ENHANCED YIELD AND FRUIT QUALITY OF REDGLOBE GRAPEVINES BY ABSCISIC ACID (ABA) AND ETHANOL APPLICATIONS

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Abstract

Aims: Redglobe has become a popular table grape cultivar in Egypt. However, in warm climates the berries often fail to develop a full red color in addition to having lower total soluble solids (TSS) at harvest time. Here we evaluate the potential for enhancing the quality of Redglobe grapes with applications of abscisic acid (ABA) and ethanol under field conditions.

Methods and results: Abscisic acid (300 mg/L) and/or ethanol (10% v/v) treatments were applied twice (10% and 75% of colored berries) for two seasons (2006 and 2007), and their effect on yield and fruit quality (TSS/acidity, anthocyanin content, firmness, and attachment force) was investigated. The application of ABA did not significantly affect yield when compared to the untreated control, whereas the ethanol treatment, alone or in combination with ABA, resulted in a significant yield increase. Total soluble solids and the ratio between TSS and acidity were increased by all treatments. The highest TSS/acidity ratio resulted from the ABA treatment due primarily to an 18% decrease in total acidity. In this regard, ABA was the most effective treatment. The total anthocyanin content in berry skins increased by approximately 48 and 38% with the ABA and ethanol treatments, respectively. Still, the highest anthocyanin content was obtained with the application of both ethanol and ABA (54% higher than in the untreated control). Berries that were treated with ethanol were markedly firmer and had higher attachment force than those of the other treatments.

Conclusion: The results indicate that the combination of ABA and ethanol is more effective in improving the color of Redglobe grapes but may also increase production efficiency. However, the ethanol treatment alone was more effective in increasing yield and berry firmness and appears to be an alternative to ABA in improving fruit quality in general.

Significance and impact of the study: The results obtained in this study will be useful to improve the fruit quality of Redglobe grapes in the field under warm conditions.

Keywords: Redglobe, anthocyanin, fruit quality, ABA, ethanol

Résumé

Objectifs : Le cépage Redglobe, cépage de raisin de table est populaire en Égypte. Toutefois, dans les climats chauds, les baies n'obtiennent pas leur couleur optimale lors des vendanges, et elles ont un taux peu élevé de solubles solides totaux. Dans ce travail, nous avons évalué le potentiel d'amélioration de la qualité des raisins issus du cépage Redglobe avec des applications d'acide abscissique (ABA) et d'éthanol en plein champ.

Méthodes et résultats : Nous avons traité avec de l'acide abscissique (300 mg/L) et/ou de l'éthanol (10 % v/v) avec deux applications (10 % et 75 % de baies colorées) pendant deux saisons (2006 et 2007). Nous avons étudié les effets sur le rendement et la qualité des fruits (TSS/acidité, teneur en anthocyanes, fermeté et résistance à l'égrenage). L'application de l'ABA n' a pas affecté significativement le rendement par rapport au témoin non traité, alors que, le traitement à l'éthanol, seul ou en combinaison avec l'ABA, a entraîné une augmentation significative du rendement. Les solubles solides totaux et le rapport entre TSS et l'acidité ont augmenté avec tous les traitements. Le taux le plus haut TSS/acidité résulte de l'ABA principalement en raison d'une diminution de 18 % de l'acidité totale. Le traitement le plus efficace a été par l'ABA. La teneur en anthocyanes totales dans les pellicules de raisins a augmenté respectivement d'environ 48 et 38 % les traitements avec l'ABA et l'éthanol. La plus forte teneur en anthocyanines a été obtenue avec l'application à la fois de l'éthanol et de l'ABA (54% de plus que le témoin non traité). Les baies traitées avec de l'éthanol ont été nettement plus fermes et bien mieux fixées que celles soumises aux autres traitements.

Conclusion : Les résultats indiquent que la combinaison de l'ABA et de l'éthanol est plus efficace pour améliorer la couleur des raisins, mais peut également augmenter l'efficacité de la production. Toutefois, le traitement à l'éthanol seul a été plus efficace en augmentant le rendement et la fermeté des baies et semble être une alternative à l'ABA pour améliorer en général la qualité des baies.

Importance et impact de l'étude : Les résultats obtenus seront utiles pour améliorer la qualité des fruits de raisins Redglobe en conditions chaudes.

