Adv. Hort. Sci., 2011 25(3): 143-150

Summer pruning in table grape

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Key words: girdling, leaf removal, thinning, trimming, *Vitis vinifera L.*

Abstract: This paper reviews cultural practices to improve fruit quality in table grape during vegetative and reproductive seasons. Summer pruning in table grape (*Vitis vinifera* L.) has more effects than winter pruning, above all with regard to plant productivity and final number of bunches for harvesting. Thinning is one of the most cultural technique and it consists in the elimination of vegetative or reproductive organs in excess. Other summer canopy management techniques include leaf removal, fruit shoots positioning, shoot trimming and girdling.

1. Introduction

Summer pruning is a cultural techniques which drives vine vigour to ensure fruit quality and plant vegetative balance. While summer pruning is the most expensive cultural operation - 44.2% of total management costs (Crescimanno *et al*., 2011) - it helps to improve the microclimate in the canopy, promotes good ripening of the grapes and creates less suitable conditions for the development of pathogens. Good results depend on the vegetative-productive behaviour of the vineyard, intensity and age of cultural operation (Crescimanno *et al*., 1986). Summer pruning defines the final productivity of plants by modifying the number of shoots per plant with shoot thinning, the number of clusters per shoot with cluster thinning, and the number of berries per bunch with berry thinning. Other summer operations include leaf removal, shoot trimming and girdling *(*Di Lorenzo, 2003*)*. General indications about summer pruning techniques to enhance quality of production are very difficult to formulate because cultivar behaviour, vigour of the vineyard and environmental conditions must all be considered.

2. Leaf removal

Leaf removal causes a reduction of vine leaf area. If it occurs at or before bloom, it may cause berry drop, a reduction in fruit set or a reduction in bud fertility in the following season (Candolfi-Vasconceloset and Koblet, 1990). The intensity of leaf removal should be based on canopy density and light penetration into the fruit zone. The removal of basal leaves around the clusters is widely adopted to improve grape quality and to reduce the incidence of fungal infection (Gubler and Marois, 1987; Caspari *et al*., 1998).

Received for publication 9 June 2011
Accepted for publication 8 September 2011

Leaf removal should be performed near berry set or after fruit softening (Dokoozlian *et al*., 2000 a). The leaves immediately above the cluster are the main source for photosynthates translocated to the cluster, particularly during the early stages of its development (Hunter and Visser, 1988). Also at pea-size stage the loss of basal leaves increases fruit abscission, reduces berry size and decreases bud fertility; it has no effect when applied at veraison (Caspari *et al*., 1998). After berry setting, usually all primary leaves and lateral shoots beginning from the base of the shoot to the node opposite the top cluster on each shoot are removed. Elimination of apparently superfluous sinks, such as lateral shoots, reduces canopy density and °Brix, but it has minor impact on TA and pH (Reynolds and Wardle, 1989; Barbagallo *et al*., 2007 a). The leaves left on the vines after defoliation increase photosynthetic activity to recover the reduction on total leaf area activity and to supply the photoassimilates demand of sinks (Poni *et al*., 2006; Scafidi *et al*., 2010). On the other hand, Candolfi-Vasconcelos and co-workers (1994) found that defoliated plants had similar or even slightly lower photosynthetic rates compared to control plants, not only during the stress period but also in the following season. A photosynthesis response to leaf removal may be apparent only if the source-sink ratio is sufficiently limited. Under conditions of source deficiency due to leaf removal in the fruit zone, plants promote the activity of apical meristems to replace the missing leaf area (Barbagallo *et al*., 2007 b). Basal leaves should not be removed before veraison, especially in varieties susceptible to heat damage or sunburn like ‘Red Globe’, ‘Thompson Seedless’.

During fruit ripening leaves opposite the clusters have limited importance compared to the younger leaves at the top of the canopy (Candolfi-Vasconcelos *et al*., 1994; Hunter *et al*., 1995). Younger leaves show a higher transpiration rate, but also higher water use efficiency than those opposite the clusters (Candolfi-Vasconcelos *et al.*, 1994).

