Gibberellic Acid Applied at Bloom Reduces Fruit Set and Improves Size of ‘Crimson Seedless’ Table Grapes

N.K. Dokoozlian¹

Department of Viticulture and Enology, University of California, Davis, and the University of California Kearney Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA 93648

W.L. Peacock

University of California Cooperative Extension, 2500 Burrell Avenue, Visalia, CA 93291

Additional index words. *Vitis vinifera*, plant growth regulators, fruit growth, flowering

Abstract. Excessive fruit set can reduce the quality of ‘Crimson Seedless’ table grapes (*Vitis vinifera* L.), resulting in compact, tightly filled clusters with small berries that are prone to bunch rot at harvest. Two separate studies were conducted to examine the effects of application timing and rate on the efficacy of GA₃ for berry thinning. In the first experiment, vines were treated with 2 g·ha⁻¹ GA₃ at one of the following stages of bloom: 1% to 5%; 20% to 30%; 50% to 60%; 80% to 90%; or 100% capfall (falling of the calyptra). The second experiment compared treatments of 0, 2.5, 6.25, 12.5, 18.75, or 25 g·ha⁻¹ GA₃ applied at ≈80% bloom. Fruit set (number of berries/cm shoulder length) was similar among vines treated between 1% to 5% and 100% bloom with 2 g·ha⁻¹ GA₃, although berry set was reduced relative to the control. However, applications made during the later stages of bloom significantly increased berry length and weight. Fruit set generally declined, and the number of shot berries per cluster increased, as the amount of GA₃ applied at bloom increased. Applications ≥6.25 g·ha⁻¹ GA₃ resulted in commercially unacceptable levels of shot berries, as well as significant reductions in cluster weight and packable yield per vine. The results indicate that a single application of 2.5 g·ha⁻¹ GA₃ near full bloom may be used to reduce fruit set and increase berry size of this cultivar without detrimental effects on packable yield or cluster number per vine the subsequent year. Chemical name used: gibberellic acid (GA₃).

‘Crimson Seedless’ is a late-ripening, red seedless table grape developed by the U.S. Dept. of Agriculture Horticultural Crops Research Laboratory at Fresno, Calif. (Ramming et al., 1995). ‘Crimson Seedless’ is currently the latest ripening seedless table grape grown in California, extending the availability of fresh fruit into the late fall. The cultivar has firm, crunchy berries and excellent flavor. However, inadequate color development and small berry size can detract from its quality. Excessive fruit set is also a problem in many commercial ‘Crimson Seedless’ vineyards, limiting potential berry growth and resulting in tightly-filled, compact clusters that are prone to bunch rot. Previous work indicated that some of these problems could be overcome with proper cultural practices (Dokoozlian et

al., 1995). For example, berry color can be improved by applying the plant growth regulator ethephon following fruit softening, while berry size can be increased by girdling the trunks at berry set. When fruit set is excessive, however, trunk girdling and other practices to improve berry size are less effective and may result in unacceptable cluster compactness. Methods to reduce the fruit set of ‘Crimson Seedless’ are therefore needed if these treatments are to be used successfully.

When applied during bloom, gibberellic acid (GA₃) reduces the fruit set of seedless table grape cultivars (Christodoulou et al., 1968; Lynn and Jensen, 1966; Weaver and Pool, 1971). However, optimum rates and treatment timings for berry thinning vary among cultivars (Jensen, 1994; Dokoozlian, 1998). For example, in California ‘Thompson Seedless’ is commonly treated with GA₃ twice during bloom. The first application is performed at 50% capfall, and the second at 85% capfall, at rates ranging from 30 to 40 g·ha⁻¹ GA₃ per application. In contrast, optimum berry thinning of ‘Ruby Seedless’ is achieved with a single application of 3 g·ha⁻¹ GA₃ at 90% to 100% capfall. Our preliminary work indicated that multiple applications of 30 to 40 g·ha⁻¹ GA₃ during bloom were phytotoxic to ‘Crimson Seedless’, resulting in excessive berry thinning, the formation of shot berries (small, round, seedless berries

that remain green at harvest) and severe reductions in the number of flower clusters per vine the following year. The purpose of this study was to determine the effect of lower rates of GA₃ applied during bloom on fruit set, berry growth, and yield components of ‘Crimson Seedless’ table grapes.