Mots-clés : Redglobe, anthocyanes, qualité des fruits, ABA, éthanol

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INTRODUCTION

Fruit quality is considered more important than yield in the production of premium table grapes (Peppi *et al.*, 2006). Important characteristics that contribute to the quality of Redglobe grapes include their large size, firm texture, and uniform red color. Poor coloration substantially reduces the economic value of table grapes and this is a serious problem in warm growing regions. Indeed, grapes grown in warm climates may develop less red color than those grown in cooler regions (Kliewer, 1970 ; Winkler *et al.*, 1974) as higher temperatures inhibit anthocyanin accumulation in berry skins (Spayd *et al.*, 2002 ; Mori *et al.*, 2007).

Abscisic acid (ABA) is an essential hormone that not only regulates plant responses to environmental stress (Davies and Zhang, 1991) and seed dormancy (Rock and Quatrano, 1995), but also plays a key role in the translocation and metabolism of organic substances (Wayne and John, 1996). In this regard, ABA has been shown to enhance the uptake of organic nutrients and regulate assimilate metabolism in cells (Opaskornkul *et al.*, 1999 ; Wayne and John, 1996). In many grape cultivars, the application of ABA especially at 300 mg/L significantly increases the anthocyanin content and improves berry color : Flame Seedless (Peppi and Fidelibus, 2008), Redglobe (Peppi *et al.*, 2007a), Beidaneh Ghermez (Amiri *et al.*, 2009) and Kyoho (Lee *et al.*, 1997). However, some of these studies (Lee *et al.*, 1997 ; Peppi *et al.*, 2007a) and a few others (Han *et al.*, 1996 ; Peppi *et al.*, 2006 ; Amiri *et al.*, 2009) have reported that ABA also causes berry softening, which is an undesirable trait. In Aki Queen grapes, Yamane *et al.* (2006) have reported that the reduction in endogenous ABA level caused by high temperatures negatively affected the expression of genes controlling anthocyanin biosynthesis. Shaked-Sachray *et al.* (2002) have suggested that temperature may not only affect synthesis but also stability. Therefore, the decrease in anthocyanin concentration at high temperatures might result from both a decrease in synthesis and an increase in degradation.

Small amounts of exogenous ethanol can trigger ethylene production and advance ripening in tomatoes (Beaulieu and Saltveit, 1997). In grape berries, spraying of ethanol enhances ethylene production and anthocyanin accumulation (Chervin *et al.*, 2001). Molecular studies on Cabernet-Sauvignon grapes have shown that the increase in ethylene production induces the expression of UFGT, an anthocyanin biosynthetic gene (El Kereamy *et al.*, 2002). Chervin *et al.* (2001) have reported that spraying a 5 % ethanol solution on Cabernet-Sauvignon bunches at veraison significantly increases anthocyanin concentration in berries. Chervin *et al.* (2005) have further demonstrated that spraying a 2.5-10 % ethanol solution on Cabernet-Sauvignon one month before harvesting significantly increases berry weight and that the 10 % ethanol solution appears to be the most effective treatment in enhancing berry color. Furthermore, Beaulieu and Saltveit (1997) have shown that low doses of ethanol could stimulate early fruit ripening while high doses inhibit it. Ethanol has also been found to amplify the effect of ethephon, a commercially available growth regulator, on berry coloration (Farag *et al.*, 1992). Other studies have shown that methanol can also enhance berry anthocyanin content (Nikolaos *et al.*, 2003) and fruit quality (Ramadan and Omran, 2005). The study reported here was conducted to evaluate the potential for enhancing fruit quality by ABA and ethanol treatments under field conditions.

MATERIALS AND METHODS

1. Vineyard description

The study was conducted during the 2006 and 2007 growing seasons on 64 Redglobe grapevines planted on their own roots in a vineyard of the El-Kessey, Minia Governorate. The vines were 7 years old, grown in clay loamy soil at 1.5 x 3 meters and trained to a bilateral cordon. Sixty buds were left on each vine (20 fruiting spurs with three buds per spur) on the third week of January of each experimental season. Crop load was adjusted to 20 clusters per vine immediately after fruit set.

