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The effects of bud load and regulated deficit irrigation on sugar, organic acid, phenolic compounds and antioxidant activity of Razakı table grape berries

Semih Tangolar[1], Güzin Tarım[1], Haşim Kelebek[2], Serpil Gök Tangolar[1], and Sevilay Topçu[3]

[1] Department of Horticulture, Faculty of Agriculture, Çukurova University, Adana, Turkey
[2] Department of Food Technology, Faculty of Engineering and Natural Sciences, Adana Science and Technology University, Adana, Turkey
[3] Department of Agricultural Structures and Irrigation, Faculty of Agriculture, Çukurova University, Adana, Turkey

Abstract. This study aims at assessing the effects of increased bud load and irrigation applications on berry quality of the Razakı table grape. Two Regulated Deficit Irrigation (RDI) having different irrigation levels (RDI-I and RDI-II) based on the growth stages, in addition to a non-irrigated control treatment together with two different bud load practices (K-normal and 2K-two-fold buds of the normal) were examined for their effects on quality attributes such as sugar and organic acids contents, phenolic compounds as well as antioxidant capacity of the berries. The non-irrigated vines had highest sugar level (198.86 g/kg) in the first year (2013) of the experiment whilst the sugar content of the berries was increased with irrigation (RDI-II) in 2014. However the highest organic acid (7.10 g/kg) was recorded from the RDI-II treatment in 2013 whereas those of from non-irrigated vines were highest (7.81 g/kg) in 2014. Considering the sugar and organic acid content of the berries, bud load effects were not significant. The total phenolic acids were higher under non-irrigated and 2K bud load conditions. Antioxidant activity of berries was increased with RDI-I irrigation and 2K practices in the first year (2013) although no significant effect was recorded in the second year of the experiment. In all applications, glucose among the sugars, tartaric acid among the organic acids, catechin and epicatechin among the phenolic compounds were detected to be higher compared to other components in berries.

1. Introduction

In places with an annual rainfall of 500–600 mm, non-irrigated viticulture can be performed depending on the soil type. However, a supplementary irrigation might be necessary to maintain high yield and quality of the grapes when the seasonal distribution of the rainfall is not appropriate [1]. Irrigation management as a tool for use in the production of grapes has continued to receive attention in many regions of the world, and the regulated deficit irrigation (RDI) is one of the strategies which have been used intensively in vineyards [2–4]. RDI further aims to allow a certain amount of water deficit on the grapevine especially between berry set and maturation periods [5–7]. In wine grape varieties, RDI may increase berry and wine quality by decreasing vegetative growth [8] and accordingly allowing more sunlight and optimum temperature conditions in microclimate around clusters send by this way it may increase skin/pulp ratio, phenolic compounds, anthocyanins and antecedent aroma compounds [9–11]. The excessive water as well as its shortage may solely affect the photosynthesis activity, shoot elongation, berry development, berry size, color and juice composition, depending on the vine nutritional status and yield charge. Ojeda et al. [12] examined the effects of various levels of deficit irrigation on phenolic compounds of Shiraz grape. Effect was realized by decreasing berry size or directly effecting biosynthesis and could be positive or negative depending on the type of phenolic compound. Besides, many researches [13–15] also stated that the total phenolic compounds, antioxidant capacities and phytochemical properties depend on grape variety, climate, soil conditions, maturation levels, cultural applications and yield amount. In this study, the effect of different RDI and bud load applications on berry quality parameters related with human health such as sugars, organic acids, phenolic compounds and antioxidant capacity [8,16–19] in Razakı grape variety were investigated.

2. Materials and methods

This study was carried out in a vineyard with sixteen years old table grape *cv.* Razakı (*Vitis vinifera* L.) in Pozanti Agricultural Research Center (1080 m alt.) of Çukurova University (Adana, Turkey) in 2013 and 2014. The own rooted vines were cultivated under non-irrigated condition. Vine rows were planted with an east/west orientation using a rectangular configuration of 3×2 m. The training system was bilateral cordon trellised to a two-wire vertical system. The soil in experimental vineyard has slightly alkaline character, with a clay-loam and loam texture on the upper soil and 30–60 cm depth, respectively. Field capacity and the permanent wilting point were 27.16 $cm^3\ cm^{-3}$ and 19.39 $cm^3\ cm^{-3}$, respectively.

