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EFFECT OF BUNCH LOAD ON THE QUALITY OF CARDINAL GRAPE VARIETY

SUMMARY

Our research aims to evaluate the effect of bunch load variation per unit area on the quality of Cardinal table grape variety. The experiments were carried out during three vegetation seasons (2014 – 2016) on Cardinal grape variety grown on pergola training system, with a planting distance of 2.5 m x 2.5 m, in Gevgelija-Valandovo vine growing region, the Republic of Macedonia. After the blooming phenophase, the number of bunches (crop load) was reduced. Three bunch thinning variants were applied: V_1 (thinning to 3 bunches/m^2), V_2 (thinning to 4 bunches/m^2) and V_3 (thinning to 5 bunches/m^2). They were then compared with the standard (S_T) where no thinning of bunches was applied.

Research results show that bunch load in Cardinal variety has a significant impact on bunch and berry mass, transportability, maturation dynamics and packed grape quantity and that the V_1 variant, with the lowest bunch density per m^2, has the largest individual bunch and berry mass (502.3 g and 8.83 g respectively), while the S_T variant yielded the smallest bunch and berry mass (451.7 g and 7.93 g respectively). We got similar results on grape transportability marked by berry firmness and berry adherence strength. The largest quantity of total harvested grapes was obtained in the V_3 (2.22 kg/m^2) and S_T (2.19 kg/m^2) variants, while the smallest quantity of total harvested grapes (1.47 kg/m^2) was obtained in the V_1 variant. The largest quantity of packed grapes (1.87 kg/m^2) was obtained in the V_2 variant, and the smallest in the V_1 variant (1.44 kg/m^2).

Keywords: table grapes, bunch thinning, bunch mass, berry mass, quantity of packed grapes

INTRODUCTION

Cardinal is a well-known table grape variety, common in all major table grape producing regions. It is a leading, very early maturing table grape variety in

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Macedonia. It is quite popular and sought after on the market, however, its production is specific. Millerandage and coulure are common. Ampelotechnical practices, mainly pinching and bunch thinning, are necessary to prevent these side effects (Bozinovic, 2010). Excessive load often results in delayed and uneven bunch maturation on the vine (Prculovski, 2019).

Summer pruning technique has a significant effect on yield and fruit quality in table grape production. It improves the microclimate in the canopy, ensures good and timely grape maturation and creates less suitable conditions for the development of pathogens (Di Lorenzo et al., 2011). By using canopy management techniques, we can influence the position and amount of leaves, shoots and fruits in order to obtain a desirable arrangement in the space and to reduce excessive shading and overloading the vine with bunches (Dry, 2000). The most significant techniques used during summer pruning are: shoot and bunch pinching, which affect the distribution of photoassimilates between leaves and bunches (Mota et al, 2010); defoliation, which regulates the air temperature, solar radiation frequency, and improvement of grape colour and maturation (Mandelli et al, 2003); and finally, bunch thinning, which regulates yield and improves grape maturation and quality (Prculovski, 2019).

The effect of these practices depends on several factors, such as the timing of implementation, its intensity, and so on. Excessive pinching or excessive shoot and bunch thinning can lead to crop yield and fruit quality reduction (Dardeniz et al., 2008). At the moment, we can find a lot of data on the effect of the timing and the bunch pinching method on yield and fruit quality in a large number of table grape varieties (Dardeniz, 2014; Akin and Coban, 2016 etc.), but there is insufficient data on the bunch thinning method and its effect on the production and technological characteristics of the grapes. The aim of our study is to determine the impact of the applied bunch thinning, which is to determine the ideal load for Cardinal variety under the conditions of the Gevgelija - Valandovo vineyard in order to obtain the largest possible quantity of extra-grade grapes without prolonging the maturity time.

MATERIAL AND METHODS

Our trial was carried out at the production plantations of "VV Vizba Valandovo," Valandovo locality of Gevgelija -Valandovo vine growing region. The research was conducted in three consecutive years, from 2014 to 2016, on Cardinal variety, grown on pergola training system with a planting distance of 2.5 m x 2.5 m. The plantations are 15 years old and are in full fruiting. Three bunch thinning variants were used, as follows:

1. V_1 – leaving 3 bunches per m^2
2. V_2 – leaving 4 bunches per m^2, and
3. V_3 – leaving 5 bunches per m^2.

Comparisons were made with the standard (S_T), in which all ampelotechnical practices were implemented, except bunch thinning, so in standard (St) variant all clusters remained.