Materials and Methods

Vineyard and cultural practices. The experiments were conducted in 1993 and 1994 in an own-rooted, flood-irrigated commercial vineyard near Exeter, Calif. In 1989, vines were planted in a clay loam soil with north-south oriented rows, at a spacing of 3.6 m between rows and 2.4 m between vines within rows (plant density = 1121 vines/ha). Vines were trained to the quadrilateral cordon system, with fruiting zones spaced 60 cm apart and located 1.2 m above the ground. The ‘T’ trellis system consisted of 2.1 m stakes and a 0.9 m crossarm at each vine. Crossarms were attached to the top of the stakes, ≈45 cm above the cordons. Three foliage support wires were evenly spaced and attached to each crossarm. In both years, 28 two-bud spurs were retained on each vine at pruning, and each spur was thinned to two shoots following budbreak. In the first year of the trial, all vines were adjusted to 36 clusters following fruit set. In the second year, no adjustments were made so that yield data would reflect treatment effects on return fruitfulness. Girdles were applied to the vine trunk at fruit set (4- to 5-mm berry diameter) using a 6-mm girdling knife. Ethephon (250 g·ha⁻¹ applied in 900-L of spray solution per ha using a commercial sprayer) was applied at color-break (≈15% berry softening) to enhance color development.

Treatments and experimental design. Two separate experiments were conducted to examine the effects of application timing and rate on the efficacy of GA₃ applications at bloom. Uniform vines were selected for use in both experiments prior to bloom in 1993. The first experiment examined the effect of bloom stage on the efficacy of GA₃ applied for berry thinning. Vines received a single GA₃ application (2 g·ha⁻¹ GA₃, Pro-Gibb 4%; Abbott Laboratories, Chicago) at one of the following stages of bloom: 1% to 5%; 20% to 30%; 50% to 60%; 80% to 90%; or 100% (percentage of flowers open or capfall). A group of untreated vines served as controls. Application dates ranged from 1 May (1% to 5% bloom) to 10 May (100% bloom) in 1993 and 2 May (1% to 5% bloom) to 11 May (100% bloom) in 1994. The second experiment examined the effects of application rate; vines were treated with either 0, 2.5, 6.25, 12.5, 18.75, or 25 g·ha⁻¹ GA₃ at ≈80% bloom. Applications were made on 8 May and 10 May in 1993 and 1994, respectively. All applications were made using a hand-held spray wand and 1800 L·ha⁻¹ of spray solution. Control vines in both experiments were treated with water. The treatments in both experiments were replicated eight times using three-vine plots arranged in a randomized complete-block design. Treatments were repeated on the same vines in both years, with

Received for publication 29 June 2000. Accepted for publication 20 Nov. 2000. The technical assistance of J. Thomas, M. Moriyama, and J. Gutierrez is gratefully acknowledged. We thank the California Table Grape Commission for their financial support, as well as Cal Western Nursery, Visalia, Calif., for providing the grapevines used in this study. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

¹To whom requests for reprints should be addressed. E-mail address: nk dokoozlian@ucak.edu

the middle vine in each plot used for data collection.

Fruit analysis. The first four shoulders (proximal portions of cluster) from eight randomly selected clusters per vine (two clusters per cordon arm; total of 32 per vine) were selected at harvest from each vine used for data collection. The numbers of normal and shot (small, green, round, seedless) berries on each shoulder, as well as shoulder length, were recorded and used to calculate the number of berries/cm shoulder length. This parameter was used as an estimate of berry set and cluster compactness (Lynn and Jensen, 1966). One-hundred normal berries were removed at harvest from 16 randomly selected clusters (four clusters per cordon; about two berries from the top, middle and bottom regions of each cluster) on each vine. The berries were weighed, then placed in a trough with their equators gently touching, and the combined diameter was recorded. Combined berry length (with stylar and receptacle ends gently touching) was measured in a similar manner. These data were used to calculate mean berry diameter and length. The berries were then macerated in an electric blender, and the macerate was filtered and allowed to settle for 30 min. Aliquots of the clear juice were used to determine soluble solids and titratable acidity. Soluble solids were determined using a hand-held, temperature compensated, refractometer (American Optical, Buffalo, N.Y.). Titratable acidity was determined by titrating a 5-mL aliquot of juice with 0.1 N NaOH to a pH endpoint of 8.2 using an automatic titrator (Radiometer America, Westlake, Ohio).

