Eur. J. Hortic. Sci. *89*(6) | ISSN 1611-4426 print, 1611-4434 online | https://doi.org/10.17660/eJHS.2024/031 | © ISHS 2024

Short communication

Abscission agents, preharvest interval, and postharvest storage time affect mechanical damage associated with destemmed 'Sheegene-12' table grapes

M.W. Fidelibus[1], J. Stogbauer[1], P. Petracek[2] and S. McArtney[2]

[1] Department of Viticulture and Enology, University of California, Davis, U.S.A.
[2] Valent BioSciences, Libertyville, IL, U.S.A.

Summary

Table grapes are mostly marketed as whole clusters, but there is increasing interest in destemmed berries, which are "ready-to-eat" as-is, and which can be incorporated into minimally processed products, such as salads. However, destemming may create unsightly stem-end wounds on grapes that are prone to rot and difficult to sanitize. Preharvest application of jasmonic acid (JA) and 1-aminocyclopropane-1-carboxylic acid (ACC), alone or in combination, activates the fruit-pedicel abscission zone (AZ) of some grape varieties, thereby reducing fruit detachment force (FDF), and mechanical damage associated with destemming. However, the AZ develops within a few days after treatment such that picking and destemming 2 days after treatment (DAT) may be too soon, with little benefit afforded by abscission agents, whereas picking a day later may be too late, due to unacceptable yield loss from preharvest abscission. We hypothesized that the AZ may continue to develop in postharvest storage. If so, then growers could apply abscission agents preharvest, harvest intact clusters of grapes before substantial abscission has occurred, and allow the abscission zones to develop in storage before destemming. To test this hypothesis, a study was conducted with 'Sheegene-12' table grapes to determine how abscission agents (JA, ACC, and JA + ACC), preharvest interval (PHI), and postharvest storage time affected berry abscission, FDF, proportion of berries with dry stem scars, berry weight, firmness, soluble solids, and color. No treatments caused preharvest abscission with a 2-day PHI, but effects on FDF, and dry stem scars were reduced compared to a 3-day PHI. Efficacy of JA was improved by co-application with ACC, which hastened abscission induced by JA. Without JA, ACC was ineffective. If fruit were destemmed at harvest, then JA + ACC with a 2-day PHI was the best approach. If the fruit could be destemmed after two or three weeks of postharvest storage, then JA alone was sufficient, harvested with a 2- or 3-day PHI.

Keywords
1-aminocyclopropane-1-carboxylic acid, fresh cut, jasmonates, Jasmonic acid, minimally processed, plant growth regulators, shatter, *Vitis vinifera* L.

Significance of this study

What is already known on this subject?

- Abscission agents have potential to improve the quality of destemmed table grapes, but harvest timing is critical for grapes destemmed at harvest because treatment effects may transition from insufficient to excessive within a day.

What are the new findings?

- If grapes must be destemmed at harvest, then JA + ACC with a 2-day PHI was the best approach. If the grapes could be destemmed after two or three weeks of postharvest storage, then JA alone was sufficient, harvested with a 2- or 3-day PHI.

What is the expected impact on horticulture?

- Growers could realize the potential benefits that abscission agents may confer to destemmed table grapes and reduce the risk of preharvest abscission by harvesting the fruit before any abscission occurs and storing the fruit for two to three weeks before destemming.

Introduction

Most table grapes are marketed as whole clusters, but they are also destemmed for fresh cut markets (Cardone, 2024; Crisosto and Crisosto, 2020; Mlikota Gabler and Smilanick, 2001; Kou et al., 2007; Sabir et al., 2024). Unfortunately, when grapes are destemmed, vascular tissues and associated parenchyma, and pieces of exocarp (skin), often remain attached to the pedicel, leaving the berry with an unsightly open wound (Kou et al., 2007; Fidelibus et al., 2007; Li et al., 2020) prone to discoloration, collapse, and decay, limiting the quality and storage life of destemmed table grapes (Ergun et al., 2008). Grapevine variety selection, and berry sanitation, packaging, and preparation methods have some potential to improve the quality of destemmed table grapes (Crisosto and Crisosto, 2020; Kou et al., 2007; Shiri et al., 2011; Ergun et al., 2008; Pawar et al., 2021). For example, varieties with large berries had fewer defects, and browning was less apparent on dark versus light skinned varieties (Ergun et al., 2008). Hot water baths improved shelf life of fresh cut grapes (Kou et al., 2007), as did chitosan coatings (Irkin and Guldas, 2013; Sabir et al., 2024), or packing in polyvinylchloride bags (as opposed to polyethylene terephthalate; Shiri et al., 2011). However, grape berries with cap stems (pedicels) attached remained in better condition than destemmed berries re-