Proper pruning, which means leaving four canes with six buds and two spurs with two buds per vine, and agrotechnical and ampelotechnical practices were implemented uniformly for each of the above variants, including the standard. Crop (bunch) load was reduced 7-14 days after blooming phenophase. The effect of bunch thinning on crop yield, harvest dynamics, bunch and berry mechanical composition and properties, quantity of packed grapes, and sugar and acid content was studied. Grapes were harvested twice. The first harvest took place when most bunches exceeded 15^{o} Brix. The second harvest took place after 10 days and the grapes that were not mature sufficiently or did not meet packing requirements were classified as residue.

Both bunch and berry mechanical composition, specifically bunch and berry average mass (g), and bunch and berry mechanical properties, in terms of berry firmness (g/cm^2) and berry adherence strength (g/berry), were examined. Total yield was set in two categories: packed grapes (kg/m^2) and residue (kg/m^2). The packed grapes quantities of the first and the second harvest (kg/m^2) depended on the harvesting dynamics. Regarding the chemical composition of the grapes, the content of sugars and total acids were analysed.

Mean values, standard deviation, and coefficient of variation were calculated based on the results. Analysis of variance (ANOVA) was applied to test our hypotheses while the mean values were compared using the LSD test.

RESULTS AND DISCUSSION

Based on the results and their analysis, it can be confirmed that the number of bunches left per vine influences the production and technological potential of Cardinal variety. The highest average bunch and berry mass for the years studied was recorded in the V_1 variant, where 11% higher bunch and berry mass was recorded compared to the standard (Tab. 1). In the V_2 variant, bunch mass increased by 10% while berry mass increased by 6% compared to the standard. In the V_3 variant, an increase of 3% in bunch mass and 2% in berry mass was recorded and the results showed a statistically insignificant difference compared with the bunch and berry mass of the standard variant.

Studying the effects of bunch thinning on bunch and berry mass in Seyval Blanc, Berkey et al. (2011) found that the impact of these treatments differed between years probably due to the influence of the management of a previous cycle on the subsequent ones, identifying bunch management in the previous production cycles as the cause. The effect of this practice is evident in several studies across the varieties which pointed to increases in bunch and berry mass when smaller bunch densities per plant are adopted (Ivanišević et al., 2020; Karoglan et al., 2014; Bubola et al., 2011; Kavoosi et al., 2009; Somkuwar and Ramteke, 2010; Gil et al., 2013). This is due to the greater availability of photoassimilates directed to bunches in vines with lower bunch density. Thinning intensity, however, should be suitable for the growing conditions and cultivar characteristics, as high bunch thinning intensity may reduce yield (Fanzone et al., 2011; Avizcuri-Inac et al., 2013).

Table 1. Cardinal variety bunch and berry mass

	Bunch mass Variant				**Berry mass** Variant			
Year	S_T	V_1	V_2	V_3	S_T	V_1	V_2	V_3
2014	479,0	528,0	519,0	508,0	8,9	9,6	9,3	9,1
2015	484,0	536,0	528,0	485,0	8,3	9,2	8,8	8,4
2016	392,0	443,0	439,0	407,0	6,6	7,7	7,2	6,8
Mean $\bar{x}$	451,7a	502,3b	495,3b	466,7	7,93	8,83	8,42	8,11
Index	100	111	110	103	100	111	106	102
SD	51,7	51,5	49,0	52,9	1,21	1,02	1,10	1,16
CV	11,5	10,3	9,9	11,3	15,3	11,6	13,1	14,3
LSD 0.05	15,50				0,20			
0.01	23,48				0,30			

*Significant deviation at p = 0.05 level against the standard for the property
The values in each column, marked with different letters, differ significantly from each other at the p = 0.05 level

Regarding the bunch and berry mechanical property, as an important segment on which the transportability and the storability of table grapes depend, we investigated the berry firmness and berry adherence strength. Table 2 shows the data from the three-year trials in relation to these two parameters in all variants tested.