Three irrigation treatments including non-irrigated as the control, and two irrigation treatments (RDI-I and RDI-II) together with two bud load treatments, traditional (K) and twofold bud loads (2K), were investigated in the experiment. In both RDI treatments, the irrigation time was scheduled according to the midday leaf water potentials (LWP) while the irrigation amount applied was calculated using the cumulative evaporation (Epan) values obtained from Class-A Evaporation Pan. The midday LWP values used for irrigation timing for both RDI treatments were the same, however these values differed at each plant growth stage: –1.0 MPa for before flowering period, –1.3 MPa between berry set-veraison and between veraison-ripening, and –1.2 MPa for post-ripening stage. Irrigation amounts applied to the RDI-I plots were 50% and 75% of the cumulative evaporation from the Class A Pan during the growth stages berry set-veraison and veraison-ripening, respectively, whilst these percentages were 75% and 50% of the evaporation from the Pan for the same growth stages, respectively. Two bud loads; control (K) which is traditional practice (20 buds for the first 500 g of pruning weight, and 10 more buds for every additional 500 g subsequently) [1,20,21] and increased bud loads (2K-double amount of control) (Table 1) were investigated in all irrigation treatments (non-irrigated, RDI-I and RDI-II). Pruning was done on March 2013 and 2014.

Irrigation water amount was calculated using following equation based on cumulative Class A pan evaporation within the irrigation intervals.

$$I = A \times E\text{pan} \times \text{Kpc} \times P$$

I: Irrigation water amount (L), A: parcel area (m^2), Epan: Evaporation from the class-A pan (mm), Kpc: The crop and pan coefficients (0.6), P: Percentage of wetted area (50%).

Irrigation was applied using drip irrigation system and the drip lines were placed close to a vine row. Fertilizers were applied in two occasions, beginning of February

Table 1. Retained bud number (n) by pruning weight (kg/vine) in Regulated Deficit Irrigation (RDI) and bud load of Razakı grapevine.

Year	Irrigation	Bud load[1]	Pruning weight	K[1]	2K
2013	All Treatments		700	24	48
2014	No irrigation	K	1050	31	62
		2K	1113	32	64
		Mean	1082	31	62
	RDI-I	K	1343	36	72
		2K	860	27	54
		Mean	1102	32	64
	RDI-II	K	1030	30	60
		2K	935	28	56
		Mean	983	29	58
	Mean	K	1141	32	64
		2K	969	29	58

[1] K (Control): 20 buds left for the first 500 g pruning weight and 10 more buds left for every additional 500 g.

(20 kg/ha N; 30 kg/ha P_2O_5; 50 kg/ha K_2O) and at the end of May (30 kg/ha N).

The midday leaf water potentials (LWP) were measured in four leaves for each treatment using a portable pressure chamber device (Model 600 Pressure chamber, PMS instrument) between 11:30 hrs and 14:00 hrs. During the ripening period of grapes (when amount of total soluble solids (TSS) have reached approximately 22–23%) 500 g berry samples with pedicels were taken from each replicate. These samples were maintained at –80°C until the following analyses were performed.

For determination of sugars and organic acids, grape samples were prepared according to the method of Sturm et al. [22] and then analysed for the content of individual sugars (glucose, fructose and sucrose) and of organic acids (tartaric and malic acids). An Agilent 1100 HPLC system (Agilent Technologies, Palo Alto CA-USA) equipped with a pump system, a refractive index detector (RID) for sugar analysis, and a diode array detector (DAD) is monitored at 210 nm for the analysis of organic acids. Sugars and organic acids were simultaneously analyzed onto an Aminex HPX-87H column (300 × 7.8 mm) (Bio-Rad-UK) and kept at 55°C. The analytical conditions used were as follows: flow 0.3 ml/min, eluent 0.045 N H_2SO_4 with 6% acetonitrile (v/v). The chromatographic peak corresponding to each sugar, and organic acid were identified by comparing the retention time with that of a standard. A calibration curve was prepared using the standards to determine the relationship between the peak area and concentration.

Extracts for analysis of phenolic compounds were prepared according to the method of Breksa et al. [23]. An Agilent 1100 HPLC system (Agilent Technologies, Palo Alto, CA, USA) with a diode array detector operated by Windows NT based ChemStation software was used for the phenolic compounds analysis. Separation was performed on a Beckman Ultrasphere ODS column (Roissy, France; 4.6 mm × 250 mm, 5 μm). The mobile phase consisted of water with 5% formic acid (solvent A; v/v) and acetonitrile with 40% solvent A (solvent B; v/v). The elution program was performed as previously described [24]. The identification and assignation of each compounds was performed by comparing their retention times and UV spectra to authentic standards and also confirmed by an Agilent 6430LC-MS/MS spectrometer equipped with an electrospray ionization source. The electrospray ionization mass spectrometry detection was performed in negative ion mode with the following optimized parameters: capillary temperature 400°C, capillary voltage –3 V, nebulizer gas flow 1.75 L/min, desolvation gas flow 1 L/min, and spray voltage 5 kV. Analysis was performed in negative and positive mode [24].