Figure 1. The stem-end of untreated 'Sheegene-12' table grapes damaged by destemming (left). Grapes treated with abscission agents (right) develop dry stem scars, and have less mechanical damage after destemming.

gardless of sanitation and packaging treatments (Kou et al., 2007; Shiri et al., 2011). Therefore, minimizing mechanical damage is important to help preserve the quality of fresh cut table grapes (Mlikota Gabler and Smilanick, 2001).

The application of certain plant growth regulators (PGRs), "abscission agents", could reduce mechanical damage associated with destemming, and thereby improve the quality of destemmed grapes, by activating an abscission zone (AZ) at the pedicel-fruit boundary (Fidelibus et al., 2022). Following activation, fruit detachment force (FDF) declines, and the berries tend to detach with dry stem scars rather than open wounds (Figure 1). Screening studies demonstrated that 1-aminocyclopropane-1-carboxylic acid (ACC), ethephon, coronatine, jasmonic acid (JA), and methyl jasmonate (MeJA) all have some potential as grape abscission agents (El Zeftawi, 1982; Hedberg and Goodwin, 1980; Szyjewicz et al., 1984; Fidelibus et al., 2007; Uzquiza et al., 2014, 2015; Ferrara et al., 2016; Fidelibus et al., 2022). Combining ethylene promoting PGRs, such as ethephon or ACC, with jasmonates, including MeJA or JA, was particularly effective (Uzquiza et al., 2014, 2015; Fidelibus et al., 2022).

Ethephon is unlikely to be selected as an abscission agent for grapes because efficacy would require application rates that were higher, and preharvest intervals (PHI) that were shorter, than those specified for improving fruit color, a currently registered use of ethephon on grapes. Increasing the application rate while decreasing the PHI could increase the risk of excess ethephon residue on grapes, which is already a concern (European Food Safety Authority, 2009). However, it should be noted that Ferrara et al. (2016) found that effective dosages of ethephon as an abscission agent did not result in excessive residues. In contrast with ethephon, ACC naturally occurs in all plants, including grapevines, and some bacteria in plant microbiomes produce ACC-deaminase, an enzyme that breaks down ACC into α-ketobutyrate and ammonia, thereby reducing ethylene levels and promoting plant growth (Orozco-Mosqueda et al., 2020). Thus, ACC could be a better option than ethephon as an active ingredient in abscission agents. Jasmonates, including jasmonic acid, also naturally occur in grapevine tissues. The Environmental Protection Agency of the United States (EPA) ruled that MeJA was exempted from the requirement of a tolerance for residues in or on all food commodities when applied pre-harvest (EPA, 2013), a ruling that could facilitate the development of jasmonates as active ingredients in agrichemicals, such as abscission agents. Besides JA and MeJA, a screening trial confirmed that coronatine, a jasmonate mimic synthesized naturally by *Psuedomonas* sp., also induce abscission in grape (Fidelibus et al., 2007), so there could be a number of jasmonates to choose from in formulating an abscission agent.

Most studies on grape abscission agents have focused on their potential to reduce mechanical damage to machine-harvested grapes (Fidelibus et al., 2007; Hedberg and Goodwin, 1980; Uzquiza et al., 2015). For this use, treatment effects must be optimized for the time of harvest (Gonzalez-Herranz et al., 2009; Hedberg and Goodwin, 1980). Ideally, FDF would be substantially reduced, detached berries would have dry stem scars, and pre-harvest abscission would be minimal. However, in 'Thompson Seedless' (*Vitis vinifera* L.), considerable preharvest berry abscission may occur within 2 to 3 days after treatment (DAT), concurrent with, or immediately following, the decline in FDF (Gonzales-Herranz et al., 2009; Uzquiza et al., 2014). Therefore, the use of abscission agents for machine-harvested grapes may require a narrow harvest window which, if missed, could result in an ineffective treatment or unacceptable yield loss (Ferrara et al., 2016; Fidelibus et al., 2022). In this study, we hypothesized that the AZ would continue to develop in postharvest storage. If so, it would allow table grape growers who want to market destemmed table grapes to avoid preharvest losses by picking treated fruit before the AZ has fully developed and storing the fruit for a period of time before destemming. However, it is unknown whether the AZ would continue to develop in storage and, if so, how much storage time may be needed before destemming. Therefore, a study was conducted to determine how abscission agents, preharvest interval, and postharvest storage time, affected the quality of destemmed 'Sheegene-12' table grapes.

