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Optimal cluster threshold for improving yield and berry quality attributes of 'Alborz' table grape in the inland Pacific Northwest U.S.A.

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Abstract

Cluster management in table grapes is an essential cultural practice for production of high quality table grapes and this has not been studied in the Intermountain northwest region of the USA. Thus, the objective of this project was to determine the optimal cluster threshold for improving yield and berry quality attributes of 'Alborz' table grape in the inland Pacific Northwest United States during 2010 through 2012. Non-thinned control vines had 71 clusters in 2010 but had 39 and 40 during 2011 and 2012, respectively. Clusters in non-thinned control vines were longer but lighter than those in the other treatments. Berries in the non-thinned control vines were always lighter in weight and smaller in size than those in the other treatments. Berries from vines with 28 clusters tended to have more uniform red color with lower overall green color while those from non-thinned control had more green color. Vines with 20 and 28 clusters tended to have greater soluble solids concentration (SSC) but those in non-thinned control and with 36 clusters had lower SSC. Overall, the cumulative yields of non-thinned control vines were similar to those with 36 clusters during two out of three years. Considering all quality attributes, between 28 and 36 clusters per vine was the optimal number for production and quality attributes.

Key words: Alternative fruit, berry size, cool region grape, crop load, grape adaptation

Introduction

Table grape is one of the most important fruit crops for many regions and even at a small scale, would fit perfectly in the operation of any wine grape and tree fruit grower in the Intermountain West region, U.S.A., which includes Washington, Idaho, Utah, Colorado, and Oregon. Table grapes in this region are harvested when most of the fresh table grapes in California are either finished or are only available in storages.

Table grapes can either be grown as a major commercial fruit crop or as an alternative fruit in a new region. As the world population grows and people of different cultural and ethnic backgrounds gather and live in a new region or city, the demand for diversification of fruits and vegetables increases to meet the needs of this new demography. Among all traditional or alternative fruit crops, table grapes are always popular because of their health benefits. Adaptation and production of table grape beyond California would reduce the cost of transportation and create a niche market (Fallahi *et al.,* 2001; Fallahi, 2006).

In the United States, various viticultural and berry sensory characteristics are well documented in California where *Vitis vinifera* is widely grown (Nelson, 1985; Nelson *et al.,* 1973; Weaver, 1976). However, despite the importance of table grapes as an alternative fruit, berry characteristics and cultural practices are less studied in other states such as Idaho (Fallahi *et al.,* 1995, 2001; Fallahi, 2006), Ohio (Cahoon *et al.,* 1985), Florida (Mortensen and Balerdi, 1974; Mortensen and Harris, 1988); and Western Oregon (Hemphill *et al.*, 1992).

Grape cluster management is a form of crop thinning that is achieved by complete removal and/or shortening of the cluster at flower or after fruit set. Crop thinning allows growers to modify vine balance (vegetative growth to fruit ratio). Cluster removal in wine grapes is often practiced in cool wine-growing regions (with low heat units) to reduce the crop load and allow certain cultivars with excessive crop to produce sufficient sugar content (Fallahi *et al.*, 2008; Skinkis, 2017). The intensity of crop thinning is highly dependent on the cultivar, vine health, and climate (Skinkis, 2017). Some cultivars may require annual crop thinning to maintain adequate vine strength.

Climatic conditions in the regions where table grapes are produced as a new crop could be significantly different than those areas where this crop has been grown for many years. Fluctuations of temperatures and the length of frost-free season play extremely important roles in the acclimation and productivity of vines in any region. Thus, similar to the situation of wine production in the cool regions, table grape crop thinning often needs to be practiced to improve berry size and marketability (Cirami *et al.*, 1992). Also, other cultural practices, including the design and architecture of the vine may need to be drastically different in order to have a sustainable production.

During the past 27 years, the University of Idaho Pomology and Viticulture Program has experimented with several new fruit crops and as a result, a new alternative fruit industry, consisting of different cultivars of table grapes, is emerging in Idaho. The goal of this research was to determine the optimal cluster threshold

for improving yield and berry quality attributes of 'Alborz' table grape in the inland Pacific Northwest United States.