Antioxidant activity analysis were performed according to the DPPH (2,2-diphenyl-1-picryl hydrazyl) method described by Kelebek et al. [24]. The absorbance was monitored at 517 nm by a UV-Visible spectrophotometer (Shimadzu UV-1201, Kyoto-Japan). Trolox calibration curve was used to calculate antioxidant activity of grape extracts and to express the antioxidant capacity in mM Trolox equivalent per kg of berry.

2.1. Statistical analysis

Variance analysis was performed according to the split plots experimental design with two replicates using SAS

Table 2. Irrigation dates and water amount applied (L/vine) in Regulated Deficit Irrigation (RDI) treatments of Razakı grapevine.

Phenological stages	Irrigation dates	2013 Year		2014 Year	
		RDI-I	RDI-II	RDI-I	RDI-II
Bud break		24 April		23 April	
Bloom		5 June		17 June	
Berry set		16 June		24 June	
	17 July	60.3	90.5		
	26 July	72	108		
	16 August			28.4	42.5
Veraison		11 August		17 August	
Total (Berry set-Veraison)		**132.3**	**198.5**	**28.4**	**42.5**
	19 August	336.8	224.6		
	22 August			72.2	48.2
Maturity		27 August		28 August	
Total (Veraison – Maturity)		**336.8**	**224.6**	**72.2**	**48.2**
	29 August	160.2	160.2	118.8	118.8
	9 Sep.			72.0	72.0
	12 Sep.	218.7	218.7		
	13 Sep.			14.4	14.4
Total (After harvest)		**378.9**	**378.9**	**205.2**	**205.2**
GENERAL TOTAL		**848**	**802**	**305.8**	**295.9**

statistical programmer, and least significant difference test (LSD) was used for separation of means of different treatments at 5% significance level.

3. Results and discussion

The water amounts applied in different periods according to applications are given in Table 2. As LWP values measured before flowering were <–1.0 MPa, irrigation was not applied until berry set. Therefore we considered that the rainfall between September and December plus until berry set in 2013 and 2014 experimental years were sufficient [1,20]. A total rainfall of 679.6 mm and 500.8 mm were recorded in the experimental area between September and August in 2013 and 2014 (Table 3), respectively.

The effects of irrigation on the content of sugars and organic acids were significantly different (Table 4). However these differences varied by the years. Glucose, fructose and total sugar values for the first year (2013) in non-irrigated and for the second year (2014) in RDI-II experiments were higher than the other treatments. On the other hand, while malic and total acid amount was highest in RDI-II subject for 2013, tartaric and total acid values were the highest in non-irrigated ones. Glucose and fructose values were close to each other in all applications. The glucose and fructose ratio was slightly higher than 1 as mentioned in previous studies [14,20]. Contrary to the researchers stating that berry growth in grapevines to which excess bud load was applied was lower compared to grapevines with less load as a result of the available sugar amount per each berry and water absorption decrease of berries [1,20], in this study, no significant difference was observed between bud load applications except for sucrose. It was determined that sucrose amount was very low compared with other sugar components. The values given in Table 4 have shown that a certain amount of increase in acidity occurred due to high bud load application. Tartaric

Table 3. Total rainfall between September, 2012 and August, 2014 in experimental area (Adana Sixth Regional Directorate of Meteorology, Pozantı Climate station).

Years	Months	Total rainfall (mm)	Total (mm)	Years	Months	Total rainfall (mm)	Total (mm)
2012	September	0.4	432.6	2013	September	1.8	62
	October	107.0			October	30.4	
	November	93.4			November	10.4	
	December	231.8			December	19.4	
2013	January	31.4	234.8	2014	January	94.8	360
	February	47.2			February	10.6	
	March	65.6			March	124.8	
	April	67.6			April	42.6	
	May	23.0			May	87.2	
	June	11.8	12.2		June	76.8	78.8
	July	0.4			July	0.6	
	August	0			August	1.4	
Total		679.6	679.6	Total		500.8	500.8

Table 4. Effects of two Regulated Deficit Irrigation (RDI) practices and two bud load levels on sugar and organic acid contents of Razakı (g/kg).