Materials and methods

This study was conducted with *Vitis vinifera* L. cv. 'Sheegene-12' table grapes in a vineyard in Tulare County,

California. The vineyard was planted in 2016, with 'Sheegene-12' grafted onto Freedom rootstock and supported by an open-gable trellis system. 'Sheegene-12' (marketed as "Krissy™" or "Summer Bliss™") is among the most widely grown mid-season red table grape varieties in California (California Department of Food and Agriculture and U.S. Department of Agriculture National Agricultural Statistics Service, 2024). It has been regularly destemmed by our grower-cooperator, can be noticeably damaged by destemming, and was responsive to abscission agents (Fidelibus, unpublished data).

Clusters of grapes were considered experimental units. Ninety-six clusters of grapes were randomly assigned to receive one of four different PGR treatments, each replicated on 24 different clusters. The PGR treatments used included: an untreated control, 500 ppm ACC, 6 mM (1,260 ppm) JA, and 6 mM JA with 500 ppm ACC. Similar treatments were shown to be effective on 'Thompson Seedless' grapes (Fidelibus et al., 2022), and showed potential on 'Sheegene-12' in a preliminary screening study (Fidelibus, unpublished data). All PGRs were provided by Valent BioSciences (Libertyville, IL, U.S.A.).

Unique tags were made for each replicate and treatment and placed in different bags, according to their replicate. Available clusters were randomly assigned to each treatment by pulling the tags out of a bag and tying them to the peduncle of each cluster. On the morning of 21 September 2021, solutions were prepared in spray bottles (Spritzer, Solo Inc., Newport News, VA, U.S.A.), with the proper amount of PGR, if any, in deionized water, with 0.05% (v/v) of Latron-B1956 spreader-sticker (Loveland Industries Inc., Greeley, CO, U.S.A.). Each solution was agitated well, and then applied to appropriately labelled clusters until runoff. The volume applied to each cluster was not measured, but was < 20 mL per cluster on average, based on the approximate amount of solution used. Polyethylene shields prevented overspray from contacting other clusters. After the clusters dried, they were enclosed in polypropylene mesh bags to catch any berries that might abscise.

On 23 or 24 September (2 or 3 DAT, respectively) 3 replicate clusters of each treatment were harvested and taken in their bags to a lab where preharvest abscission was determined, and fruit detachment force, stem end condition after detachment, berry weight, and soluble solids were measured from a subsample of 20 berries per cluster, following methods described previously (Fidelibus et al., 2022). Briefly, small shears were used to clip berries from all around each cluster, taking care to retain the pedicel and a portion of rachis. Each berry was then placed in a cradle attached to a force gauge (DPS-11; Imada, Northbrook, IL, U.S.A.), and the stem was pulled until it detached from the berry. The force required to detach the berry from its pedicel was recorded, and berries detached from their pedicels during FDF measurements were considered "destemmed". After destemming, the stem end condition of each berry was noted and the percentage having dry stem scars was calculated. Grapes from the same subsample were also used to determine color index of red grapes (CIRG; Carreño et al., 1995), using data from a chroma meter (CR-400, Konica-Minolta Sensing Americas, Ramsey, NJ, U.S.A.). Fruit firmness was determined with a fruit texture analyzer (GUSS, Strand, South Africa). Each berry was laid on its side and a stainless-steel probe 2 mm in diameter was driven 5 mm into the side of each berry at a rate of 5 mm sec^{-1}. Following the firmness measurements, all the berries in each sample were crushed together, and juice soluble solids were measured with a refractometer (Palette 101, Atago, Farmingdale, NY, U.S.A.).

At each harvest, nine additional replicate clusters of each treatment were placed into perforated zipper bags and three replicates were packed into each of three separate plastic straight-wall boxes with liners and stored at 0°C and 90% relative humidity (Crisosto and Crisosto, 2020; Venkitasamy et al., 2019) in a commercial postharvest storage facility. Each week for the next three weeks, one tote from each harvest was removed from storage and the measurements listed above were repeated.

