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The impact of abscisic acid application on grape quality attributes at harvest and post-harvest period

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Abstract

Table grape varieties do not reach commercially acceptable colour levels in some growing seasons in viticultural areas. This situation has led to the consideration of applications that can enhance grape coloration. The study examined the effects of abscisic acid on 'Spil Karası' grape clusters and berries at harvest time and after harvest. A single application of 400 mg L^{-1} ABA was made during the veraison period to evaluate its effects on berry coloration and post-harvest quality. Cluster weight losses were measured on days 7 and 15, while titratable acidity (TA), Brix, and fruit and rachis colour analyses were conducted on days 15 and 30 after harvest. The research results indicated that the application of ABA (abscisic acid) was not effective in terms of the parameters examined during harvest time analyses. The weight loss due to ABA application on the 15th day was 1.1% higher compared to the control. The ABA treatment group exhibited higher Lightness (L) values compared to the control group 30 days after harvest. The control group recorded the lowest Hue values at the same time point. However, this group displayed a high Chroma value. Conversely, the ABA treatment group showed a low Chroma (C) value during the same analysis period. Also the lowest L values were determined in ABA treatment and control groups 30 days after harvest in rachis.

Keywords: Grape coloration, Spil Karası, Lightness, Weight loss, Chroma

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INTRODUCTION

The skin color of table grapes is one of the important fruit quality criteria for consumers (Palau et al., 2010), while the preservation of fruit quality after harvest is a critical factor for producers and in preventing post-harvest losses. The appearance of grapes, particularly their color, influences their commercial value, making colored varieties the most sought-after on the market due to their price and attractive visual appeal. Various regulators are applied to achieve coloration and ripening in grape berries. Abscisic acid is a critical regulator of the ripening process in non-climacteric fruits, with its functions involving epigenetic mechanisms (Li et al.,2024). ABA is a multifunctional phytohormone that begins to accumulate in grape berries as they ripen (Koyama et al., 2009). Abscisic acid (ABA) emerges as a key hormone in regulating alcohol dehydrogenase (ADH) gene expression and the synthesis of C6 volatiles during postharvest storage of grape (Chong et al, 2020). Due to its cost-effectiveness, ABA application has gained popularity, and its positive effects on berry color during veraison have been documented (Kataoka et al., 1982; Koyama et al., 2009), making it a potential alternative to treatments with ethephon (Cantin et al., 2007).

The color of grape berries is determined by the quantity and composition of anthocyanins in the skin (Ban et al., 2003). Anthocyanin accumulation in grapes begins at veraison, the onset of ripening, and it has been reported that this accumulation is at least partially regulated by the ABA (Hiratsuka et al., 2001; Ban et al., 2003). Several studies have shown that exogenous application of ABA increases the anthocyanin content in grape berries, thereby supporting the pigmentation of the skin (Ban et al., 2003; Jeong et al., 2004; Peppi et al., 2006; Yamane et al., 2006; Giribaldi et al., 2010).

Studies conducted on table grape varieties have demonstrated that ABA application is effective in achieving optimal coloration more rapidly compared to untreated grapes (Kataoka et al., 1982; Peppi et al., 2006, 2007; Cantin et al., 2007). In addition to abscisic acid, other chemicals such as ethylene, auxin, and brassinosteroids (BRs) have been studied to determine their effects on ripening and colouration. In the case of non-climacteric grapes, different results have been observed in its treatment with ethylene, with anthocyanin accumulation being observed in only some cases (Coombe and Hale, 1973; Delgado et al., 2004; Tira-Umphon et al., 2007). It has been observed that auxin delays ripening by slowing down anthocyanin accumulation (Coombe and Hale, 1973; Davies et al., 1997; Jeong et al., 2004; Wheeler et al., 2009). BRs may also play a role in grape berry ripening; however, the application of brassinazole, an inhibitor of BR synthesis, has been found to delay ripening (Wheeler et al., 2009). In addition to all these, abscisic acid (ABA) also plays a role in fruit ripening.