Source of variance[1]	Glucose[1]		Fructose		Sucrose		Total sugars		Tartaric acid		Malic acid		Total organic acids	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Irrigation														
No irrigation	100.37a	84.89c	97.69a	75.82c	0.80b	2.59a	198.86a	163.30c	4.48	5.47a	2.13c	2.34c	6.61b	7.81a
RDI-I	91.66b	87.69b	90.10b	78.65b	1.09a	2.48a	182.85b	168.82b	4.38	4.27b	2.29b	2.51b	6.67b	6.78b
RDI-II	90.97b	92.49a	89.38b	85.45a	1.24a	2.00b	181.59b	179.94a	4.43	3.63c	2.67a	2.59a	7.10a	6.22c
LSD 5%	1.60	1.02	1.68	1.31	0.10	0.24	2.94	1.47	NS	0.33	0.06	0.10	0.22	0.28
Bud load level														
K	94.94	88.30	92.97	80.29	0.54b	2.52a	188.45	171.11	4.18b	4.35	2.41a	2.54a	6.59b	6.89
2K	93.73	88.41	91.81	79.66	1.55a	2.20b	187.10	170.26	4.68a	4.57	2.31b	2.41b	6.99a	6.98
LSD 5%	NS	NS	NS	NS	0.08	0.20	NS	NS	0.07	NS	0.05	0.08	0.18	NS
Interaction														
No irr. × K	101.66a	92.92b	99.09a	84.37b	1.61c	2.49b	202.36a	179.78b	5.02ab	4.26c	2.09d	2.66ab	7.10b	6.92c
No irr. × 2K	99.09a	76.86f	96.28ab	67.28e	0.00d	2.69ab	195.37b	146.83f	3.95d	6.67a	2.17d	2.02d	6.12c	8.69a
RDI-I × K	94.87b	83.97e	93.43bc	75.45d	0.00d	2.97a	188.30c	162.40e	3.25e	5.13b	2.40c	2.50c	5.65d	7.63b
RDI-I × 2K	88.45c	91.41c	86.78d	81.86c	2.19b	1.99c	177.41d	175.25c	5.50a	3.40d	2.18d	2.53bc	7.69a	5.93d
RDI-II × K	88.28c	88.01d	86.40d	81.06c	0.00d	2.09c	174.68d	171.16d	4.27cd	3.65d	2.75a	2.47c	7.02b	6.12d
RDI-II × 2K	93.66b	96.97a	92.37c	89.84a	2.47a	1.91c	188.51c	188.72a	4.59bc	3.62d	2.59b	2.70a	7.18b	6.32d
LSD 5%	2.27	1.45	2.37	1.85	0.15	0.34	4.16	2.07	0.38	0.47	0.08	0.15	0.31	0.40

[1] Means followed by different letters on the same column are significantly different according to LSD at $P < 0.05$. NS. Not significant.

acid values were higher than malic acid in all applications. Such conclusions were also reached by many researchers before [1,14,20]. It was observed that irrigation applications did not change this situation. Irrigation and bud load interactions were statistically significant in all sugars and organic acid properties examined.

Thirteen different phenolic compounds (PC), including two flavanols, six phenolic acids, and five flavonols were identified in Razakı berries (Tables 5–7). Considering these compounds differences between application effects and interactions were statistically significant. Besides catechin and epicatechin, rutin, myricetin-3-glucoside total PC values were highest in rainfed application.

Total and PC values, except gallic and caffeic acid was higher in 2K application. The total PC values ranged 2013 and 2014 respectively from 161.72 and 173.63 mg/kg (in RDI-I 2K) to 542.96 and 570.63 mg/kg (in No irrigation 2K). The total value of berry skin phenolics of Syrah was stated as between 1878 and 2478 μg/g by Wessner and Kurtural [25] and detected by Kurtural et al. [26] as between 2170 and 2548 μg/g. Kelebek [14] detected non-coloured phenolic compounds of the wines obtained from Kalecik karasi, Okuzgozu and Bogazkere grapes. In his study, the phenolic amounts of the studied varieties changed between 142 mg/L and 349 mg/L. According to the Göktürk Baydar et al. [27], total phenolic contents varied from 217 to 1336 mg/L in wines from Cabernet Sauvignon, Kalecik Karası and Narince grape cultivars. Catechin and epicatechin were the most important elements among phenolic compounds [10,28,29].