Data expressed as percentages (preharvest abscission and berries with a dry stem scar) were arcsine transformed before statistical analyses, but for ease of interpretation, non-transformed treatment means are shown. Data were analyzed using the Mixed procedure of SAS (SAS Inc., Cary, NC, U.S.A.), first testing for main effects and interactions of PGR treatment and storage time by PHI. The PGR treatments interacted with storage time to affect many of the variables measured, so effects of storage time on PGR treatments, by PHI, were also analyzed, as were effects of PGR at each storage time (by PHI), and the data displayed in two-way tables (Gomez and Gomez, 1984). Least squares (lsmeans) were used for post hoc analyses.

Results

Treatments had little or no effect on berry abscission with a 2-day PHI (0 days of storage) or after 1, 2, or 3 weeks of postharvest storage (Table 1). However, JA and, especially, JA + ACC, significantly reduced FDF at harvest, and FDF continued to decline throughout the storage period (Table 1). After 3 weeks of storage, JA treatment reduced FDF by approximately 50%, and JA + ACC reduced FDF by approximately 62%, compared to untreated grapes. Likewise, for grapes treated with JA and harvested 2 DAT, the proportion grapes having a dry stem scar increased from 10% at harvest to 77% after three weeks of storage (Table 1). The majority of grapes treated with JA + ACC already had dry stem scars by 2 DAT, and the proportion did not significantly increase throughout storage, although nearly all the grapes had dry stem scars after 2- or 3-weeks storage (Table 1). Application of ACC alone did not affect abscission, FDF, or the proportion of detached berries having a dry stem scar (Table 1). Few, if any, of the control fruit had dry stem scars after detachment, at either harvest, or after any length of storage (Table 1). None of the treatments affected berry fresh weight, soluble solids, or firmness, when harvested 2 DAT, or during storage thereafter (Table 2). The CIRG increased during storage for grapes treated with ACC and JA + ACC and harvested on 2 DAT (Table 3).

On the second harvest, 3 DAT, neither JA nor ACC affected abscission when applied singly, but >25% of the grapes abscised from clusters treated with JA and ACC together, and abscission increased after 1 week in storage, plateauing thereafter (Table 1). By 3 DAT, all treatments reduced FDF compared to control (Table 1). Grapes treated with JA + ACC had particularly low FDF at harvest, and FDF continued to decline in storage, reaching very low levels (~10% of control) after 2 weeks storage. Jasmonic acid was less effective at reducing FDF than JA + ACC, but more effective than ACC alone, at harvest (on 3 DAT), and after postharvest storage (Table 1). As with JA + ACC, FDF declined in storage, reaching a minimum after 1 week, plateauing thereafter. Approximately 50% of the fruit treated with JA had dry stem scars when harvested 3 DAT, and this did not change significantly during storage

Table 1. Effects of preharvest interval, plant growth regulator treatment, and storage time, on percent abscised fruit, fruit detachment force, and proportion of berries with a dry stem scar.

Preharvest interval	Abscised fruit (%)				Fruit detachment force (N)				Berries with a dry stem scar (%)			
	Storage period (days)				Storage period (days)				Storage period (days)			
PGR treatment	0	7	14	21	0	7	14	21	0	7	14	21
2 DAT												
Control	0	0	0 b	0	5.34 a A	3.63 b C	4.49 a B	5.06 a AB	0 b	2 b	0 c	0 b
JA	0	0	0 b	0.5	3.63 b A	3.62 b A	3.25 b AB	2.72 b B	10 b B	45 ab AB	63 b A	77 a A
ACC	0	0	0 b	0.4	5.65 a	4.89 a	4.93 a	4.85 a	0 b B	2 b B	8 c A	2 b B
JA + ACC	0.5	1.5	4.5 a	8.4	2.02 c AB	2.51 c A	1.49 c B	1.81 c B	65 a	80 a	98 a	87 a
3 DAT												
Control	0 b	0	0	0 b	5.19 a A	5.22 a A	4.22 a B	5.35 a A	0 c	0 b	3 c	2 b
JA	0 b	28	24	12 ab	3.00 c A	1.34 b B	2.20 b A	2.32 c A	49 b	57 a	65 b	76 a
ACC	0 b	0	0	0 b	4.10 b B	5.68 a A	3.75 a B	4.45 b B	2 c	5 b	2 c	0 b
JA + ACC	27 a B	35 A	49 A	60 a A	1.68 d A	1.29 b A	0.49 c B	0.74 d B	89 a	98 a	100 a	100 a

Values are treatment means within postharvest interval (PHI) and storage-time period. Values followed by a different lower-case letter are significantly different within columns and DAT. Values followed by a different upper-case letter are significantly different within rows.