While numerous studies have examined the post-harvest effects of hormones like abscisic acid that enhance grape coloration, the efficacy and practical applicability of these findings remain unclear. Literature reviews, however, indicate that most research has primarily focused on coloration, with limited attention given to post-harvest quality assessments. The fact that the role of ABA in fruit ripening is still not fully understood has led us to focus our research on this aspect. This study seeks to address this gap. The Spil Karası grape variety was used in this research, and a single application of 400 mg L^{-1} ABA was made during the veraison period to evaluate its effects on berry coloration and post-harvest quality. Cluster and weight losses were measured on days 7 and 15, while acidity, Brix, and fruit and stem analyses were conducted on days 15 and 30.

MATERIALS AND METHODS

Locations and plant material

The experiment was conducted in a commercial vineyard situated in Fevziye village, Pamukova district, within Sakarya province (Figure 1A) in 2024. The geographic coordinates of the study site were 40°28'22.9"N, 30°06'12.5"E. The 'Spil Karası' grape variety was developed by the Manisa Viticulture Research Institute. The Spil Karası has a blue-black colored, seeded cultivar characterized by a conical cluster structure, with cluster weights ranging from 400 to 440 grams and individual berry weights of 4 to 5 grams.

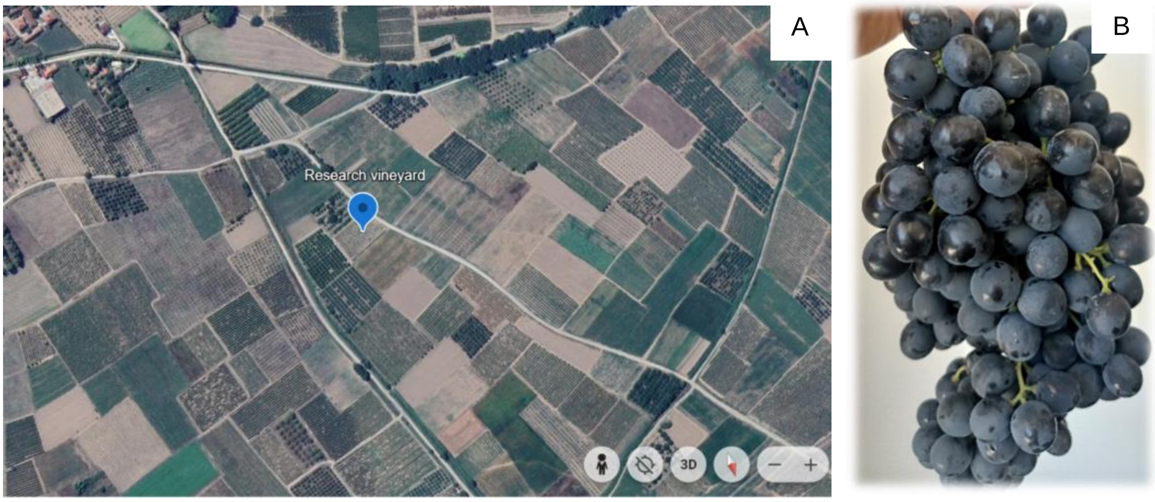

Figure 1. A) Research vineyard, B) Spil Karası grape (photo by G.G.Kandilli).

The experimental area

The vineyard was planted in 2021 with ‘Spil Karası’ grape cultivar (*Vitis vinifera* L.) grafted on 1103 Paulsen rootstock (Figure 1B). Vines were trained on a high wire cordon system at 120- 150 cm above the ground.with two arms per vine. The vine rows were oriented south-southeast to north-northwest, with a spacing of 2 m between vines and 3 m between rows. The soil type is well-drained, clay-loam with pH 7.76. The vineyard was drip irrigated, and the irrigation amount was determined by monitoring soil, plant, and precipitation conditions every other day. This experiment was conducted using a completely randomized block design with three replicates, each replicate has three vines. The study utilized comparable vine capacity and crop load and standard cultural practices were followed (basal leaf removal, and shoot thinning).