Antioxidant activity level was higher in RDI-I and 2K treatments (Table 8) in 2013. However there were no significant differences among the treatments in 2014.

Table 5. Effects of two Regulated Deficit Irrigation (RDI) practices and two bud load levels on flavanol contents (mg/kg) of Razakı.

Source of variance[1]	Catechin[1]		Epicatechin	
	2013	2014	2013	2014
Irrigation				
No irrigation	141.64a	153.76a	197.00a	197.86a
RDI-I	77.73b	84.39b	114.58c	115.08c
RDI-II	58.24c	61.14c	119.32b	118.95b
LSD 5%	0.81	2.68	0.87	2.66
Bud load level				
K	72.86b	77.71b	126.54b	126.50b
2K	112.22a	121.82a	160.73a	161.42a
LSD 5%	0.66	2.19	0.71	2.17
Interaction				
No irr. × K	56.71d	61.56c	111.10e	111.58d
No irr. × 2K	226.57a	245.95a	282.91a	284.13a
RDI-I × K	100.43b	109.02b	153.52b	154.18b
RDI-I × 2K	55.04e	59.75c	75.65f	75.97e
RDI-II × K	61.44c	62.53c	115.00d	113.74d
RDI-II × 2K	55.04e	59.75c	123.63c	124.17c
LSD 5%	1.15	3.79	1.23	3.76

[1] Means followed by different letters on the same column are significantly different according to LSD at $P < 0.05$.

Table 6. Effects of two Regulated Deficit Irrigation (RDI) practices and two bud load levels on phenol acids (mg/kg) contents of Razakı.

Source of variance[1]	Gallic acid		Protocatechuic acid		Trans caftaric acid		Trans coutaric acid		Caffeic acid		*p*-Coumaric acid	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Irrigation												
No irrigation	5.20c	4.49c	3.12b	2.37b	12.45b	19.58b	4.98b	5.91b	0.49c	0.52c	0.61a	0.65a
RDI-I	7.56a	6.52a	2.12c	1.61c	9.54c	15.01c	4.89c	5.81b	0.78a	0.84a	0.00b	0.00b
RDI-II	5.33b	4.60b	4.36a	3.32a	18.14a	28.54a	6.98a	8.28a	0.75b	0.80b	0.00b	0.00b
LSD 5%	0.006	0.01	0.02	0.05	0.08	0.36	0.03	0.10	0.005	0.02	0.0006	0.002
Bud load level												
K	6.05a	5.22a	2.94b	2.24b	12.20b	19.19b	4.13b	4.90b	0.78a	0.83a	0.22a	0.24a
2K	6.01b	5.18b	3.45a	2.63a	14.56a	22.90a	7.10a	8.42a	0.57b	0.60b	0.18b	0.19b
LSD 5%	0.005	0.01	0.02	0.04	0.06	0.29	0.02	0.08	0.004	0.01	0.0005	0.002
Interaction												
No irr. × K	5.58c	4.81c	4.36b	3.32b	16.70b	26.27b	3.78f	4.49f	0.97a	1.04a	0.67a	0.72a
No irr. × 2K	4.83f	4.16f	1.87e	1.42e	8.20f	12.90f	6.17b	7.32b	0.00f	0.00f	0.54b	0.57b
RDI-I × K	7.10b	6.12b	1.86e	1.42e	8.65e	13.60e	4.43d	5.26d	0.74d	0.78d	0.00c	0.00c
RDI-I × 2K	8.01a	6.91a	2.38d	1.81d	10.43d	16.41d	5.35c	6.36c	0.83c	0.89c	0.00c	0.00c
RDI-II × K	5.47d	4.71d	2.61c	1.98c	11.25c	17.69c	4.18e	4.97e	0.64e	0.68e	0.00c	0.00c
RDI-II × 2K	5.20e	4.48e	6.12a	4.65a	25.04a	39.39a	9.77a	11.60a	0.87b	0.93b	0.00c	0.00c
LSD 5%	0.008	0.02	0.03	0.07	0.11	0.51	0.04	0.14	0.007	0.02	0.0009	0.003

[1] Means followed by different letters on the same column are significantly different according to LSD at $P < 0.05$.

Table 7. Effects of two Regulated Deficit Irrigation (RDI) practices and two bud load levels on content of flavonols and total phenolic compounds (mg/kg) of Razakı.