Some weeks before harvest random defoliation is usually undertaken to fully develop the colour of white, red and some black grape varieties.

3. Thinning

Thinning consists in the elimination of vegetative or reproductive organs in excess. It is very rarely performed before bloom since negative climatic events can lead to the loss of many shoots or irregular fruit set; in some areas and for some cultivars thinning performed before bloom can lead to excessive fruit set and tight bunches.

Shoot thinning

Shoot thinning is the elimination of double, weaker and sterile shoots and it is very important to aerate the canopy, improve the growth of remaining shoots and adjust cluster numbers. There may be an advantage with shoot thinning in vigorous vines to reduce shoot crowding and thus increase light exposure of the remaining shoots. Shoot thinning should be performed when shoot length reaches 25-30 cm. (Dokoozlian *et al.*, 2000 b) when it is possible to define which shoots have bunches in good position and which are well located as pruning material for the next year. On spur-pruned vines two shoots per spur are retained and latent shoots are removed from older wood, arms and cordons, while cane-pruned vines are sometimes shoot thinned, especially when several canes are wrapped together on a single wire.

Cluster thinning

Cluster thinning is usually performed after fruit set in order to adjust the crop load, distribute clusters evenly on the vine and canes, select the best clusters (shape, size and position) and eliminate those that are misshaped and weak (Figs. 1 and 2). Generally the aim is to have an equal number of cluster and shoots on the plant, leaving two clusters on the distal shoots. The number of flowers per inflorescence, berry per cluster and cluster weight (Table 1) is positively affected by the node position long the cane (Sottile *et al.*, 1996). A cluster/shoot ratio of less than 0.8 usually determines a reduction in terms of yield (Tables 2 and 3) without any significant improvement in terms of quality (Di Lorenzo, 2003). Several studies demonstrated that crop removal significantly increases soluble solids (Fig. 3) and berry colour (Dokoozlian *et al.*, 1995). In a trial conducted on 'Flame Seedless' in Fresno California, berry weight, size and fruit composition varied little among vines thinned one week prior to bloom and those thinned four weeks following fruit set (Dokoozlian *et al.*, 1995).

Berry thinning

Berry thinning is a widely performed technique and involves the removal of a few berries from the cluster (Di Lorenzo, 2003). This operation is necessary to decrease the compactness of bunches and to give them a more attractive shape with large, uniform-size berries (Fig. 4 - Table 4). Berry thinning is performed when berries are at pea-size in order to give more uniform clusters in terms of weight and shape, satisfying packaging and marketing needs. In some cases for some cultivars, the partial removal of inflorescence or flowers with small scissors or small combs is performed in order to avoid an excessive clusters weight and/or closeness (Di Lorenzo, 2003). How the berries are removed depends on the cultivar. The best results are ob-

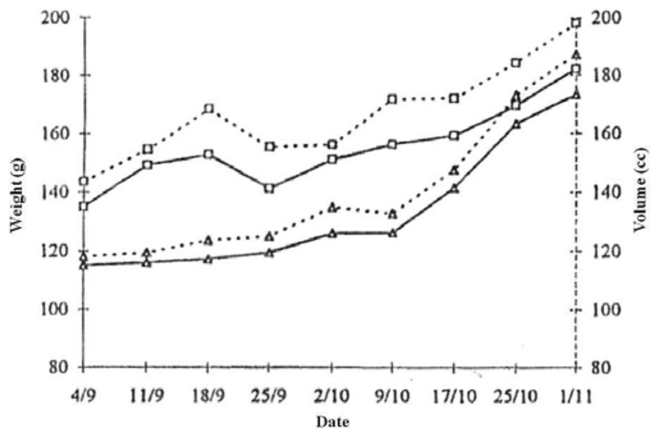

Fig. 1 - Effect of cluster thinning on evolution of berry weight (dotted line) and volume (continuous line) in treated (square) and control (triangle) plants.