Materials and methods

General description of the experimental vineyard: The field trial was conducted at the University of Idaho Parma Research and Extension Center, near Parma Idaho, USA. The experimental site was located at 43.8° N latitude, 116.9° W longitude, and 673 m elevation above sea level, with an annual precipitation of about 297 mm and a sandy loam soil of pH ~ 7.3. About 70 days before planting the grapevines, the ground was prepared and fumigated with Toluene 2. A drip irrigation system was installed, and vines were irrigated according to the ETc information provided from the Agrimet Weather Station at the University of Idaho Parma Research and Extension Center.

Dormant cuttings of 'Alborz' (a mutation of 'Flame seedless') were gathered from the University of Idaho vineyards, propagated as self-rooted plants, and planted at 1.8 x 2.7 m in the spring of 2003. The vines were trained into bilateral cordon canopy system. General cultural practices were similar to the guidelines established in California but modified to suit the local growth cycle and conditions (Fallahi *et al.*, 2011). Vines were sprayed with gibberellic acid (GA) three times, each time at 50 mg L^{-1} at the rate of 1817 L.ha^{-1}. The first spray was made at the beginning of fruit set (berries at about 4 mm) between June 12 and June 18 and the second and third GA sprays were applied at a weekly interval after the first spray each year.

The experiment started and data were collected when vines were completely mature in 2010, 2011, and 2012. Treatments consisted of non-thinned control, and vines thinned to 20, 28, and 36 clusters per vine, respectively in mid- June from 2010 through 2012.

Eight spurs on each arm were trained to have 3-bud shoots between March 1 and March 20th every year. Four treatments were established between June 12 and June 18 each year as follows: 1) control: no cluster was removed or tipped; 2) Only 10 clusters per arm (20 clusters per vine) remained on the vine; 3) 14 clusters per arm (28 clusters per vine) remained on the vine; 4) 18 clusters per arm (36 clusters per vine) remained on the vine. One-third from the tip of each cluster in treatments 2, 3, and 4 were cut at the time of fruit set.

Vine survival after each winter was monitored, and cold tolerance of each grape was determined. Table grape fruit quality attributes, including berry size, color, berry skin characteristics, and cluster length and weight at harvest were measured according

to the procedures described by Fallahi *et al.* (2011). Skin color was visually ranked on a scale of 1 = greenish or poor red, progressively to 5 = 100 %, most uniform and deep red. Time of harvest was judged by the relative development of red color and when soluble solids concentration (SSC) in different treatments reached or slightly exceeded 18 °Brix. If needed, a portion of grapes was harvested in a second harvest. Dates for the first and second (if applied) harvests were 9-17-2010 and 9-24-2010; 9-8-2011; 9-9-12 and 9-15-12.

Approximately the same number of berries from each cluster of each vine was sampled to make a 50-composit sample. Average berry diameter on these 50 berries was measured, using a digital caliper (Steel Digital Caliper, Garrett Wade, Cincinnati, OH). These berries were weighed to calculate the average berry weight. The composite berries were subsequently crushed with a fruit compressor (manufactured in our laboratory) and SSC of the extracted juice was measured using a temperature-compensated refractometer (Atago N1, Tokyo, Japan).

Experimental designs and statistics: The experiment was arranged based on a completely randomized design in each of the three years. There were six blocks, each with a single vine. The assumption of normal data distribution was checked by performing univariant analyses for all vines.

Analyses of variance were conducted using SAS (2007), with PROC GLM and means separated using Fisher's Protected Least Significant Difference (LSD) at $P \leq 0.05$.

Results and discussion

Year-treatment interactions: There was no year-treatment interaction for any of the yield or quality attributes measured in this study. Therefore, in addition to the effect of each treatment per year, influence of treatments on the pooled values over all years are also reported in Tables 1-5.