Abscisic acid treatments

The ABA application was made one time during the veraison period, identified as the appropriate time in previous studies. (Li and Dami 2015, Karimi et al. 2016, Zhang and Dami 2012). Concentration of abscisic acid (ABA) was 400 mg. L^{-1} . In each replicate group, a total of 9 vines were treated with three vines. No treatment was done to the control group.

Post harvest experiments and analysis of Brix, titratable acidity, berry and rachis colour

Only clusters meeting commercial standards were harvested. Clusters from each vine were harvested subsequent to the determination that the majority (75%) of the fruits had surpassed the commercial requirements of 17% total soluble solids (TSS). An initial analysis was conducted immediately following the harvest (T1), followed by two subsequent analyses (T2 and T3) at 15 days (DAH: days after harvest) intervals during the storage period. The grapes were stored under normal atmospheric conditions (NAC) at a temperature of 0±1°C and a relative humidity of 85% - 90%.

A digital refractometer (Atago PAL-BX/ACID2) was used for Brix (%) and titratable acidity (%) analysis. The grape berry and grapes rachis colour was measured using chroma meter (Konica Minolta CR-400 Japan). The values obtained from colour analysis were converted to chroma and hue values by formulation.

Weight loss (WL): The percentage weight loss was calculated as the percentage of the harvest weight that had been lost, using the equation WL=((Wi- Wf)/Wi)*100. WL is the weight loss, Wi is the initial weight (g), Wf is the weight at each storage time (Trindate et al., 2023). The WL analyses carried out harvest, the followed two analyses 7 days interval in the postharvest periods.

Statistical analysis

The results of the study were subjected to one-way ANOVA at $p \leq 0.05$ level and statistically significant means were compared by the LSD using the JMP statistical program The colour values (chroma, hue and L) values were illustrated by using scatter plot analysis in JMP (version. 7.0, SAS Institute Inc., Cary, NC) (SAS, 2003).

RESULTS AND DISCUSSION

The harvested grapes cluster and berry some morphological responses to ABA treatment were investigated. The treated grapes and the control group grapes did not differ statistically, as Table 1 illustrates. In other studies reported in parallel with our findings, that the quality attributes berry weight (Cantin et al, 2007, Yamamoto et al., 2015), berry width and length (Shahab et al., 2020, Yamamoto et al., 2015) and cluster weight (Gu et al., 2011) remained unaffected in ABA treatments. However Wheeler et al. (2009) found that ABA application increased berry weight. Weight loss, a straightforward and quantifiable parameter, is commonly used to effectively evaluate the impacts of treatments on the postharvest quality of fruits (Crisosto et al. 2001). There was no significant difference between ABA-treated and control plants in yield.

Table 1. Cluster and berry size at harvest time

Treatment	Cluster weight (g)	Berry weight (g)	Berry width (mm)	Berry length (mm)
ABA	410.3	4.29	1.82	2.12
Control	483	4.68	1.84	2.19
p	*NS*	*NS*	*NS*	*NS*

NS: Non significant ($p \leq 0.05$)

The impact of ABA treatment on weight loss on the 7th and 15th day after harvest was examined, and it was found that the weight loss due to ABA application on the 15th day was 1.1% greater than that of the control (Table 2). After harvest, table grapes are highly vulnerable as they experience significant water losses due to rachis and pedicel desiccation, leading to browning, weight reduction, and berry softening (Romero et al.,2020). The study found that weight loss, a critical factor limiting the shelf life of the products, increased over the storage period. Although the extent of weight loss varied with the treatment, it consistently grew with time. These weight losses during storage adversely impacted other quality attributes, leading to concurrent declines in fruit appearance and discoloration of the rachis and pedicels as maturity progressed. Weight loss, a straightforward and quantifiable parameter, is commonly used to effectively evaluate the impacts of treatments on the postharvest quality of fruits (Crisosto et al. 2001). Undesirable outcomes for fresh grapes during post-harvest storage include loss of mass, shattering, and decay, as these factors diminish the overall quality of grape clusters (Neto et al., 2017).