Fig. 2 - Cluster thinning.

Table 1 - Influence of node position on number of flowers per inflorescence, number of berries per cluster, and berry and cluster weight (Sottile *et al.*, 1996)

Node position	Flower (No.)	Berry (No.)	Berry weight (g)	Cluster weight (g)
1-4	258	101	7.0	779
5-9	517	128	7.3	1015
10-12	744	148	6.9	1090

Table 2 - Influence of cluster:bud ratio on production of grape cv. Italia. Score of grapes from different vineyards and different thesis (Crescimanno *et al*., 1986)

Vineyards	Different time					
	I		II		III	
	0.6	0.8	0.6	0.8	0.6	0.8
1	627.45	509.15	592.20	565.40	581.17	499.62
2	680.17 ab	539.25 b	724.47 a	708.97 a	731.80 a	704.95 a
3	336.27 ABab	305.20 ABcd	355.67 Aab	230.77 Bc	393.22 Aa	303.65 ABbc
4	948.55	816.72	960.07	842.97	846.05	860.92
2A	919.72	890.85	945.70	845.75	851.62	894.35
3A	821.75 ab	871.47 ab	698.35 b	782.85 ab	946.00 a	787.62 ab
4A	832.05 a	633.78 b	714.30 ab	756.52 ab	818.62 ab	774.40 ab

Values sharing the same letter are not significantly different from each other by Duncan's multiple range test at $P \leq 0.01$ and $P \leq 0.05$.

Table 3 - Influence of cluster:bud ratio on production of grape cv. Italia. Score of grapes from different vineyards and different thesis (Crescimanno *et al*., 1986)

	Different time					
	I		II		III	
Vineyards	0.6	0.8	0.6	0.8	0.6	0.8
1	-	-	-	-	-	-
2	9	8	9	8	8	8
3	-	-	-	-	-	-
4	9	8	8	8	7	8
2A	10	9	8	8	9	8
3A	10	9	9	9	9	8
4A	10	7	10	10	8	8
Thesis average	9.6	8.4	8.8	8.6	8.2	8
Time average	9		8.7		8.1	

- = Poor quality of the product (not packable).

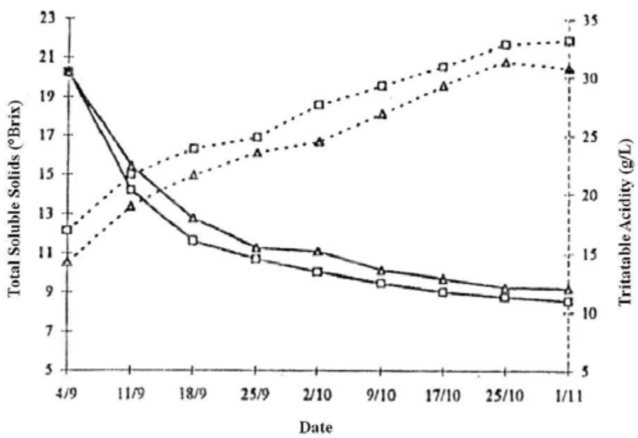

Fig. 3 - Effect of cluster thinning on evolution of °Brix content (dotted line) and total acidity (continuous line) in berries of treated (square) and control (triangle) plants.

tained with the "helicoidal" method, which consists of eliminating shoulders arranged in a spiral around the axis of the rachis. Another method is the "fish spine" system where two parallel cuts are made on each side of the axis of the rachis, but without injuring it. The resulting bunch is very flat, but when the berries grow, the respective ramification occupies the space around the rachis. In 'Thompson Seedless' the most common method is to clip the cluster leaving only the upper four to six shoulders (Dookolzian *et al*., 1995); in 'Red Globe' and 'Flame Seedless' usually the upper six to eight shoulders are kept (Dookolzian and Hirschfelt, 1995); in Superior Seedless® one-third of the bottom part of the cluster is removed. In cultivars such as 'Italia', instead, berry thinning requires plucking small seedless or irregularly developed berries by hand, a very expensive operation which may take up to 50-80 labour days/hectare.