The berry firmness ranged from 1536 g/cm^2 in the standard variant to 1800 g/cm^2 in the V_1 variant, which is 17% higher than the standard. The average berry firmness during the trial in the V_2 variant was 1670 g/cm^2, which is 9% higher than in the S_T variant, while in the V_3 variant we found that the berry firmness was 1563 g/cm^2, which is 2 % higher than the standard.

The berry adherence strength ranged from 405 g/berry in the standard variant to 460 g/berry in the V_1 variant. The V_2 variant had an average berry adherence strength of 441 g/berry, while the V_3 variant had an average berry adherence strength of 419 g/berry. The percentage increase in the berry adherence strength of the variants compared to the standard (S_T) ranged from 3% (V_3) to 14% (V_1).

In our study, a statistically significant difference at the p = 0.05 level in both the berry firmness and berry adherence strength was only observed in the V_1 variant compared to the S_T variants. We determined that the berry firmness and berry adherence strength of all studied variants of Cardinal variety are within varietal characteristics, which was confirmed by the studies of several authors in the region and they range from 1.400 to 1.800 g per berry firmness and 300-600 g per berry adherence srength (Roičev, 2012; Bozinovik et al., 2010; Žunić and Garić., 2017). Perez et al. (1998) reported in their study that lower bunch density per vine may lead to greater berry firmness.

Table 2. Cardinal variety bunch and berry mechanical properties

		Variant				Index			
	Year	S_T	V_1	V_2	V_3	S_T	V_1	V_2	V_3
Berry firmness	2014	1 610	1 820	1 710	1 640				
	2015	1 600	1 900	1 800	1 650				
	2016	1 400	1 680	1 500	1 400				
	x̄	1 536a	1 800b	1 670ab	1 563ab	100	117	109	102
	SD	118,5	111,4	153,9	141,5				
	CV	7,7	6,2	9,2	9,1				
Berry adherence strength	2014	410	456	433	423				
	2015	430	530	500	450				
	2016	375	393	391	385				
	x̄	405a	460b	441ab	419a	100	114	109	103
	SD	27,8	68,6	55,0	32,7				
	CV	6,9	14,9	12,5	7,8				

**Significant deviation at p = 0.05 level against the standard for the property.*
The values in each column, marked with different letters, differ significantly from each other at the p = 0.05 level

According to them, lower bunch density provides greater availability of carbohydrates and other molecules and certain minerals that, when incorporated into the berry cell walls, give the berries greater firmness. On the other hand, De Souza Leão and Coelho De Lima (2017) found no relationship between bunch density and berry firmness.

Certain differences between variants were found in the sugar and acid content. The sugar content (figure 1) ranged from 160 g/l in the S_T variant to 170 g/l in the V_1 variant. Statistically significant differences compared to the standard variant were detected in both V_1 and V_2 variants, where the sugar content was higher by 6% and 3% respectively compared to the standard.

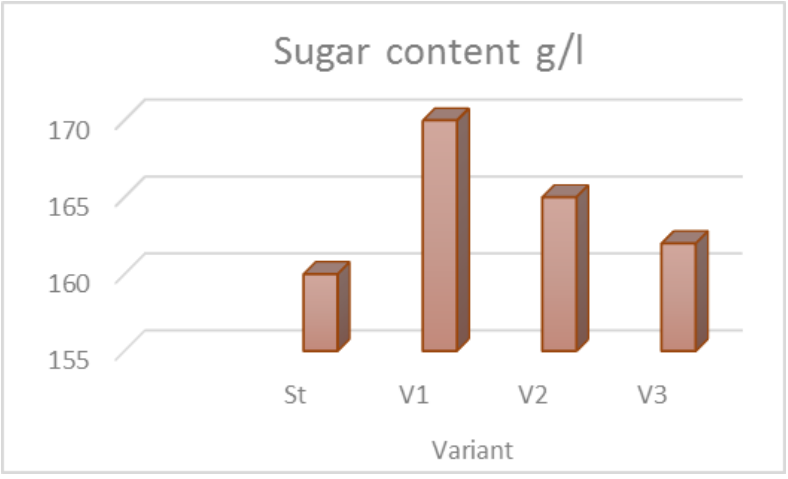

Figure 1. Sugar content by variants in cardinal varieties

The acid content was very variable, changing from year to year, in all variants. It varied from 5.46 g/l in the S_T variant to 6.11 g/l in the V_3 variant (graph 2), and no correlation was observed between the bunch thinning and total acid content.