Table 2. Effects of preharvest interval, plant growth regulator treatment, and storage time, on berry fresh weight, soluble solids, and firmness.

Preharvest interval	Fresh weight (g berry^{-1})				Soluble solids (%)				Firmness (kg)			
	Storage period (days)				Storage period (days)				Storage period (days)			
Treatment	0	7	14	21	0	7	14	21	0	7	14	21
2 DAT												
Control	8.79	6.41	6.56	7.44	22.2	21.4	21.9	22.0	0.86	0.85	0.81	0.87
JA	6.68	6.01	6.19	6.91	20.7	20.9	21.5	22.1	0.77	0.82	–	0.82
ACC	8.67	7.51	8.29	8.48	23.4	22.5	22.9	22.8	0.89	0.84	0.84	0.89
JA + ACC	6.24	7.15	7.34	6.93	21.7	22.0	23.3	22.6	0.87	0.85	0.79	0.82
3 DAT												
Control	8.54	8.53	7.92	8.08 a	22.2	20.9	22.1 b	22.8	0.89	0.85	–	0.79
JA	7.15 A	4.27 B	5.89 AB	6.80 ab A	22.1	21.3	21.3 b	21.5	0.89	0.86	–	0.84
ACC	8.09	7.81	7.53	8.90 a	23.3 A	21.9 B	23.5 a A	21.7 B	0.89	0.87	–	0.79
JA + ACC	7.59	5.30	6.90	3.15 b	22.5	22.4	21.2 b	22.9	0.91	0.91	–	0.75

Values are treatment means within postharvest interval (PHI) and storage-time period. Values followed by a different lower-case letter are significantly different within columns and DAT. Values followed by a different upper-case letter are significantly different within rows.

Table 3. Effects of preharvest interval, plant growth regulator treatment, and storage time, on color index of red grapes.

Preharvest interval	Color index for red grapes (CIRG)			
	Storage period (days)			
PGR treatment	0	7	14	21
2 DAT				
Control	3.48	3.39 b	3.48 c	3.45 b
JA	3.43	3.46 b	3.60 bc	3.60 ab
ACC	3.08 B	3.79 a A	3.75 ab A	3.64 a A
JA + ACC	3.59 BC	3.55 b C	3.87 a A	3.75 a AB
3 DAT				
Control	3.18 B	3.31 c AB	3.31 c AB	3.69 A
JA	3.29	3.51 bc	3.52 bc	3.60
ACC	3.41 B	3.61 ab AB	3.96 a A	3.57 AB
JA + ACC	3.37	3.74 a	3.69 b	3.75

Values are treatment means within postharvest interval (PHI) and storage-time period. Values followed by a different lower-case letter are significantly different within columns and DAT. Values followed by a different upper-case letter are significantly different within rows.

(Table 1). Nearly 100% of grapes treated with JA + ACC had dry stem scars after detachment at harvest and throughout the storage period (Table 1). Untreated grapes were generally without dry stem scars, and treatment with ACC alone did not increase the proportion of grapes with dry stem scars (Table 1). Treatment effects on berry fresh weight, soluble solids, and firmness were few and inconsistent when harvested 3 DAT, or in storage thereafter (Table 2). Grapes treated with ACC alone, or untreated, and harvested 3 DAT saw improvement of CIRG during storage (Table 3).

Discussion

Abscission agents may facilitate destemming and improve the quality of destemmed grapes, but those potential benefits are countered by the risk of preharvest abscission. Thus, the primary goal of this study was to determine whether treated grapes could be harvested before abscission occurred, and allow abscission layers to develop in postharvest storage, thereby avoiding preharvest fruit drop and realizing the benefits of abscission agents at destemming. Our data confirmed previous studies showing that abscission progresses rapidly after application of the most effective treatments. For example, jasmonic acid alone was relatively ineffective at 2 DAT, but efficacy improved substantially when harvested a day later, reinforcing the fact that abscission zone development proceeds rapidly after initiation (Gonzales-Herranz et al., 2009; Uzquiza et al., 2015). Combining JA with ACC improved efficacy at either harvest date, confirming an earlier study with 'Thompson Seedless' (Fidelibus et al., 2022). If JA is used as an abscission agent on 'Sheegene-12' table grapes, and the grapes were to be destemmed at harvest, a 2-d PHI would be too short, as few berries would have dry stem scars; harvesting a day later would increase the proportion of berries having dry scars by five times. However, if JA + ACC is used as an abscission agent on 'Sheegene-12', harvest may be needed before 3 DAT to prevent excess preharvest drop. Data collected at harvest, on 2 and 3 DAT, confirm that ACC alone is ineffective as an abscission agent (Uzquiza et al., 2014; Fidelibus et al., 2022).