Harvest. The experiments were harvested on 28 and 25 Oct. in 1993 and 1994, respectively. All clusters were removed from the sampled vines and assigned a visual quality grade (either packable or cull) based on commercial standards. Clusters were graded cull if quality defects exceeded 25% of total cluster weight, or the defect could not be removed by trimming. Cull defect categories were as follows: poor color, bunch rot, or excessive shot

berries and cluster deformation (cluster or rachis stem stiff and brittle; straggly, unfilled clusters). The weights of packable fruit and of the fruit in each cull category were recorded separately.

Statistics. Statistical analyses of all data were performed using analysis of variance and general linear modeling procedures in SAS (SAS Institute, Cary, N.C.).

Results and Discussion

Expt 1. The number of normal berries/cm shoulder length was similar for clusters treated with 2 g·ha⁻¹ GA₃ between 1% to 5% and 100% bloom (Table 1), set in both years being reduced an average of 20% (clusters treated at 1% to 5% bloom) to 27% (clusters treated at 100% bloom) compared to nontreated clusters. Mean shoulder length (data not presented), as well as shot berries/cm shoulder length, did not differ among the treatments. GA₃ applied during the latter stages of bloom (≥80% capfall) significantly increased berry length and weight in both years, but not berry diameter (mean berry diameter ≈ 17.5 mm; data not presented). GA₃ treatment increased soluble solids, but had no effect on mean cluster weight, total yield or cull yield per vine in either year (data not presented).

Expt 2. All rates of GA₃ significantly decreased the number of normal berries/cm shoulder length, with mean reductions over the 2 years ranging between 24% (2.5 g·ha⁻¹) and 57% (25 g·ha⁻¹) (Table 1). The number of shot berries/cm shoulder length increased significantly as the amount of GA₃ applied at bloom increased, while mean shoulder length was not affected (data not presented). In both years, the application of ≥6.25 g·ha⁻¹ GA₃ resulted in commercially unacceptable levels of shot berries (>0.2 shot berries/cm shoulder length) per cluster. GA₃ applications increased berry weight and length, with maximum berry size in both seasons obtained on vines treated with 2.5 and 6.25 g·ha⁻¹ GA₃. Increases in berry weight and length in vines treated with 2.5

g·ha⁻¹ GA₃ averaged 13% and 6%, respectively, over the 2 years. GA₃ applied at bloom had no effect on berry diameter (mean berry diameter ≈ 17.8 mm; data not presented), and little or no effect on fruit soluble solids. As a result of reduced berry set, as well as increases in the number of shot berries, GA₃ applications ≥6.25 g·ha⁻¹ significantly reduced mean cluster weight (Table 2). Despite reduced fruit set, cluster weight on vines treated with 2.5 g·ha⁻¹ GA₃ was not affected. This was attributed to increases in berry size as a result of GA₃ treatment.

Total and packable yield per vine declined sharply as GA₃ applied at fruit set increased from 0 to 18.75 g·ha⁻¹, then leveled off (Fig. 1A). In contrast, cull yield declined only gradually as GA₃ rate increased; the amount of fruit graded cull because of poor color and rot declined, while the number of clusters with excessive shot berries (Fig. 1B). Reductions in the amount of poorly colored and rotten fruit with increased GA₃ resulted from reduced cluster weights, and therefore crop loads, per vine. Packable yield declined from 16.3 kg per vine for the control to 5.5 kg for vines treated with 25 g·ha⁻¹ GA₃ in 1993. In 1994, packable yield per vine ranged between 13 kg for the control and 1.1 kg for vines treated with 25 g·ha⁻¹ GA₃. In 1993, all vines were adjusted to similar cluster numbers at fruit set, thus yield differences among treatments reflected current-year effects on fruit development (fruit set and berry weight). Yield differences in 1994 reflected current-year effects on fruit development, as well as carry-over effects on vine fruitfulness (cluster number per vine and cluster size) from applications made the previous year. Previous work has shown that GA₃ applied to grapevines in the spring and early summer can reduce both cluster number and cluster size the following year (Weaver and McCune, 1961). Cluster number per vine in both 1994 and 1995 was significantly reduced when ≥6.25 g·ha⁻¹ GA₃ was applied at bloom the previous year (Table 2).