According to international standards, the minimal sugar concentration in table grapes may vary from 14.0 to 17.5 °Brix depending on the variety (Maia et al., 2014). The sugar and acid contents, as components directly affecting the quality of grapes besides the varietal characteristics, depend on a number of factors: environmental conditions, crop load, time of harvest, application of agrotechnical and ampelotechnical practices, etc. (Avizcuri-Inac et al., 2013). Kavoosi et al. (2009), studying the effect of bunch density in Ascari variety, suggested that decreasing the number of bunches significantly increased the sugar content, sugar/acid ratio, and must pH. Results similar to these were reported in different cultivars by several authors (Dokoozlian et al., 1995; Ezzahouani and Wiliams, 2003; Kunihisa et al., 2003). They also concluded that this influence varies greatly from year to year.

On the other hand, De Souza Leão et al. (2017), investigating the effect of bunch thinning on sugar and acid content in Sugraone variety, did not determine any impact or relation between these elements.

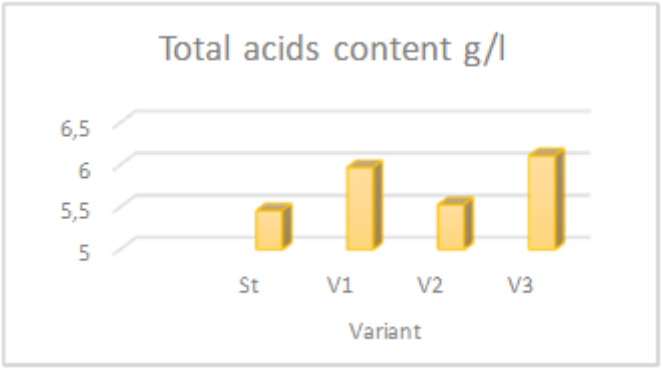

Figure 2. Total acid content by variants in Cardinal varieties

Contrary to the sugar content, where some correlation with bunch thinning was identified in most studies, no such correlation was identified for the content of total acids in most tests (Somkuwar and Ramteke, 2010; Pastore et al., 2011; Miele and Rizzoni, 2013).

Based on the results, we can conclude that the amount of total grapes harvested is closely related to the number of grapes per m^2 (Table 3). The greater the number of bunches, the higher the total yield. However, the quantity of packed grapes increases to a certain load and then starts to decrease, i.e. the quantity of packed grapes decreases and the quantity of residue increases (grapes for processing).

The largest quantity of total grapes harvested was recorded in V_3 (2.22 kg/m^2) and S_T (2.19 kg/m^2), and the smallest in V_1 (1.47 kg/m2). The largest quantity of packed grapes was obtained in V_2 (1.87 kg/m^2) and the smallest in V_1 (1.44 kg/m^2). The quantity of residue (grapes that do not meet the minimum criteria for the category of packed grapes) was 24.9% in S_T and 21.4% in V_3 of the total harvested quantity, while in V_1 and V_2, a significantly lower percentage was statistically recorded: 2.0% and 4.1% respectively of the total harvested quantity.

Table 3. Effect of bunch density on yield of the studied Cardinal variety

Type	Year	Variant				Percent			
		S_T	V_1	V_2	V_3	S_T	V_1	V_2	V_3
Packed grapes kg/m^2	2014	1,65	1,42	1,85	1,82	76,7	95,3	95,9	79,1
	2015	1,74	1,5	1,95	1,88	76,7	99,3	97	81
	2016	1,55	1,39	1,83	1,55	71,8	99,3	94,8	75,6
	$\bar{x}$	1,65b	1,44a	1,87c	1,75b	75,1	98	95,9	78,6
	SD	1,0	0,6	0,6	1,8				
	CV	5,8	4,0	3,4	10,0				
Residue kg/m^2	2014	0,5	0,07	0,08	0,48	23,3	4,7	4,1	20,9
	2015	0,53	0,01	0,06	0,44	23,3	0,7	3	19
	2016	0,61	0,01	0,1	0,5	28,2	0,7	5,2	24,4
	$\bar{x}$	0,55c	0,03a	0,08a	0,47b	24,9	2	4,1	21,4
	SD	0,057	0,035	0,020	0,031				
	CV	10,4	115,5	25,0	6,5				
Total kg/m^2	2014	2,15	1,49	1,93	2,3				
	2015	2,27	1,51	2,01	2,32				
	2016	2,16	1,4	1,93	2,05				
	$\bar{x}$	2,19c	1,47a	1,96b	2,22c	100	100	100	100
	SD	0,067	0,059	0,046	0,150				
	CV	3,04	4,00	2,36	6,77				