If the grapes can be held in postharvest storage before destemming, then efficacy of JA could be substantially improved. Grapes treated with JA, harvested 2 DAT, and stored for two to three weeks before destemming had far greater dry stem scar incidence than grapes that were destemmed at harvest. In fact, if grapes could be held for three weeks before destemming, then ACC might not be needed to improve efficacy of JA. However, prolonged storage reduces the sensory shelf-life of fruit (Oms-Oliu et al., 2010), so a three-week storage period may be impractical, as the fruit would then be destemmed and marketed. Combining JA with ACC eliminates the need for prolonged storage time to achieve good efficacy. These results suggest that ACC hastened abscission initiated by JA. Nearly 100% efficacy, with respect to dry stem scar incidence, could be achieved by treating grapes with JA + ACC, harvesting them 2 DAT, and storing them for two weeks before destemming. This method could also avoid the risk of preharvest fruit drop, and not affect berry weight, firmness, or soluble solids. Previously, Lavee (1959) observed that the preharvest application of NAA could reduce postharvest abscission of 'Muscat of Alexandria' grapes held at room temperature for three days before cold storage. Thus, postharvest abscission of grapes can be promoted, to improve the quality of destemmed grapes, or retarded, to improve the quality of grapes marketed as whole clusters, by preharvest applications of certain PGRs. Grapes in some treatments, including controls harvested 3 DAT, became more red-colored (CIRG increased) during postharvest storage. It is unclear why this was observed, but others have shown that table grapes can become more red-colored during postharvest storage (Irkin and Guldas, 2013), and Flores et al. (2015) noted that exposure of grapes to a postharvest MeJA vapor treatment increased their anthocyanin content. Since we packed grapes of every treatment in each box, it's possible that volatile ethylene (from metabolization of ACC), or JA might have inadvertently affected control fruit such that color was slightly affected. Additional data are needed to determine if effects on color during storage are consistently related to PGR treatments.

Abscission agent efficacy varies among grape varieties (Fidelibus et al., 2007; Fidelibus, unpublished), so additional research is needed to determine the applicability of our results to other varieties. However, it is notable that abscission agents are effective on 'Sheegene-12' because it is a globally important mid-season red table grape variety. Moreover, we demonstrated that harvesting treated grapes before preharvest abscission occurs and holding them for a few weeks in postharvest storage before destemming can maximize potential benefits of abscission agents while preventing preharvest losses. Basic research to better understand the underlying physiological basis for the effects observed might lead to in-

sights on how to improve efficacy and, possibly, help prevent postharvest abscission when it is not desired (Yu et al., 2024). Jasmonic acid has been shown to increase ACO and ACS activity in strawberry, another non-climacteric fruit, thereby increasing ethylene biosynthesis (Liu et al., 2024). Thus, JA plus ACC might be particularly effective due to upregulation of ACO and ACS by JA while, at the same time, ACC is immediately available for conversion to ethylene by ACO.

Conclusion

In conclusion, we found that JA and especially JA + ACC, reduce FDF and increase the proportion of grapes having dry stem scars after detachment without affecting berry size, brix, or firmness. Therefore, abscission agents could be used to improve the quality of destemmed grapes by reducing mechanical damage associated with destemming without adversely affecting other important quality parameters. Moreover, we showed that the AZ continues to develop after harvest, so treatment effects on preharvest fruit drop can be avoided by harvesting 'Sheegene-12' grapes within 2 DAT, and storing the fruit treated with JA or JA + ACC for one to three weeks after harvest before destemming to optimize beneficial treatment effects. Additional work is needed to determine applicability for other varieties.

Acknowledgments

The authors gratefully acknowledge the grower-cooperator, and technical support from Jorge Osorio-Aguilar and Valeria Cisneros. Active ingredients and financial support were provided by Valent BioSciences.

References

California Dept. of Food and Agriculture and U.S. Dept. of Agriculture, National Agricultural Statistics Service. (2024). California Grape Acreage Report, 2023 Crop (Sacramento, CA, U.S.A.: California Dept. of Food and Agriculture and U.S. Dept. of Agriculture).