During the 2 years of this study, 2.5 g·ha⁻¹

Table 1. Influence of GA₃ application timing and rate during bloom of the fruit set, berry size, and soluble solids of 'Crimson Seedless' table grapes.

Timing on rate of GA ₃ application	1993					1994				
	Berries/cm shoulder length		Wt (g)	Length (mm)	Soluble solids (°Brix)	Berries/cm shoulder length		Wt (g)	Length (mm)	Soluble solids (°Brix)
	Normal	Shot				Normal	Shot			
<i>Expt. 1</i>										
Mean flowers open per cluster (%) ^z										
Nontreated	2.4 ^y	0.2 a	4.1 c	22.1 c	18.6 a	2.3 a	0.1 a	4.5 c	21.8 d	19.2 a
1–5	2.0 b	0.2 a	4.4 ab	22.0 cd	18.0 b	1.8 b	0.2 a	4.8 b	22.3 c	18.5 b
20–30	1.9 b	0.3 a	4.3 bc	22.1 c	17.9 b	1.7 b	0.1 a	4.9 b	22.4 c	18.6 b
50–60	1.9 b	0.2 a	4.3 bc	22.4 bc	18.1 b	1.7 b	0.1 a	5.0 ab	22.6 bc	18.4 b
80–90	2.0 b	0.2 a	4.6 a	22.6 ab	18.2 b	1.6 b	0.2 a	5.2 a	22.8 ab	18.4 b
100	1.8 b	0.3 a	4.6 a	22.8 a	17.9 b	1.6 b	0.1 a	5.2 a	23.0 a	18.5 b
<i>Expt. 2</i>										
GA ₃ (g·ha ⁻¹)										
0	2.7 a	0.1 d	4.8 c	25.0 c	19.9 b	2.4 a	0.2 c	5.0 c	23.8 c	20.2 a
2.50	2.1 b	0.2 d	5.4 a	26.3 a	20.2 ab	1.8 b	0.1 c	5.6 a	25.6 a	20.1 a
6.25	1.9 bc	0.5 c	5.3 a	26.0 a	20.3 a	1.6 bc	0.4 b	5.7 a	25.6 a	20.1 a
12.50	1.8 c	0.9 b	5.2 ab	26.1 a	20.3 a	1.5 c	0.5 b	5.4 b	25.4 a	20.2 a
18.75	1.4 d	1.1 b	5.1 b	25.6 b	20.4 a	1.1 d	0.8 a	5.3 b	25.2 b	20.3 a
25.0	1.1 e	1.7 a	5.1 b	25.6 b	20.5 a	1.1 d	0.9 a	5.3 b	25.1 b	20.3 a

¹Vines treated with 2 g·ha⁻¹ GA₃.

²Mean separation within columns and experiments by Duncan's multiple range test, $P \leq 0.05$.

³Applied at 80% bloom.

Table 2. Influence of GA₃ applied at 80% bloom on the average cluster weight (1993–94) and return fruitfulness (1994–95) of ‘Crimson Seedless’ table grapes.

GA ₃ (g·ha ⁻¹)	Mean cluster wt (g)		Cluster no./vine the year following GA ₃ application	
	1993	1994	1994	1995
0.0	528 a ^z	503 a	40 a	50 a
2.5	475 a	442 a	44 a	48 a
6.25	388 b	378 b	31 b	40 b
12.5	264 c	369 b	28 b	38 b
18.75	258 c	228 c	23 c	28 c
25.00	226 d	218 c	18 d	30 c

^zMean separation within columns and experiments by Duncan’s multiple range test, $P \leq 0.05$.

