Available online at www.sciencedirect.com
ScienceDirect
Postharvest Biology and Technology 46 (2007) 237–241
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

Application of abscisic acid (ABA) at veraison advanced red color development and maintained postharvest quality of 'Crimson Seedless' grapes

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Received 14 February 2007; accepted 24 May 2007

Abstract

'Crimson Seedless' is a popular table grape cultivar, but in warm-climates, its fruits often fail to develop adequate red color, even after they have been treated with ethephon. Application of abscisic acid (ABA) may improve color more effectively than ethephon, but its potential effects on postharvest quality must be considered before recommending its use on table grapes. Therefore, we compared the postharvest quality attributes of grapes treated preharvest with 250 $\mu L\,L^{-1}$ ethephon, the current industry standard, to that of grapes treated with 150 or 300 $\mu L\,L^{-1}$ ABA, or nontreated. Treatment with either ethephon or 150 $\mu L\,L^{-1}$ ABA allowed grapes to be harvested 10 d before nontreated fruit, and fruits treated with 300 $\mu L\,L^{-1}$ ABA attained marketable quality 30 d before nontreated fruit. Early harvest was possible because the treatments induced more rapid coloring of the grapes, and though total yield was not affected by any plant growth regulator (PGR), all PGRs doubled packable yields by improving the color of the grapes. ABA-treated grapes were characterized by superior appearance both in berries and clusters' rachises compared to ethephon-treated and control grapes. Other quality attributes such as firmness, berry weight, decay incidence, and shatter remained unaffected among treatments. Therefore, ABA is an effective alternative to ethephon for enhancing the color and maintaining postharvest quality of 'Crimson Seedless' grapes.

Keywords: Ethephon; Firmness; Fruit quality; Rachis; Shatter; Storage; *Vitis vinifera* L.

1. Introduction

In California, most 'Crimson Seedless' table grapes (*Vitis vinifera* L.) are grown in the San Joaquin Valley, a warm-climate region. Often, 'Crimson Seedless' grapes fail to achieve the desired level of red color, in part due to high temperatures which inhibit the accumulation of anthocyanins (Spayd et al., 2002), the class of pigments that impart red color to grape berries (Peppi et al., 2006). Applications of the plant growth regulators (PGRs) gibberellic acid (GA_3) and forchlorfenuron (CPPU), which may be needed to increase berry size, can further inhibit coloring. Careful canopy and crop management, and application of ethephon, optimize the color of 'Crimson Seedless' grapes (Dokoozlian et al., 1994), but even grapes subjected to these ideal cultural practices may remain poorly colored, especially when grown in regions or seasons with supraoptimal temperatures (Kliewer, 1970; Dokoozlian et al., 1994; Spayd et al., 2002).

In grapes, anthocyanin accumulation begins at veraison, the onset of maturation. This accumulation appears to be regulated, at least in part, by the plant hormone abscisic acid (ABA) (Kataoka et al., 1982; Hiratsuka et al., 2001; Ban et al., 2003), and exogenous applications of ABA increased the anthocyanin content of grape skins (Peppi et al., 2006, 2007). In general, grapes having high skin anthocyanin content will appear darker and more red-colored, than grapes having low anthocyanin content, but the relationships between pigments and berry color characteristics are non-linear, so relatively large differences in pigment content may have little effect on berry color (Peppi et al., 2006, 2007). Even so, ABA treatment improved the color

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doi:10.1016/j.postharvbio.2007.05.017

of 'Flame Seedless' (Peppi et al., 2006) and 'Redglobe' grapes (Peppi et al., 2007).

Historically, the cost to produce ABA was too high to justify its use as an agrochemical, but recently ABA production methods have improved sufficiently to reconsider its potential use in viticulture. Furthermore, ABA proved to be more effective than ethephon at improving the color of 'Crimson Seedless' table grapes but the most effective treatments sometimes induced berry softening (Peppi, personal communication), an undesirable condition for fresh grapes that might have further implications for their postharvest storage. Table grapes tend to senesce and deteriorate during postharvest handling (storage and marketing) which limits their market life (Crisosto and Mitchell, 2000). Quality deterioration in clusters of grapes is expressed in terms of weight loss, rachis senescence or necrosis, berry shatter, fruit softening, undesirable color changes in the berries or rachis, and the development of fungal rots (Carvajal-Millan et al., 2001; Crisosto et al., 2002). The severity of these quality changes vary according to cultivar, and to practices in the vineyard and in the postharvest storage facility (Carvajal-Millan et al., 2001; Crisosto et al., 2002). Thus, the postharvest quality of ABA-treated grapes should be considered before recommendations on the use of ABA are made. The objective of this study was to determine whether the postharvest quality of grapes treated with different concentrations of ABA differed from that of grapes treated with 250 $\mu L\,L^{-1}$ ethephon, a standard commercial practice, or from grapes not treated with either PGR.