Table 2. Cluster weight loss during postharvest

Treatment	1	7	15	WL (%)
ABA	472	358	245	4.8
Control	466	383	292	3.7

Cluster weight :g, 1: Harvest, 7: 7 DAH, 15: 15 DAH.

The analysis of ABA application's effect on Brix and acidity at harvest and post-harvest revealed that the treatment group berries had higher Brix content only in the analyses conducted 15 days after harvest. The acid content did not change significantly with ABA treatment (Table 3). Similar results were reported in other studies investigating the effect of ABA on grape titratable acidity and brix (Ferrara et al. 2015, Gu et al., 2011, Shahab et al., 2020). Conversely, certain studies have found that the application of ABA can enhance the total soluble sugar (Wheeler et al., 2009, Kok, 2022) and reducing sugar levels in grape berries (Sun et al., 2019). The application of abscisic acid to grape clusters during post-harvest storage was found to decrease the titratable acidity and increase the total-soluble solids content (Chong et al., 2020).

Table 3. Influence of ABA application on Brix and acidity levels over postharvest periods

Treatment	Brix (%)	Titratable acidity (%)
T1	18,23	0,48
C1	19,70	0,69
T2	19,20 a	0,66
C2	18,50 b	0,54
T3	20,57	0,69
C3	20,10	0,70

Different letters denote statistically significant differences between treatments and postharvest periods based on LSD test (($p< 0.05$) . T: ABA Treatment, C: Control, * The numbers next to the treatment abbreviations represent the number of days after harvest when the measurements were take (1: Harvest, 2: 15 DAH, 3: 30 DAH).

To comprehend the relationship between chroma and hue values and L, the response variable in this investigation, a three-dimensional scatter plot was employed. In both the berry colour and rachis colour plots, the highest L value was obtained in the analysis at harvest time. Shahab et al., (2020) and Yamamoto et al., (2015) reported that the application of abscisic acid resulted in a lower L value in harvested grapes. A lower L value is often associated with a more intense, darker berry color according to existing research (Roberto et al., 2012; Tecchio et al., 2017). The L values of the ABA treatment 30 days after harvest are higher than those of the control group in berry colour (Figure 2A). The lowest hue values were recorded in the control group 30 days after harvest. However, this group showed a high chroma value. On the other hand, a low chroma value was observed in the ABA treatment at the same analysis period. Kok 2022 found that abscisic acid application during the veraison period decreased the hue values of grapes at harvest time. However, the current investigation was unable to determine the effect of ABA application on harvest-time hue values.

The lowest L values were determined in ABA treatment and control groups 30 days after harvest in rachis (Figure 2B). High chroma and hue values were measured in both treatment and control groups at harvest, and average chroma values were measured in both groups 30 days after harvest. There was no significant distribution of the colour values measured in both the berry colour and the rachis colour in the analyses carried out 15 days after the harvest. Rachis browning is a prevalent issue that compromises the quality and marketability of table grape clusters. To consumers, a green rachis signifies freshness, whereas a brown rachis can lead to consumer rejection and eventually, fruit waste (Lichter, 2016). While water loss is acknowledged as the primary contributor to this problem, measurements have typically focused on the weight loss of the entire grape cluster (Balic et al., 2012), with limited investigations specifically examining the rachis (Hamie et al., 2022). Increased anthocyanin levels and antioxidant capacity have been associated with improved resistance of the grape rachis against browning (Qin et al., 2022).

During the early stages of fruit development, endogenous abscisic acid content is closely associated with fruit water loss. In the initial phase of fruit development, ABA content declined; nevertheless, it increased continuously after the color change period (Chong et al., 2020).