2. ABA and ethanol treatments

Treatments were imposed on the same vines each year. The treatments were as follows : a) untreated control, b) vines sprayed with a 10 % ethanol solution, c) vines sprayed with a 300 mg/L abscisic acid (ABA) solution and d) vines sprayed with both ethanol and ABA at the aforementioned concentrations. Treatments were applied twice per season, when 10 % and 75 % of the berries showed color development. One liter of solution was applied to the clusters with a handheld sprayer until runoff. The experimental procedures followed a randomized complete block design (RCBD) with four replicates and four vines per treatment. Borders were left untreated around and between each replicate and treatment as well as between blocks. For all the vines tested in this study, local cultural practices (fertilizer, irrigation, diseases and pest control) were followed, including Dormex treatment in accordance with standard commercial practices for Redglobe table grapes.

3. Yield component and fruit quality

Yield was recorded at the time of harvest (around the middle of August in both seasons). A sample of 32 clusters per treatment were picked and weighed. Sixteen berries were clipped from each cluster (pedicels attached) and kept for firmness and anthocyanin level analyses. Twenty additional berries were removed and used for the remaining fruit quality measurements. The number of berries per cluster was counted and rachis weight (g) was measured.

The berry samples were first weighed to obtain the mean berry weight (g). Berry length and diameter (mm) were measured. Berries were homogenized in a blender and the juice was filtered. The total soluble solids (TSS) of the juice were determined with a handheld refractometer (American Optical, Model 10430). Titratable acidity (g of tartaric acid per 100 ml of juice) was determined by titration with 0.133.N NaOH using phenolphthalein as indicator, and the TSS/acidity ratio was calculated. The total anthocyanin content in berry skin was determined with 7.mm discs of berry skins sampled from the apical region. The absorbance of the extracts was measured at 520 nm with a spectro-photometer (Perkin-Elmer, LAMBDA 2) according to Rabino *et al.*, (1977). Berry firmness and attachment force were estimated using a Pushpull dynamometer (Model FD101) without removing the berry skin.

4. Statistical analysis

Statistical analyses were performed using SPSS (SPSS Inc.). Analysis of variance was carried out using a general one – way model and the Student-Newman-Keuls (S-N-K) was used for comparison between particular means. Linear regressions were carried out between different parameters.

RESULTS AND DISCUSSION

1. Yield component

The average weight of berries treated with a 10 % ethanol solution was approximately 8 % higher than of control berries (Table 1). This increase in berry weight may be due to a greater uptake of both water and sugar into the fruit. Ethanol may stimulate phloem unloading in berries (Coombe and McCarthy, 2000) or may simply be used by the plant as an extra carbon source (Haakana *et al.*, 2001). The combination of ethanol and ABA significantly increased berry weight by approximately 11 % over the control berries. However, the ABA treatment alone did not affect berry weight during the two growing seasons, suggesting that ABA may regulate berry composition rather than fruit growth (Düring *et al.*, 1978 ; Kataoka *et al.*, 1982 ; Matsushima *et al.*, 1989). Berry diameter and length significantly increased upon application of ethanol alone or combined with ABA in both seasons. Berry number per cluster, cluster weight and yield per vine were also significantly increased when ABA was combined with ethanol. ABA alone, however, had little to no effect on these parameters. Taken together, our data generally support the view that ABA treatments alone result in no significant changes to fruit weight or berry length and diameter (Peppi *et al.*, 2007b).

The greatest changes to berry number per cluster, cluster weight, and yield per vine resulted from the application of 10 % ethanol alone. In this case, ethanol may have enhanced the skin strength of berries, decreasing the occurrence of bunch rot caused by fungal pathogens, or may have acted directly against decay agents (Avissar and Pesis, 1991 ; Lichter *et al.*, 2005 ; Omran *et al.*, 2009). In past studies, methanol has been shown to have positive effects on berry production, where diminished photorespiration would increase photosynthate allocation (Nonomura and Benson, 1992). Ethanol might have a similar mode of action. Figure 1 shows the linear regression relationship between rachis weight and berry size (length/diameter). A highly positive correlation was observed between rachis weight and berry length (R^2 = 0.924), and between rachis weight and berry diameter (R^2 = 0.954). Ethanol alone or combined with ABA resulted in the highest values for rachis weight, whereas the application of ABA alone was ineffective.