In seedless varieties the use of giberelic acid (GA_3) is widespread; dose and time of application is highly dependent on the variety. The success of treatment is extremely variable, and is greatly influenced by climate during flow-

Fig. 4 - Berry thinning.

Table 4 - Effect of two different thinnings on qualitative traits (Di Lorenzo, 2003)

Thinnings	Cluster weight (g)	Berry weight (g)	Berry weight variation coefficient (%)	Closeness index
Thinning intensity more than 40% of traditional	626	10.6	23.1	2.59
"Traditional" berry thinning	934	8.9	28.1	3.39

ering (especially air temperature). One of the goals of breeding programs is to obtain varieties that do not require berry thinning.

4. Girdling and cane-scoring

Girdling is the removal of a ring of bark (only phloem) around the trunk or bases of the individual canes, while scoring is a simple knife-cut encircling the branch (Fig. 5 a and b). The phenological stage at which girdling is carried out is the greatest factor determining the nature and magnitude of the obtained effects (Di Lorenzo, 2003). Both operations stop movement through the phloem, modifying the hormonal balance of the vine after girdling (Kriedemann and Lenz, 1972) and consequently producing an increase of carbohydrates above the girdle (Weaver and McCune, 1959); carbon exchange between the shoot and the rest of the vine is thus eliminated.

Girdling reduces net CO_2 assimilation rate and stomatal conductance of leaves until the girdle heals (Kriedemann and Lenz, 1972; Williams and Ayars, 2005). Water use efficiency decreases following girdling without an application of GA_3 at berry set. Once the girdle heals, vine water use increases up to harvest (Bucks *et al*., 1985; Williams and Ayars, 2005). The reduction in stomatal conductance, and concomitant reduction in vine water use in response to girdling is probably due to an accumulation of abscisic acid (ABA) in the leaves (Loveys and Kriedemann, 1974; During, 1978; Williams *et al*., 2000; Williams and Ayars, 2005).

Girdling has negative effects on some berry characteristics, such as a decrease of malic acid concentration in the must (Orth *et al*., 1994).

The effect of girdling is reduced by leaf removal and declines while the number of leaves decreases (Caspari *et al*., 1998). Cane girdling at 12°Brix sugar content on cv. Vittoria determines a qualitative improvement of grapes (Tables 5 and 6): particularly, single girdling increases ratio sugar: acidity, double girdling (first time performed at pea-size stage, second time at veraison) increases the berry weight (Fig. 6) (Di Lorenzo and Gambino, 2010). Cane-scoring increases the average berry size of 'Emperatriz' seedless grape and bunch weight compared to unscored vines, but has no effect in 'Aledo' seeded grape (Casanova *et al*., 2009). The author supposes that in seeded fruits the availability of carbohydrates is guaranteed by the seed's ability to synthesize plant growth hormones leading to powerful sink capacity, while seedless fruit has an insufficient sink capacity to grow.

Trunk girdling is a more rapid technique than cane girdling and all clusters are subjected to treatment. With cane girdling or scoring there may be a few clusters, located below the cut, that remain unaffected. The bark ring removed has to be complete; incomplete cuts result ineffective (Jensen *et al*., 1979).

Usually the girdle cut heals in approximately four weeks through callus formation that recovers the vascular connections (Williams *et al*., 2000).

Girdling and cane scoring are carried out seven to 10 days before flowering to improve berry-set, at berry set to increase berry size, and at veraison to advance sugar and colour development in red varieties.

Fig. 5 - Cane girdling and trunk girdling.