Cardone, M.F. (2024). Enhancing table grape production: Addressing challenges and opportunities for sustainability and quality improvement. IVES Conference Series, Open GPB 2024.

Carreño, J., Martínez, A., Almela, L., and Fernández-López, J.A. (1995). Proposal of an index for the objective evaluation of the colour of red table grapes. Food Res. Intl. *28*, 373–377. https://doi.org/10.1016/0963-9969(95)00008-A.

Crisosto, C.H., and Crisosto, G.M. (2020). Manual on Postharvest Handling of Mediterranean Tree Fruits and Nuts (Boston, U.S.A.: CABI), p. 216.

El-Zeftawi, B.M. (1982). Effects of ethephon on clusters loosening and berry composition of four wine cultivars. J. Hortic. Sci. *57*, 457–463. https://doi.org/10.1080/00221589.1982.11515078.

Environmental Protection Agency. (2013). Jasmonate, M. Exemption from the requirement of a tolerance. Fed. Reg. *78*, 22789–22794.

Ergun, M., Akkaya, O., and Ergun, N. (2008). Suitability of some mid-season table grape cultivars and types for minimally processed produce. J. Intl. des Sciences de la Vigne et du Vin *42*(2). http://doi.org/10.20870/oeno-one.2008.42.2.820.

European Food Safety Authority. (2009). Review of the Existing Maximum Residue Levels (MRLs) for Ethephon. Scientific Report Vol. 7 (Parma, Italy: Eur. Food Safety Authority).

Ferrara, G., Mazzeo, A., Matarrese, A.M.S., Pacucci, C., Trani, A., Fidelibus, M.W., and Gambacorta, G. (2016). Ethephon as a potential abscission agent for table grapes: Effects on pre-harvest abscission, fruit quality, and residue. Front Plant Sci. *7*. https://doi.org/10.3389/fpls.2016.00620.

Fidelibus, M.W., Petracek, P., and McArtney, S. (2022). Jasmonic acid activates the fruit-pedicel abscission zone of 'Thompson Seedless' grapes, especially with co-application of 1-aminocyclopropane-1-carboxylic acid. Plants *11*, 1245. https://doi.org/10.3390/plants11091245.

Fidelibus, M.W., Cathline, K.A., and Burns, J.K. (2007). Potential abscission agents for raisin, table, and wine grapes. HortScience *42*, 1626–1630.

Flores, G., Glanch, G.P., and del Castillo, M.L.R. (2015). Postharvest treatment with (-) and (+) methyl jasmonate stimulates anthocyanin accumulation in grapes. LWT-Food Sci. Technol. *62*, 807–812. https://doi.org/10.1016/j.lwt.2014.12.033.

Gomez, K.A., and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research, 2nd edn. (New York, U.S.A.: John Wiley and Sons), 680 pp.

Gonzalez-Herranz, R., Cathline, K.A., Fidelibus, M.W., and Burns, J.K. (2009). Potential of methyl jasmonate as a harvest aid for 'Thompson Seedless' grapes: Concentration and time needed for consistent berry loosening. HortScience *44*, 1330–1333. https://doi.org/10.21273/HORTSCI.44.5.1330.

Hedberg, R.P., and Goodwin, P.B. (1980). Factors affecting natural and ethephon-induced grape berry abscission. Am. J. Enol. Vitic. *31*, 109–113. https://doi.org/10.5344/ajev.1980.31.2.109.

Irkin, R., and Guldas, M. (2013). Chitosan coating of red table grapes and fresh-cut honey melons to inhibit *Fusarium oxysporum* growth. J. Food Process. Preserv. *38*, 1948–1956. https://doi.org/10.1111/jfpp.12170.

Kou, L., Luo, Y., Wu, D., and Liu, X. (2007). Effects of mild heat treatment on microbial growth and product quality of packaged fresh-cut table grapes. J. Food Sci. *72*, S567–S573. https://doi.org/10.1111/j.1750-3841.2007.00503.x.

Lavee, S. (1959). Physiological aspects of post-harvest berry drop in certain grape varieties. Vitis *2*, 34–39.

Li, M., Huang, Z., You, X., Zhang, Y., Wei, P., Zhou, K., and Wang, Y. (2020). Relationships between cell structure alterations and berry abscission in table grapes. Front. Nutr. *7*, 69. https://doi.org/10.3389/fnut.2020.00069.