GA₃ applied at 80% bloom reduced the number of berries/cm shoulder length $\approx 24\%$. This reduction is similar to that reported for GA₃-mediated berry thinning on other seedless cultivars, although specific rate responses vary (Chaturvedi and Khanduia, 1979; Christodoulou et al., 1968; Dokoozlian, 1998; Lynn and Jensen, 1966; Weaver and Pool, 1971). Christodoulou et al. (1968) reported that ≈ 12 to 90 g·ha^{-1} GA₃ applied at bloom had similar effects on the fruit set of ‘Thompson Seedless’, reducing the number of berries/cm shoulder length $\approx 25\%$. Similar levels of berry thinning (20% to 25% reduction in the number of berries/cm shoulder length) have been obtained on ‘Flame Seedless’ with 5 to 20 g·ha^{-1} GA₃ and for ‘Autumn Royal’ using 2 g·ha^{-1} GA₃ (Dokoozlian, 1998). Seedless cultivars also vary in their susceptibility to shot berries as a result of GA₃ applications. In this study, bloom applications $\geq 6.25 \text{ g·ha}^{-1}$ GA₃ resulted in unacceptable numbers of shot berries in ‘Crimson Seedless’ clusters. In contrast, bloom applications ranging from 10 to 100 g·ha^{-1} GA₃ did not increase the number of shot berries per cluster in ‘Thompson Seedless’ (Christodoulou et al., 1968; Lynn and Jensen, 1966) or ‘Flame Seedless’ (Dokoozlian, 1998). Note that while bloom applications ranging from 20 to 100 g·ha^{-1} GA₃ had relatively minor effects on the return fruitfulness of ‘Thompson Seedless’ and ‘Flame Seedless’ (Dokoozlian, 1998), applications $\geq 6.25 \text{ g·ha}^{-1}$ GA₃ severely reduced the number of clusters per vine on ‘Crimson Seedless’. These differences illustrate the need to fully characterize the responses of individual seedless table grape cultivars to GA₃ applications before commercial recommendations are made.

Although time of treatment had no significant effect on the amount of berry thinning, GA₃ probably should be applied to ‘Crimson Seedless’ during the later stages of bloom in order to obtain maximum increase in berry size. These results are in agreement with previous work on ‘Thompson Seedless’, which showed that similar levels of berry thinning were achieved when GA₃ was applied between 0% and 75% bloom (Christodoulou et al., 1968). Christodoulou et al. (1968) also reported that applications made during the later stages of bloom were more effective for increasing berry size, and particularly berry length, than those made earlier. Similar results were found in this study. Previous work on

Fig.1. Influence of GA₃ applied at 80% bloom on the (A) total, packable, and cull yield and (B) cull yield components of ‘Crimson Seedless’ grapevines. Open and closed symbols indicate data from 1993 and 1994, respectively. Each data point represents the mean of eight, three-vine replicates for each treatment; points were fitted to the following equations: A: total yield: $y = 20.295 - 1.184x + 21.03 - 0.01x^2$, $r^2 = 0.9164$; packable yield: $y = 14.646 - 0.981x + 0.021x^2$, $r^2 = 0.854$; cull yield: $y = 5.65 - 0.203x + 4.265x^2$, $r^2 = 0.583$. B: $y = 4.103 - 0.356x + 8.333x^2$, $r^2 = 0.772$; shot berries: $y = 0.081 + 0.232x - 5.312x^2$, $r^2 = 0.855$; rot: $y = 1.463 - 0.0783x + 1.244x^2$, $r^2 = 0.827$.

‘Crimson Seedless’ indicated that trunk girdling at fruit set increased berry weight over 30% (Dokoozlian et al., 1995). All vines used in this study were girdled at fruit set, thus the optimum GA₃ treatment at bloom increased berry weight an additional 13% over girdling alone (experimental control).

Based on the results of this study, a single application of 2.5 g·ha^{-1} applied at 80% to 100% bloom is recommended for berry thinning ‘Crimson Seedless’ table grapes. This treatment significantly reduced berry set and increased berry weight and length, but did not reduce cluster weight, packable yield, or cluster number per vine the following year. It also eliminated the need for manual berry thinning (Jensen, 1994), a labor-intensive practice used to reduced cluster compactness, which may cost up to \$1000/ha in California. Based on current prices in California, the cost per hect-

are of GA₃ for this application is $\approx \$2.50$. Since optimum berry thinning and maximum berry size were obtained with relatively low rates of GA₃ applied during the later stages of bloom, a single bloom application, rather than multiple applications as commonly practiced for other seedless table grape cultivars (Dokoozlian, 1998), is recommended for ‘Crimson Seedless’. Multiple GA₃ applications during bloom increase the potential for excessive berry thinning and shot berry formation in this cultivar (Dokoozlian, 1998). Single applications $\geq 6.25 \text{ g·ha}^{-1}$ GA₃ at bloom also resulted in loose, straggly clusters with excessive numbers of shot berries in this study. These treatments resulted in stiff and deformed rachis stems, increased the propensity for berry shatter during harvest (Christodoulou et al., 1968), and reduced vine fruitfulness the following year.

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