Table 5 - Effect of early girdling (1), girdling at 12°Brix sugar content (2), and double girdling (3) on parameters of berries at ripening on cv. Vittoria (Di Lorenzo *et al.*, 2010)

	Average berry weight ±SE (g)	Weight range			Average P.D. ±SE (mm)	Average E.D ±SE (mm)	Average berry form (DP/DE)
		<6	6-8	> 8			
1	8.3 c ±0.20	15	42	43	27.3 bc ±0.39	21.1 b ±0.30	1.30 ±0.02
2	7.4 b ±0.16	21	44	35	26.8 b ±0.23	19.7 a ±0.20	1.47 ±0.01
3	8.7 c ±0.19	10	35	55	27.8 c ±0.33	21.0 b ±0.17	1.32 ±0.01
Control	6.8 a ±0.10	38	43	19	25.0 a ±0.21	21.1 b ±0.14	1.18 ±0.01

In a trial of trunk girdles applied at fruit set on ‘Crimson Seedless’, vines girdled at fruit set produced larger berries compared to vines girdled at berry softening and ungirdled vines. Trunk girdles applied at fruit set increased berry weight 38%, berry length 12% and berry diameter 10% compared to the fruit of ungirdled vines. The berry weight and diameter of vines girdled at veraison were significantly lower than those of ungirdled vines, while the berry length of these treatments was similar. In addition, berry firmness of vines girdled at fruit set was significantly greater compared to vines girdled at berry softening and ungirdled vines. Due primarily to their larger berry size, the total yield of vines girdled at fruit set was approximately 45% greater than vines girdled at berry softening and ungirdled vines. A fruit quality defect among the girdling treatments was poor colour, and so only a portion of this increase in total yield was packable fruit (Dokoozlian *et al.*, 1995; Dokoozlian *et al.*, 2000 a). In contrast, in the same variety, Brar and coworkers (2008) indicated that girdling at berry set was an effective practice to stimulate berry colour development. In ‘Autumn Royal’ berry weight can be increased 10 to 15% by girdling at berry set, but also in this variety girdling delays colour development and harvest (Dokoozlian *et al.*, 2000 a).

Table 6 - Effect of early girdling (1), girdling at 12°Brix sugar content (2), and double girdling (3) on harvest parameters (cv. Vittoria) (Di Lorenzo *et al.*, 2010)

	Soluble solids °Brix		Total acidity (g/l)	
	05-07	15-07	05-07	15-07
1	13.2 b	13.3 a	5.8 a	5.5 a
2	12.0 a	14.2 b	6.2 b	5.8 b
3	13.2 b	13.5 a	5.8 a	5.9 b
control	12.0 a	13.5 a	6.2 b	5.8 b

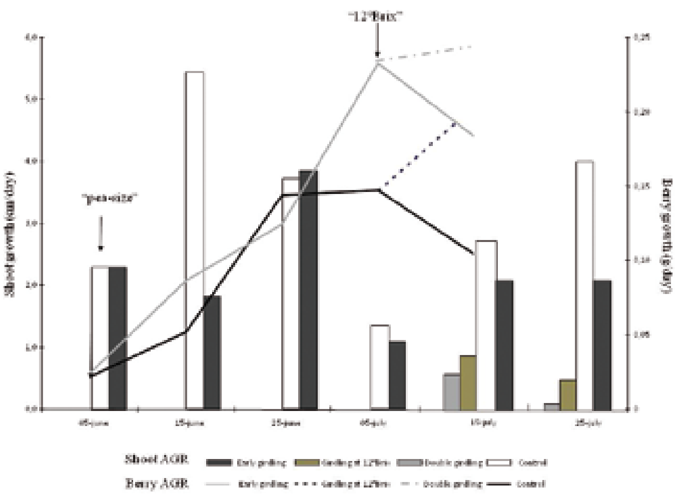

Fig. 6 - Effect of early girdling (1), girdling at 12°Brix sugar content (2), and double girdling (3) on growth rate of the shoot and berry (Di Lorenzo and Gambino, 2010).

Trunk girdling at berry set and bunch thinning, in an early-season black seedless table grape variety (Sugrathirteen® or Midnight Beauty®) improved berry size, sugar content and berry firmness (Gentilesco *et al.*, 2011).