Liu, M., Wang, C., Ji, H., Sun, M., Liu, T., Wang, J., Cao, H., and Zhu, Q. (2024). Ethylene biosynthesis and signal transduction during ripening and softening in non-climacteric fruits: An overview. Front. Plant Sci. *15*. https://doi.org/10.3389/fpls.2024.1368692.

Mlikota Gabler, F., and Smilanick, J.L. (2001). Postharvest control of table grape gray mold on detached berries with carbonate and bicarbonate salts and disinfectants. Am. J. Enol. Vitic. *52*, 12–20. https://doi.org/10.5344/ajev.2001.52.1.12.

Oms-Oliu, G., Rohas-Grau, M.A., Gonzalez, L.A., Varela, P., Solvia-Fortuny, R., Hernando, M.I.H., Munuera, I.P., Fiszman, S., and Martin-Belloso, O. (2010). Recent approaches using chemical treatments to preserve quality of fresh-cut fruit: A review. Postharvest Biol. Technol. *57*, 139–148. https://doi.org/10.1016/j.postharvbio.2010.04.001.

Orozco-Mosqueda, M.C., Glick, B.R., and Santoyo, G. (2020). ACC deaminase in plant growth-promoting bacteria (PGPB): An efficient mechanism to counter salt stress in crops. Microbiol. Res. *235*, 126439. https://doi.org/10.1016/j.micres.2020.126439.

Pawar, D.A., Giri, S.K., and Sharma, A.K. (2021). Development and performance evaluation of grape debunching machine for production of raisins and stemless table grapes. J. Food Process Engin. *44*, e13898. http://doi.org/10.1111/jfpe.13898.

Sabir, F.K., Unal, S., Adyin, S., and Sabir, A. (2024). Pre- and postharvest chitosan coatings extend the physiochemical and bioactive qualities of minimally processed 'Crimson Seedless' grapes

during cold storage. J. Sci. Food Agric. *104*(13), 7834–7842. https://doi.org/10.1002/jsfa.13613.

Shiri, M.A., Ghasemnezhad, M., Bakhshi, D., and Dadi, M. (2011). Changes in phenolic compounds and antioxidant capacity of fresh-cut table grape (*Vitis vinifera*) cultivar 'Shahaneh' as influenced by fruit preparation methods and packaging. Austral. J. Crop Sci. *5*(12), 1515.

Szyjewicz, E., Rosner, N., and Kliewer, W.M. (1984). Ethephon ((2-chloroethyl) phosphonic acid, Ethrel, CEPA) in viticulture – A review. Am. J. Enol. Vitic. *35*, 117–123. http://doi.org/10.5344/ajev.1984.35.3.117.

Uzquiza, L., Martin, P., Sievert, J.R., Arpaia, M.L., and Fidelibus, M.W. (2014). Methyl jasmonate and 1-aminocyclopropane-1-carboxylic acid interact to promote grape berry abscission. Am. J. Enol. Vitic. *65*, 504–509. http://doi.org/10.5344/ajev.2014.14038.

Uzquiza, L., González, R., Gonzalez, M., Fidelibus, M., and Martin, P. (2015). A preharvest treatment of ethephon and methyl jasmonate affects mechanical harvesting performance and composition of 'Verdejo' grapes and wines. Eur. J. Hortic. Sci. *80*, 97–102. http://doi.org/10.17660/eJHS.2015/80.3.1.

Venkitasamy, C., Zhao, L., Zhang, R., and Pan, Z. (2019). Grapes. In Integrated Processing Technologies for Food and Agricultural By-Products, Z. Pan, R. Zhang, and S. Zicari, eds. (London, U.K.: Academic Press), p. 133–163. https://doi.org/10.1016/B978-0-12-814138-0.00006-X.

Yu, P., Li, S., Sun, Y., Meng, X., Shi, Q., Zhao, X., and Yu, Y. (2024). Transcription factor VlbZIP14 Inhibits postharvest grape berry abscission by directly activating *VICOMT* and promoting lignin biosynthesis. Intl. J. Molec. Sci. *25*(17), 9479. https://doi.org/10.3390/ijms25179479.

Received: Jun. 7, 2024
Accepted: Oct. 12, 2024

Addresses of authors:
Matthew W. Fidelibus[1], J. Stogbauer[1], P. Petracek[2] and S. McArtney[2]
[1] Department of Viticulture and Enology, University of California, Davis, CA 95616, U.S.A.
[2] Valent BioSciences, Libertyville, IL, 60048, U.S.A.