Source of variance[1]	Ferulik asit		Rutin[1]		Myricetin 3-glucoside		Isoramnetin 3-glucoside		Quercetin 3-glucoside		Total phenols	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Irrigation												
No irrigation	0.32c	0.34c	1.11a	1.18a	5.54a	5.90a	0.47b	0.52b	0.00	1.29b	372.90a	394.34a
RDI-I	0.47a	0.50a	0.53b	0.57b	2.59c	2.76c	0.50a	0.55a	0.00	1.38a	221.31b	235.01b
RDI-II	0.46b	0.49b	0.39c	0.41c	3.06b	3.26b	0.40c	0.45c	0.00	1.11c	217.44c	234.32b
LSD 5%	0.002	0.006	0.006	0.02	0.03	0.12	0.001	0.003		0.008	1.67	5.26
Bud load level												
K	0.38b	0.41b	0.53b	0.56b	2.27b	2.41b	0.43b	0.48b	0.00	1.19b	229.34b	243.86b
2K	0.45a	0.48a	0.82a	0.88a	5.20a	5.54a	0.48a	0.53a	0.00	1.33a	311.76a	331.93a
LSD 5%	0.002	0.005	0.005	0.02	0.03	0.09	0.0008	0.002		0.006	1.36	4.29
Interaction												
No irr. × K	0.15f	0.16f	0.49e	0.52c	1.93f	2.05e	0.39e	0.43e	0.00	1.08e	202.85d	218.05d
No irr. × 2K	0.48c	0.51c	1.73a	1.84a	9.14a	9.74a	0.54b	0.60b	0.00	1.49b	542.96a	570.63a
RDI-I × K	0.58a	0.62a	0.56b	0.59b	2.48d	2.64d	0.55a	0.61a	0.00	1.53a	280.90b	296.39b
RDI-I × 2K	0.36e	0.39e	0.51d	0.54c	2.70c	2.88c	0.45d	0.49d	0.00	1.23d	161.72e	173.63e
RDI-II × K	0.41d	0.43d	0.54c	0.57bc	2.39e	2.54d	0.35f	0.39f	0.00	0.97f	204.27d	217.14d
RDI-II × 2K	0.51b	0.54b	0.24f	0.25d	3.74b	3.99b	0.46c	0.50c	0.00	1.26c	230.61c	251.51c
LSD 5%	0.003	0.008	0.008	0.03	0.05	0.16	0.001	0.004		0.01	2.36	7.43

[1] Means followed by different letters on the same column are significantly different according to LSD at $P < 0.05$.

Table 8. Effects of two Regulated Deficit Irrigation (RDI) practices and two bud load levels on antioxidant activity (mM Trolox/kg) of Razakı.

Source of variance[1]	Antioxidant activity	
	2013	2014
Irrigation		
No irrigation	305.18b	381.71
RDI-I	309.49a	433.21
RDI-II	305.38b	468.38
LSD 5%	1.11	NS
Bud load level		
K	305.67b	406.75
2K	307.69a	448.78
LSD 5%	0.90	NS
Interaction		
No irr. × K	308.45b	368.83
No irr. × 2K	301.90e	394.58
RDI-I × K	302.90de	409.83
RDI-I × 2K	316.08a	456.58
RDI-II × K	305.65c	441.58
RDI-II × 2K	305.10cd	495.17
LSD 5%	1.57	NS

[1] Means followed by different letters on the same column are significantly different according to LSD at $P < 0.05$. NS. Not significant.

Results indicated that applying deficit irrigation did not change the antioxidant activity in grapes.

The effect of RDI changes according to phenological stage and the level of applied irrigation stress [5], and the berry and wine quality may be enhanced [10]. Bowen et al. [4] and Keller et al. [3] stated in their studies that fruit composition, anthocyanin and berry content had been effected slightly or inconsistently from deficit irrigation and yield load balance and that the effect varied according to years or seasonal changes. Benismail et al. [30] on Cardinal; Fawzi et al. [31] on Seedless grape variety determined that the vegetative growth decreased depending on bud load increase per grapevine, while there were no change in the biochemical contents in grapes.

4. Conclusion

The overall findings of the present study indicate that RDI-I strategy, applying lower amount of water between berry set and veraison, can be used for maintaining better quality and yield of grapes. The application of 2K bud load together with the deficit irrigation practice (RDI-I) did not change significantly investigated quality attributes of the berries. Findings of this study showed that in addition to an increase in grape yield due to higher bud load practice, optimum values from essential compounds could also be obtained with a supplementary irrigation application using regulated deficit irrigation.

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