Girdling increases the risk of skin burn, and should never be done on the same vine more than once a year. Repeated girdling over a number of years may reduce bunch size and the life expectancy of the plant.

5. Shoot trimming

Intensive growth of vines in warm climates requires measures to control vigour in order to ensure fruit quality and vegetative balance of the plants. The main control measure, besides the careful use of water and fertilizers, is shoot trimming which is usually performed after flowering; the exact moment depends on the cultivar and the objective of the culture (Camargo, 2005). Shoot trimming carried out just before bloom may improve fruit set: in fact in this stage it stops trophic competition of top shoot. In “T”, “Y” or open gable trellis, shoot trimming or hedging can be performed to improve cluster exposure to sunlight and to reduce humidity within the fruit zone. Early hedging may stimulate lateral shoot growth. Hedging should be performed after berry softening to avoid potential problems with fruit sunburn. Both sides of the canopy should be trimmed to allow the uniform penetration of sunlight into the canopy interior. Care must be taken not to remove too much foliage when hedging as excessive foliage removal may slow fruit maturation and significantly retard fruit colour development (Dokoozlian *et al.*, 2000 a).

6. Plant growth regulators

Plant growth regulators play a notable role in current worldwide table grape cultivation. Some of these can be included among summer management techniques, in order to reduce berry set, increase berry size and accelerate or improve fruit ripening. Before discussing their effects and possible uses, it must be pointed out that in each country there are different rules and regulations for their use (e.g. forchlorfenuron and ethephon are forbidden in many countries).

Gibberellic acid (GA_3)

Gibberellic acid (GA_3) is commonly used to reduce fruit set and increase berry size of seedless table grape cultivars. GA_3 rates and timing applications are quite specific and depend on the cultivar, region, and desired effects on berry growth and fruit quality (Dokoozlian *et al.*, 1995).

GA_3 sprays are generally carried out:

- *Several weeks before bloom* to elongate the cluster rachis.

  While many studies have reported that pre-bloom GA_3 application has no effect on cluster length or compactness at harvest (Dokoozlian, 2000), commercially it is still used (about 10 ppm rate). It could have a negative influence on bud fruitfulness in the following year.
- *Between 30 and 100% bloom* to improve berry thinning.

  The mechanism by which gibberelic acid works as fruit thinner is still not understood. An initial hypothesis was that GA_3 acts as a pollenicide, interfering with pollen germination, however many studies have shown that the GA_3 concentration normally applied for thinning does not reduce pollen germination. Some authors suggest, instead, that GA_3 applied at bloom alters the endogenous hormone balance causing flower or fruit abscission. The most reliable hypothesis is that GA_3 induces nutrient competition between flowers and shoots, and among flowers/small fruits within the cluster. In the latter case GA_3 stimulates nutrient competition among berries, and so physiologically advanced berries become strong sinks, while weaker berries are unable to compete for nutrients and drop (Dokoozlian, 2000).

  The GA_3 rate is closely related to variety and climate conditions, and it can vary from 1 to 20 ppm. A higher rate of GA_3 applied at bloom generally does not improve thinning, but can significantly increase the number of shot berries per cluster. Single or multiple applications usually result in similar levels of fruit thinning, however it seems that multiple applications produce larger berries at harvest compared to single applications (Dokoozlian, 2000). GA_3 spray at bloom often produces inadequate levels of berry thinning, which results in a need for manual berry thinning.
- *After fruit set* to increase berry size.

  Gibberellic acid applied to growing berries increases cell division and elongation.

  Also in this case the rate depends on the cultivar and prefixed quality target. The timing of application has a big influence on the efficacy of treatment; usually berry size should be in the range 4-6 mm, to a maximum of 10 mm. GA_3 treatments can increase berry size at harvest 50% or more, but they delay fruit maturity and reduce berry colour in red varieties (Dokoozlian, 2000). Also in this stage, high rates might cause a decrease in bud fruitfulness in the following year.