2. Fruit quality

a) TSS and acidity

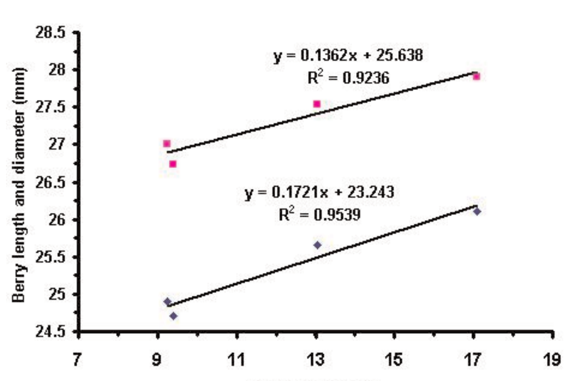

Figure 1 - Relationship between rachis weight and berry length and diameter of Redglobe berries.
Values are the average of the two seasons.

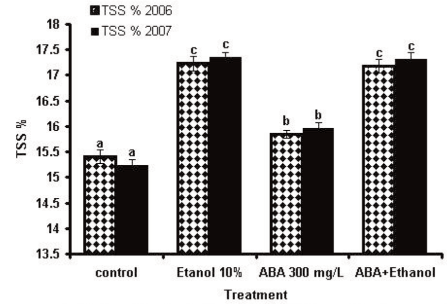

Figure 2 - The effects of ethanol and ABA applications on total soluble solids (TSS) of Redglobe berries.
Values are means ±SE, n = 4 for each column. Values with a different letter are significantly different at $p \leq 0.05$.

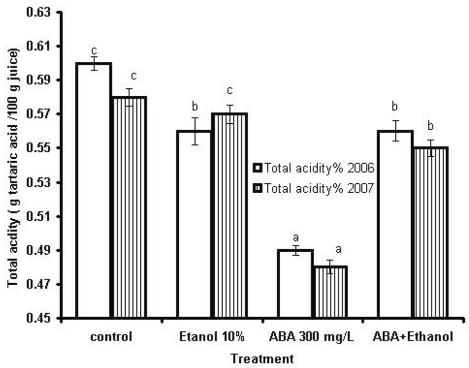

Figure 3 - The effects of ethanol and ABA applications on the total acidity of Redglobe berries.
Values are means ± SE, n = 4 for each column. Different letters indicate significant differences at $p \leq 0.05$.

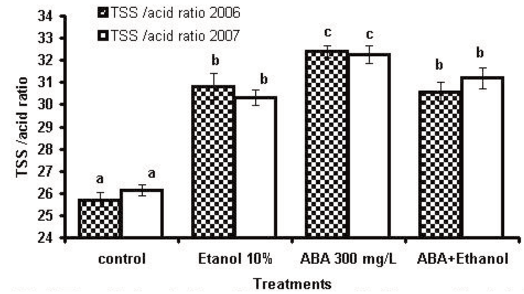

Figure 4 - The effects of ethanol and ABA applications on the total soluble solids/total acidity (TSS/TA) ratio of Redglobe berries.
Values are means ± SE, n = 4 for each column. Different letters indicate significant differences at $p \leq 0.05$.

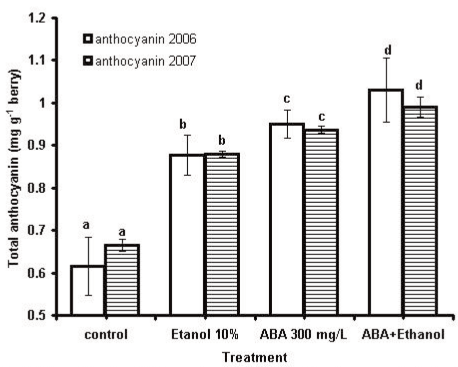

Figure 5 - The effects of ethanol and ABA applications on total anthocyanins of Redglobe berries.
Values are means ± SE, n = 4 for each column. Different letters indicate significant differences at $p \leq 0.05$.