2. Materials and methods

2.1. Plant material and PGRs applications

Nine-year-old own-rooted 'Crimson Seedless' grapevines (Kearney Agricultural Center, Parlier, CA) of similar capacity and crop load were used in the study. Each vine was trained to quadrilateral cordons, supported by an open gable trellis, and spur-pruned. The vines were spaced 2.4 m within rows and 3.6 m between rows. The vineyard was drip irrigated and standard cultural practices were followed, including berry thinning (2.5 g GA_3 per ha at 80% anthesis), girdling for berry sizing (6 mm girdle at fruit set), basal leaf removal, and shoot thinning. Ethephon was not applied as part of the usual cultural practices (Dokoozlian et al., 1994), but was included as a treatment.

Vines were randomly assigned to receive one of four treatments; 0, 150, or 300 $\mu L\,L^{-1}$ ABA, or 250 $\mu L\,L^{-1}$ ethephon. All PGRs were dispersed in water with 0.05% (v/v) adjuvant (Latron B-1956) and applied at veraison (21 July 2006) when approximately 20% of the berries on 50% of the clusters had softened. The PGRs were applied directly to the clusters with a hand-held sprayer until runoff. Plastic shields prevented overspray or runoff from contacting other clusters.

2.2. Initial quality evaluations

Clusters from each vine were harvested after most (60%) of the fruits were considered to have exceeded the minimum market requirements of 16.5% total soluble solids (TSS), a 20:1 total soluble solids:titratable acidity ratio, and full red berry color. Only commercially acceptable clusters were harvested on any date, so plots were harvested two or three times during the harvest season. At harvest, all the harvested clusters were counted and weighed, and then each cluster was inspected and berries that were green-colored, or had other quality defects, were removed with shears and discarded. The cleaned clusters were reweighed, and then packed in Styrofoam boxes that included liners and an SO_2 pad, following instructions for long distance shipping (Crisosto and Mitchell, 2000). Before sealing the boxes, 20 berries were randomly selected from each of the eight replicates (boxes) per treatment.

Skin anythocyanin content has been used to infer grape berry color, but anthocyanin content has a non-linear effect on berry color characteristics such that relatively large differences in pigment content may have little effect on berry color (Peppi et al., 2006, 2007). Thus, we measured the surface color of berries in each sample with a reflectance colorimeter (CR-200, Minolta Inc., Ramsey, NJ), using the CIELAB color system. From these data, the color index of red grapes (CIRG; Carreño et al., 1995) was calculated as $CIRG = (180 - h^{\circ})/(C^* + L^*)$, where L^* is the lightness and corresponds to a black-white scale (0, black; 100, white), h° is the hue angle on the color wheel, and C^* is the chroma, a measure of the intensity of color, which begins at zero (achromatic) and increases in intensity (McGuire, 1992). Three equidistant color measurements were made around the equator of each berry; the mean values for each sample were subjected to statistical analyses.

The berries of each sample were then weighed and subjected to tests with a fruit texture analyzer (FTA) (Güss, GS.14, Strand, South Africa) which used a flat plate traveling at a speed of 5 mm s^{-1} to compress each whole berry by 4 mm. Peak force expressed in Newtons (N) was recorded and considered to be an indicator of fruit firmness. These berries were then discarded, and a second sample of 20 randomly selected berries per box was subjected to berry retention force measurements using a digital force gauge (DPS-110R, Imada, Northbrook, Ill.). Juice from these berries was extracted with a hand press and filtered through cheesecloth. The TSS of the filtered juices were measured with a refractometer (Cambridge Instruments, Buffalo, NY), and the titratable acidities (TAs) were determined by titration of 3 mL of juice with 0.1 N sodium hydroxide (NaOH) to an end point of pH 8.2 and expressed as H^+ mol L^{-1}. After the berry samples were collected, the boxes were sealed and placed in cold storage at 0 °C and 85% relative humidity.

2.3. Postharvest quality evaluation

After 30 and 60 d of cold storage (0 °C, 85% RH), boxed grapes from each treatment were removed from storage, and fruit quality was evaluated. At both times, the overall visual appearance of the boxed grapes was rated according to the following scale: (1) excellent, (2) acceptable, or (3) commercially unacceptable. Rachis condition was then rated according to Crisosto et al. (2002), as follows: (1) healthy = entire rachis including the pedicels green and healthy, (2) slight = rachis in good condition,