*Significant deviation at p = 0.05 level against the standard for the property

The values in each column, marked with different letters, differ significantly from each other at the p = 0.05 level

The yield in all Cardinal variety variants is within the range of varietal characteristics (15-25 t/ha) supporting the data published by several authors (Avramov and Žunić, 2001; Žunić and Garić, 2017; Roičev, 2012; Božinović, 2010).

Kavoosi et al. (2009), studying the effects of bunch thinning, found a decrease in total yield but also an improvement in both the fruit quality and the balance between yield and quality. Berkey et al. (2011), examining the impact of this practice on Seyval Blanc production, found that the impact differed between

years due to the conditions in the year of production. Multiple study data show that high bunch thinning intensity may decrease yield significantly (Fanzone et al., 2011; Avizuri-Inac et al., 2013).

Table 4. Effect of bunch density on maturation dynamics of the studied Cardinal varieties

Harvest	Year	Variant				Percent			
		Ст	B_1	B_2	B_3	Ст	B_1	B_2	B_3
First harvest kg/m²	2014	1,42	1,31	1,6	1,48	86,1	92,3	86,5	81,3
	2015	1,48	1,34	1,65	1,55	85,1	89,3	84,6	82,4
	2016	1,35	1,24	1,64	1,39	87,1	89,2	89,6	89,7
	x̄	1,42b	1,3a	1,63c	1,47b	86,1	90,3	86,8	84,5
	SD	0,065	0,051	0,026	0,080				
	CV	4,6	4,0	1,6	5,4				
Second harvest kg/m²	2014	0,23	0,11	0,25	0,34	13,9	7,7	13,5	18,7
	2015	0,26	0,16	0,3	0,33	14,9	10,7	15,4	17,6
	2016	0,2	0,05	0,19	0,16	12,9	10,8	10,4	10,3
	x̄	0,23b	0,11a	0,25b	0,28b	13,9	9,7	13,2	15,5
	SD	0,030	0,055	0,055	0,101				
	CV	13,0	51,6	22,3	36,6				
Total kg/m²	2014	1,65	1,42	1,85	1,82				
	2015	1,74	1,5	1,95	1,88				
	2016	1,55	1,39	1,83	1,55				
	x̄	1,65b	1,44a	1,87c	1,75bc	100	100	100	100

*Significant deviation at p = 0.05 level against the standard for the property
The values in each column, marked with different letters, differ significantly from each other at the p = 0.05 level

Maturation process dynamics of bunches within the vine and, at the same time, maturation of the berries within the bunch is of great importance for the table grapes. The tendency for very early and early maturing varieties is to obtain as much packed grapes as possible in the first harvest. Our research shows that bunch thinning affects the maturation index and maturation time (Table 4), which has been confirmed in the studies by several authors (Ozer et al., 2012; Silvestri et al., 2017).

The largest quantity of packed grapes was obtained in V_2 in the first harvest (1.63 kg/m^2), while the smallest was in S_T (1.3 kg/m^2). The percentage share of the first harvesting was from 84.5% (V_3) to 90.3% (V_1). The amount of

packed grapes in the second harvest varies from 0.11 kg/m^2 (V_1), to 0.28 kg/m^2 (V_3).

Bunch thinning in Cardinal variety in the first harvest showed statistically significant differences in the quantity of packed grapes in the V_1 and V_2 variants compared to the V_2 and S_T variants.

CONCLUSIONS

Bunch thinning in the period of 7-14 days after blooming showed a significant increase in average bunch and berry mass, better transportability, due to higher berry firmness and berry adherence strength, greater quantity of packed grapes, as well as better maturation dynamics. In Cardinal variety, the best results in relation to these parameters were obtained in the V_2 variant (density of 4 bunches per m^2).

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