Effects on cluster weight and length: Our goal in this study was to create four treatments, each with 20, 28, 36, or unknown (non-thinned) clusters per vine per year. Table 1 shows that with the small exception to the 36 clusters per vine, we were quite successful in achieving the targeted numbers. On average, we could create only 34 clusters per vine rather than the targeted number of 36 cluster (Table 1). Non-thinned control vines had 71 clusters in 2010 but had 39 and 40 during 2011 and 2012, respectively. Non-thinned control vines had a greater number of clusters in 2010 than in 2011 and 2012 perhaps due to freezing temperatures in 2011 and 2012.

Table 1. Effect of cluster management on cluster number, weight, and length in 'Alborz' table grape during 2010-2012

Treatment	Cluster number				Cluster weight (g)				Cluster length (cm)			
	2010	2011	2012	All Years	2010	2011	2012	All Years	2010	2011	2012	All Years
Control	71 a^z	39 a	40 a	150 a	663 b	402 b	589 a	536 b	17.0 a	29 a	28 a	26 a
20 Clusters per vine	19 c	19 c	20 c	58 c	870 a	627 a	686 a	728 a	16.8 a	20 b	21 b	18 b
28 Clusters per vine	28 bc	28 b	28 bc	83 b	1003 a	540 ab	618 a	720 a	16.9 a	20 b	22 b	18 b
36 Clusters per vine	34 b	35 a	34 ab	103 b	820 ab	498 ab	624 a	648 ab	16.8 a	21 b	21 b	19 b

^{z} Values within each column followed by different letters are significantly different using Fisher LSD, at 5 % level. There were 6 single-vine replications for each value in each year.

Clusters in non-thinned control vines were longer but lighter than those in the other treatments because they were not shortened. However, differences were not always significant (Table 1). Differences were more pronounced when values were pooled over three years.

According to Winkler *et al.* (1974), retention of 80 to 100 berries per cluster will suffice to produce clusters of 454 to 681 g. In our study, cluster weight in all treatments varied between 498 to 1003 g. In particular, when each vine was thinned down to 28 clusters per vine, the average cluster weight varied between 1003 g (in 2010) and 540 g (in 2011), which exceed Winkler's recommendation. This observation indicates that with the proper cluster thinning, GA applications, and frost prevention, we can produce commercially profitable table grapes in the inland Pacific Northwest region.

Berry weight and size: Berries in the non-thinned control vines were always lighter in weight and smaller in size than those in the other treatments (Table 2). There is a strong linear correlation between berry weight, diameter, and length as observed in one of our previous studies (un-published data) which was also confirmed by an earlier study on 'Flame Seedless' in California (Peacock and Simpson, 2017). Based on that study, an average berry size of 3.5 g would have about 17 mm (11/16 inches) diameter in 'Flame seedless' (Peacock and Simpson, 2017).

Growers and retailers usually characterize berries by diameter or length rather than berry weight. For example, they would describe a box of 'Flame seedless' as having berries mostly 17 mm (11/16 inch) in diameter rather than as having mostly 3.5 g berries. In our study, berries in all treatments had a larger size than 17 mm diameter and higher than 3.59 gram weight (Table 2), and thus puts Idaho-grown grape berries well into the category of acceptable California standards. Nevertheless, market pays a higher price for the 'Flame seedless' berries that average heavier than 4 g (Peacock and Simpson, 2017). This observation underscores the importance of cluster thinning.

Berry color and soluble solids concentration: Vines with 28 clusters tended to have better berry color while those of non-thinned control had lower color (Table 3). Vines with 20 and 28 clusters tended to have greater SSC but those in non-thinned control and with 36 clusters had lower SSC. Vines with 28 clusters per vine had significantly lower percentage of "green" berries than those in control. This indicates that thinning to 28 clusters per vine should be an optimal threshold for berry color development.