  GA_3 molecules enter in plant tissues better if applied in low pH solution (pH ≈ 4) since at low pH GA_3 molecules are neutral and are able to move easily through plant tissues.

Forchlorfenuron (CPPU)

Forchlorfenuron (CPPU) is a synthetic cytokinin that increases cell division and elongation.

Usually, CPPU can be sprayed on grape:

- *Immediately before bloom* to increase fruit set (≈ 10 - 20 g/ha) (Dokoozlian, 2000);
- *After fruit set* to increase berry size (≈ 5 - 40 g/ha).

  In different varieties ('Thompson Seedless', 'Ruby Seedless', 'Redglobe' and 'Melissa') CPPU applied at fruit set increased berry weight, diameter and length, while CPPU applied at fruit softening had no significant effect on berry growth. A two-week delay in harvest of most cultivars was obtained when 9-12 mg/l CPPU was applied at berry set, while pigment accumulation was either delayed or significantly reduced (Dokoolzian, 2001).

  CPPU does not reduce the fruitfulness of either seedless or seeded table grape cultivars, while it increases the rachis size and the force required to remove berry from the capstem (Dokoolzian *et al.*, 1995).

Ethephon

Ethephon (trade name Ethrel®) is commonly applied to red-pigmented table grape cultivars at the beginning of fruit ripening to enhance berry colour. The active ingredient in ethephon, [(2-chloroethyl) phosphonic acid], produces ethylene upon its degradation. Ethylene is an endogenous plant hormone that accelerates the ripening of many fruits, including grapes.

Ethephon, applied on 'Crimson Seedless' when approximately 5 to 10% of the berries were showing red colour, had no effect on fruit soluble solids content, however vines treated with ethephon had lower titratable acidity compared to untreated vines (Dokoozlian *et al.*, 1995).

Ethephon had no significant effect on berry weight, length or diameter, while it significantly improved fruit colour, increasing packable yield (+38%), but significantly reduced berry firmness compared to untreated vines (Dokoozlian *et al.*, 1995).

Abscisic acid (ABA)

The plant hormone abscisic acid (ABA) appears to be one of the factors for anthocyanin accumulation. Exogenous applications of ABA increased the anthocyanin content of grape skins (Peppi *et al.*, 2006; Peppi *et al.*, 2007).

Application of abscisic acid (ABA) may improve colour more effectively than ethephon, but it may potentially influence postharvest quality, though in a trial carried out on 'Crimson Seedless' the ABA and ethephon treatments did not affect berry firmness or predispose the fruit to postharvest shatter (Cantína *et al.*, 2007). In that trial grapes treated with 300 µl l^{-1} ABA coloured quickly and thus were harvestable about 30 days earlier than untreated grapes, and 10 days earlier than grapes treated with ethephon. On average, grapes treated with 150 µl l^{-1} ABA were harvestable at about the same time as grapes treated with 300 µl l^{-1} ABA or ethephon, and grapes treated with either 150 µl l^{-1} ABA or ethephon were harvestable about 15 day before non-treated grapes. However, TSS, TA, and the ratio of TSS to TA differed among treatments. Grapes treated with 300 µl l^{-1} ABA were harvested at the lowest TSS, followed by grapes treated with 150 µl l^{-1} ABA, and grapes treated with ethephon or not treated. Grapes treated with 300 µl l^{-1} ABA or ethephon had the highest acidity (≈ 5.0 g l^{-1}) and the lowest TSS:TA ratio (Cantína *et al.*, 2007).

In 'Flame Seedless' 300 ml l^{-1} ABA applied at veraison was superior to the other ABA concentrations and to ethephon applied at any of the tested times. Moreover, any concentration of ABA between 75 and 300 mg l^{-1} applied after veraison improved colour better than ethephon applied at the same time (Peppi *et al.*, 2006), although the same rate in 'Red Globe' increased pigmentation and improved colour, it also caused fruit softening (Peppi *et al.*, 2007).

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