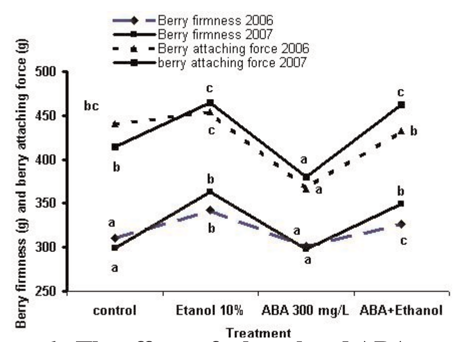

Figure 6 - The effects of ethanol and ABA applications on the berry firmness and berry attachment force of Redglobe berries.
Values are means ± SE, n = 4 for each column. Different letters indicate significant differences at $p \leq 0.05$.

All treatments increased the TSS content of berries (figure 2). However, only the ethanol and the ABA-ethanol combined treatments significantly increased TSS by approximately 13 % over the control. The ABA treatment alone had little effect on TSS (3 % increase over the control).

ABA alone was the most effective treatment with regard to total acidity (figure 3). The application of ABA significantly reduced total acidity by approximately 18 % as compared to the control, whereas the other treatments only reduced total acidity by 4-5 %. When examining the TSS to acidity ratio, ABA alone resulted in a TSS/TA ratio increase by 25 % over the control, whereas the other two treatments increased the ratio by 19 % (figure 4). These results agree with previous studies where high levels of endogenous ABA during fruit maturation were positively correlated with TSS and negatively correlated with total acidity (Coombe and Hale, 1973 ; Coombe, 1976 ; Düring *et al.*, 1978).

b) Anthocyanin

All treatments significantly increased the level of anthocyanins in berry skin as compared to the control (figure 5). During the 2006 and 2007 growing seasons, the application of ethanol increased anthocyanin levels by 43 and 32 %, respectively. The application of ABA alone was more effective than the ethanol treatment, as anthocyanin levels were increased by 54 and 41 % over the control during the two growing seasons. This was most likely due to enhanced anthocyanin biosynthesis by ABA (Jeong *et al.*, 2004). Although separate applications of ethanol and ABA significantly enhanced fruit color, the greatest improvement was obtained with the combination of the two treatments, which increased anthocyanin levels by 67 and 49 % over the control in the 2006 and 2007 growing seasons, respectively.

3) Firmness and berry attachment force

Firmness is a very important characteristic of quality table grapes (Peppi *et al.*, 2007a). We found that the ABA treatment did not have a significant effect on berry firmness during the two growing seasons (figure 6). On the other hand, berries treated with ethanol, or a combination of ethanol and ABA, had better firmness than untreated

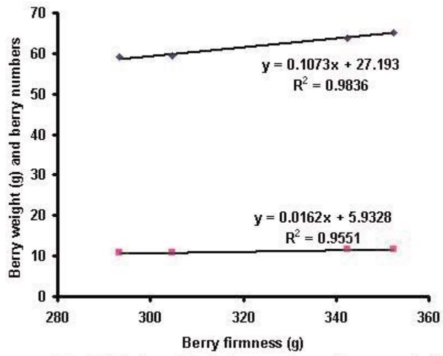

Figure 7 - Relationship between berry firmness (g), berry number and berry weight (g) of Redglobe berries.
Values are the average of the two seasons.

berries. More specifically, the ethanol treatment markedly increased berry firmness by 15-21 % as compared to the control. Our results are in agreement with Cantin *et al.* (2007) who reported that ABA treatment does not affect the firmness of Crimson Seedless berries. Conversely, Lee *et al.* (1997) found that ABA reduces the firmness of Kyoho grapes. In contrast to berry firmness, the ABA treatment significantly reduced the attachment force when compared to the control. On the other hand, treatments incorporating ethanol resulted in an increase in berry attachment force when compared to the untreated control berries. A positive relationship between berry firmness and berry number per cluster ($R^2 = 0.984$), in addition to a positive relationship between berry firmness and berry weight ($R^2 = 0.955$), was also observed (figure 7).

CONCLUSION

For practical purposes, we can conclude that two sprays of 300 mg/L of ABA or a 10 % ethanol solution onto berry clusters at 10 % and 75 % of colored berries should enhance TSS percentage as well as berry color. An ethanol treatment may be an effective addition to current growing practices to enhance the coloration without softening the berries. In some situations, ethanol appears to enhance the effectiveness of ABA, perhaps by promoting its transport across the berry cuticle. Lastly, our results indicate that a combination of ethanol and ABA seems to be a practical means to enhance the fruit quality of Redglobe grapes under field conditions.

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