Yield: Yield in all treatments were lower in 2011 than those in 2010 or 2012 (Table 4). Minimum temperatures in the winter of 2009-10 and 2011-12 were higher than -15 °C but the minimum temperature in the winter of 2010-2011 was about -18 °C leading to lower yield in that season. During 2010 and 2012, a majority

Table 2. Effect of cluster management on berry weight and size in 'Alborz' table grape during 2010-2012

Treatment	Average berry weight (g)				Average berry size (mm)			
	2010	2011	2012	All Years	2010	2011	2012	All Years
Control	3.64 b[z]	3.59 b	4.11 b	3.82 b	16.6 b	18.4 b	17.4 b	17.4 b
20 Clusters per vine	3.75 a	4.15 a	5.16 a	4.36 a	17.1 a	20.4 a	18.9 a	18.8 a
28 Clusters per vine	3.86 a	4.00 a	5.03 a	4.29 a	17.2 a	19.5 ab	18.7 a	18.5 a
36 Clusters per vine	3.97 a	3.84 a	4.76 ab	4.19 a	17.1 a	19.3 ab	18.4 ab	18.2 ab

[z] Values within each column followed by different letters are significantly different using Fisher LSD, at 5 % level. There were 6 single-vine replications for each value in each year.

Table 3. Effect of cluster management on berry color and soluble solids concentration in 'Alborz' table grape during 2010-2012

Treatment	Color (1-5)				Green (%)	Soluble solids concentration (%)			
	2010	2011	2012	All Years	2012	2010	2011	2012	All Years
Control	3.3 b[z]	3.3 b	3.7 b	3.5 c	35.0 a	18.9 b	18.6 b	18.8 b	18.8 b
20 Clusters per vine	3.6 ab	4.3 a	4.1 a	4.0 ab	17.3 ab	20.1 a	19.5 ab	20.4 a	20.0 a
28 Clusters per vine	4.0 a	4.4 a	4.1 a	4.2 a	9.3 b	20.3 a	19.9 a	19.6 ab	19.9 a
36 Clusters per vine	3.7 ab	4.0 a	3.9 ab	3.9 b	18.0 ab	20.1 a	19.1 ab	18.6 b	19.3 ab

[z] Values within each column followed by different letters are significantly different using Fisher LSD, at 5 % level. There were 6 single-vine replications for each value in each year.

Table 4. Effect of cluster management on yield in 'Alborz' table grape during 2010-2012

Treatment	2010 yield (kg/vine)			2011 yield (kg/vine)		2012 yield (kg/vine)			Three-year cumulative yield	
	1st har.	2nd har.	Total	1st har.	Total	1st har.	2nd har.	Total	(kg/vine)	(t.ha⁻¹)
Control	2.6 b[z]	27.4 a	29.6 a	13.3 b	13.3 b	9.5 a	10.1 a	19.6 a	62.5 a	124.4 a
20 Clusters per vine	9.2 ab	8.1 b	14.6 c	12.3 b	12.3 b	11.6 a	2.5 a	13.3 b	40.2 b	80.0 b
28 Clusters per vine	10.1 a	11.9 b	20.0 b	14.5 ab	14.5 ab	13.4 a	3.2 a	15.5 ab	50.1 b	99.7 b
36 Clusters per vine	11.9 a	13.9 b	25.8 a	17.9 a	17.9 a	11.6 a	8.9 a	20.5 a	64.2 a	127.8 a

[z] Values within each column followed by different letters are significantly different using Fisher LSD, at 5 % level. There were 6 single-vine replications for each value in each year.

of the clusters of the non-thinned control vines were harvested during the second harvest because the berries did not have sufficient color during the first harvest (Table 3). Overall, the cumulative yields of non-thinned control vines were similar to those with 36 clusters during two out of three years (Table 4). In 'Tokay' grapes, quality of berries were improved when moderate pruning was accompanied by appropriate thinning (Winkler *et al.*, 1974) which is consistent with our results.

Considering all quality attributes, it seems that between 28 and 36 clusters per vine is the threshold for production factors. Removal of clusters down to 10 clusters per arm (20 clusters/vine) and shortening of about 33 % from the tip of the remaining clusters would lead to good berry size and packable cluster size in 'Alborz' table grape. However, keeping between 28 and 36 clusters per vine is the optimal threshold for production and fruit quality attributes. Leaving greater than these numbers of clusters per vine may slightly increase the yield but will likely lead to a decline in berry weight, size, color, and soluble solids concentration.

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