are among the most determinant aptitudes in visual or biochemical quality properties.

Acknowledgement. This article has been generated from the part of the master thesis of Irem Turkoglu whose study was granted by the Scientific Research Projects Units of Selcuk University (21201081).

REFERENCES

[1] Jones, G. V., White, M. A., Cooper, O. R., Storchmann, K. (2005): Climate change and global wine quality. Climate Change 73: 319–343.

[2] Sabir, A., Yazar, K. (2015): Diurnal dynamics of stomatal conductance and leaf temperature of grapevines (*Vitis vinifera* L.) in response to daily climatic variables. Acta Scientiarum Polonorum Hortorum Cultus 14: 3-15.

[3] Poudel, P. R., Mochioka, R., Beppu, K., Kataoka, I. (2009). Influence of Temperature on Berry Composition of Interspecific Hybrid Wine Grape 'Kadainou R-1' (*Vitis ficifolia* var. ganebu × *V. vinifera* 'Muscat of Alexandria'). Journal of Japanese Society for Horticultural Science 78 (2): 169–174.

[4] Mori, K., Sugaya, S., Gemma, H. (2005): Decreased anthocyanin biosynthesis in grape berries grown under elevated night temperature condition. Scientia Horticulturae 105: 319–330.

[5] Mori, K., Sugaya, S., Gemma, H. (2007): Changes in the coloration and activities of enzymes involved in anthocyanin synthesis of 'Kokuo' grapes grown under different temperature conditions during ripening. Horticulture Reseasrch (Japan) 3: 209–214 (In Japanese with English abstract).

[6] Yamane, T., Jeong, S. T., Goto-Yamamoto, N. Koshita, Y., Kobayashi, S. (2006): Effect of temperature on anthocyanin biosynthesis in grape berry skins. American Journal of Enology and Viticulture 57: 54–59.

[7] Greer, D. H., Weston, C. (2010): Heat stress affects flowering, berry growth, sugar accumulation and photosynthesis of *Vitis vinifera* cv. Semillon grapevines grown in a controlled environment. Functional Plant Biology 37: 206–214.

[8] Pirie, A. J. C. (1978): Comparison of the climates of selected Australian, French and Californian wine producing areas. Aust. Grapegrower Winemaker 172: 74–78.

[9] Abeysinghe, S. K., Greer D. H., Rogiers, S. Y. (2019): The effect of light intensity and temperature on berry growth and sugar accumulation in *Vitis vinifera* 'Shiraz' under vineyard conditions. Vitis 58: 7–16.

[10] Orduna, R. M. (2010): Climate change associated effects on grape and wine quality and production. Food Research International 43: 1844–1855.

[11] Sugiura, T., Sumida, H., Yokoyama, S., Ono, H. (2012): Overview of recent effects of global warming on agricultural production in Japan. Japanese Agricultural Research Quarterly 46: 7–13.

[12] Tomana, T., Utsunomiya, N., Kataoka, I. (1979): The effect of environmental temperature on fruit ripening on the tree. II. The effect of temperatures around whole vines and clusters on the coloration of 'Kyoho' grapes. Journal of Japanese Society for Horticultural Science 48: 261–266 (In Japanese with English abstract).

[13] Shinomiya, R., H. Fujishima, K. Muramoto and M. Shiraishi. 2015. Impact of temperature and sunlight on the skin coloration of the 'Kyoho' table grape. Sci. Hortic. 193: 77-83.

[14] Sabır, A. (2008): Ampelographic and molecular characterization of some grape cultivars and rootstocks. Ph.D Dissertation, Institute of Natural and Applied Sciences University of Çukurova 154p.

[15] Aktürk, B., Uzun, H.İ. (2019): Effective heat summation requirements and matching to different sites of table grape cultivars in Antalya. Mediterranean Agricultural Sciences, 32: 267–273.

[16] OIV (1983): Le code des caracte`resdescriptifs des varie´te´setespe´ces de Vitis. Office International de la Vigneet du Vin. Dedon, Paris.

[17] McGuire R. (1992): Reporting of objective color measurements. Horticultural Science 27: 1254–1255.

[18] Peppi M. C., Fidelibus, M. W., Dokoozlian, N. (2006): Abscisic acid application timing and concentration affect firmness, pigmentation and color of 'Flame Seedless' grapes. Horticultural Science 41: 1440–1445.

[19] Fidelibus M. W., Cathline K. A., Burns, J. (2007): Potential abscission agents for raisin, table, and wine grapes. Horticultural Science 42: 1626–1630.

[20] Caravia, L., Collins, C., Petrie, P. R., Tyerman, S. (2016): Application of shade treatments during Shiraz berry ripening to reduce the impact of high temperature. Australian Journal of Grape and Wine Research 22: 422–437.

[21] Kliewer, W. M. (1977): Influence of temperature, solar radiation and nitrogen on coloration and composition of Emperor grapes. American Journal of Enology and Viticulture 28 (2): 96–103.

[22] Kliewer, W. M., Torres, R. E. (1972): Effect of controlled day and night temperatures on grape coloration. American Journal of Enology and Viticulture 23 (2): 71–77.

[23] Sabir, F., Sabir, A., Unal, S. (2021b): Quality response of minimally processed 'Alphonse Lavallée' table grapes during cold storage as influenced by preharvest sustained deficit irrigation and postharvest UV-C irradiation. Erwerbs-Obstbau 63(Suppl 1): S141–S148.

[24] Barnuud, N. N., Zerihun, A., Gibberd, M., Bates, B. (2014): Berry composition and climate: Responses and empirical model. International Journal of Biometeorology 58: 1207–1223.

[25] Yamane, T., Shibayama, K. (2006): Effects of changes in the sensitivity to temperature on skin coloration in 'Aki Queen' grape berries. Journal of Japanese Society for Horticultural Science 75: 458–462.

[26] Sabir, A., Sari, G., Sabir, F. K., Yildirim, B. (2021a): Color and physical resistance of table grapes as affected by deficit irrigation and Zn pulverization as adaptive strategies to climate change. International Journal of Agricultural and Natural Sciences, 14(1): 25–32.

[27] Cagnasso, E., Caudana, A., Rolle, L., Gerbi, V. (2005): Profili di maturazione e scelta di vinificazione per la valorizzazione varietale. Information Agraria Supplement 1–14: 23–26

[28] Lang, A., During, H. (1990): Grape berry splitting and some mechanical properties of the skin. Vitis 29: 61–70.

[29] Zoffoli, J., Latorre, B. A., Rodriguez, J., Aguilera J. M. (2009): Biological indicators to estimate the prevalence of gray mold and hairline cracks on table grapes cv. Thompson Seedless after cold storage. Postharvest Biology and Technology 52(1): 126–133.