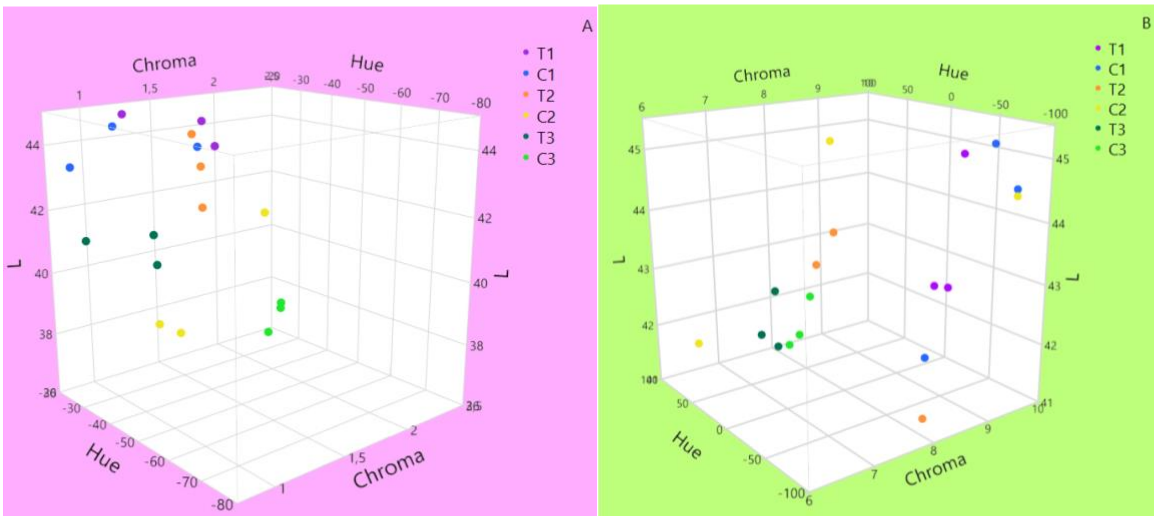

Figure 2. Scatter plots for Chroma, Hue and L values. A) Grapes berry color (n=3), B) Grapes rachis color (n=3), T: ABA treatment, C: Control; 1: Harvest time, 2: 15 days after harvest, 3: 30 days after harvest.

Grapes exhibit an accumulation of anthocyanins, the pigments responsible for their color, during the veraison stage of development. This process appears to be regulated, at least in part, by the plant hormone abscisic acid (Owen et al., 2009). Exogenous abscisic acid application enhanced the accumulation of anthocyanins, particularly the petunidin and malvidin types and quantitative real-time PCR analysis demonstrated that ABA treatment around the véraison stage led to the upregulation of genes encoding enzymes involved in the biosynthesis of both general flavonoids and anthocyanins (Katayama-Ikegami et al. 2016). Recent studies have shown that ABA treatment can alter global DNA methylation patterns in grapes. These findings indicate that ABA induces changes in the DNA of genes related to ripening and stress response during grape maturation (Li et al., 2024). In addition, ABA affects the transcription of genes and the activity of proteins involved in sugar accumulation and metabolism during grape ripening (Wheeler et al., 2009).

CONCLUSION

In conclusion this study offers a new perspective on the effects of ABA application during the both at harvest time and in the post-harvest period. While previous ABA studies have primarily focused on harvest measurements, the examination of quality parameters during the post-harvest period is limited. This study contributes to this understudied area. The results indicate that ABA application did not impact cluster weight, berry size and weight, Brix, or titratable acidity, which is consistent with previous findings. However, a key finding is that ABA application increased cluster weight loss and accelerated a darker coloration, characterized by higher L (lightness) and lower chroma (saturation) values, in the post-harvest period. The measurement of grape rachis color further enhanced the originality of this study.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Declaration of Interests

The authors have no conflict of interest to declare.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the text, figures, and tables are original and that they have not been published before.

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