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ORIGINAL ARTICLE / ORIGINALBEITRAG

Different Treatment Timings of Basal Leaf Removal and Reflective Mulch Affect Biochemical and Electrochemical Characteristics of cv. Cabernet Sauvignon Wine Grapes (*V. vinifera* L.)

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Abstract
Bioactive compounds and electrochemical characteristics are remarkable quality components for wine grapes and quality characteristics of grape are influenced by various factors such as grape cultivar, environmental and viticultural practices in a vineyard. There has recently been growing interest in improvement of wine grape quality characteristics by means of basal leaf removal (BLR) and reflective mulch (RM) practices. In current study, treatments of BLR, RM and BLR + RM were performed at two different phenological stages of grapevine, including pea size period (PSP) and vérasion period (VP). At the end of research, study results revealed that different treatment timings of basal leaf removal and reflective mulch had crucial roles on increasing of wine grape quality. Consequently, BLR-PSP + RM-PSP treatment especially led to significant enhancements in biochemical characteristics of cv. Cabernet Sauvignon like phenolic compounds, anthocyanins and electrochemical characteristics.

Keywords Wine grape · Basal leaf removal · Reflective mulch · Electrochemical quality parameter · Biochemical characteristics

Unterschiedliche Termine beim Entfernen der Basalblätter und beim Einsatz mit reflektierendem Mulch beeinflussen die biochemischen und elektrochemischen Eigenschaften von Trauben der Rotweinsorte 'Cabernet Sauvignon' (*V. vinifera* L.)

Schlüsselwörter Weintraube · Basale Entblätterung · Reflektierender Mulch · Elektrochemische Qualitätsparameter · Biochemische Eigenschaften

Introduction

Wine grape quality is frequently assessed by determining of physical and biochemical characteristics of grapes (Zoecklein 2010).

Although there is a great deal of physical and physicochemical methods in determining grape quality, these methods mostly require high-priced laboratory equipment, trained staff and time (Ergun 2012). In order to avoid these drawbacks, there has recently been an increasing interest in assessing of electrochemical fruit quality characteristics in various fruit species by calculating *p*-value. This method is one of the most practical ways to assess internal fruit quality of different species (Hoffmann 1991; Ergun 2012, 2017; Kok 2017; Kok and Bal 2017b).

Grape quality is affected by various factors such as grape variety, cultural practices and also prevailing ecological conditions of vineyard (Kok 2017).

Climate is one of the most important factors, affecting wine grape quality and is potent modulator of grape composition (Fraga et al. 2013; Barnuud et al. 2014; Kok 2014).

In viticulture, there are three major climate scales that are considered as macroclimate, mesoclimate and microclimate and microclimate is defined as the climate within

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and immediately surrounding the grapevine canopy (Sluys 2006).

Microclimatic characteristics of grapevine canopy consists of a number of factors such as solar radiation, temperature, wind speed, humidity and evaporation (Goldammer 2018). Among these microclimatic factors, light environment within grapevine canopy is important factor, affecting grape composition (Dokoozlian and Kliewer 1995; Smart and Robinson 1991), fruitfulness, grape ripening and hardiness of buds and canes (Howell et al. 1991).

Direct sunlight penetration into grapevine canopy is useful for bunch formation, bud differentiation, grape composition, photosynthetic efficiency and decreasing the incidence of fungal diseases (Smithyman et al. 1997).

Microclimatic characteristics of grapevine canopy can be manipulated by different viticultural practices (Keller 2015; Goldammer 2018).

Basal leaf removal and mulching are some of the major viticultural practices to modify the bunch microclimate, particularly in a cool and wet climate where these practices can improve sunlight in fruit zone and grape temperature (Osrecak et al. 2015, 2016), leading to the enhancements in grape ripening, quality characteristics and disease suppression (Hostetler et al. 2007a, b; Lemut et al. 2011).

Reflective mulches, enhancing microclimate characteristics of grapevine canopy are especially used for altering wine quality in cool climate regions (Razungles et al. 1996; Reynolds et al. 2008).

Achieving desired outcomes of viticultural practices depend on application time and intensity of related viticultural practices, as well as climate (Smart and Robinson 1991) and all these factors have remarkable effects on wine grape composition (Lee and Skinkis 2013).

Basal leaf removal and reflective mulching practices can be commonly applied between grape set period and vérasion period in most wine grape growing regions of world (Percival et al. 1994; Diago et al. 2010; Guerra and Steenwerth 2012; Hostetler et al. 2007a, b).

The objective of present study was to assay effects of different treatment timings of basal leaf removal and reflective mulch on biochemical and electrochemical characteristics of cv. Cabernet Sauvignon wine grape.

Material and Methods

Plant Material and Vineyard Site

This research was carried out in a commercial cv. Cabernet Sauvignon vineyard (lat. 41°01′05.76″N, long. 27°40′24.98″E; 57 m a.s.l.) located in Tekirdağ, Turkey in the course of vegetation period of 2016 year.

In the study, it was utilized from 13-year-old cv. Cabernet Sauvignon grapevines grafted onto 110R rootstock (*Berlandieri Resseguier No. 2xRupestris Martin 110 Richter*) and were trained to a bilateral cordon with a bud load 12 buds per grapevine. The grapevines were planted at a spacing of 2.5 m between rows and 1.0 m between grapevines within a row in the vineyard. Related cultural practices and disease-pests preventing applications employed in vineyard were performed in accordance with normal commercial standards.

The prevailing climate characteristic of research area is temperate. In terms of general climate characteristics, annual values of mean temperature, relative humidity and total precipitation were in order of 15.54 °C, 80.95% and 791.20 mm for 2016 year.

Physical and Biochemical Parameters

In present study, grape length (mm), grape width (mm), grape weight (g), bunch length (cm), bunch width (cm) and bunch weight (g) were measured as physical parameters. Besides, total soluble solids content (%), titratable acidity (g/L), must pH, total soluble solids content × pH^2 (%), electrochemical quality assessment as *p*-value (µW), total phenolic compounds content (mg GAE/kg fw) and total anthocyanin content (mg GAE/kg fw) were found out as biochemical parameters.

Treatment Timings of Basal Leaf Removal and Reflective Mulch

In the research, treatments of basal leaf removal and reflective mulch were employed at two different phenological stages of grapevines such as pea size period (PSP) and vérasion period (VP) (Table 1).

Basal Leaf Removal (BLR) Treatment

Basal leaf removal treatments were conducted at two different phenological stages of grapevine such as pea size period (7 mm diameter) and vérasion period. For this purpose, two

Table 1 Treatments and treatment times considered in the research

1-	C		
2-	BLR-PSP	*5-*	BLR-VP
3-	RM-PSP	*6-*	RM-VP
4-	BLR-PSP + RM-PSP	*7-*	BLR-VP + RM-VP

C Control, *BLR-PSP* Basal leaf removal at pea size period, *RM-PSP* Reflective mulch at pea size period, *BLR-PSP + RM-PSP* Basal leaf removal at pea size period + Reflective mulch at pea size period, *BLR-VP* Basal leaf removal at vérasion period, *RM-VP* Reflective mulch at vérasion period, *BLR-VP + RM-VP* Basal leaf removal at vérasion period + Reflective mulch at vérasion period

Table 2 Diverse characteristics of reflective mulch Tyvek® (DuPont™)

Basis weight (g/m^2)	Delamination (N/2.54)	Thickness (µm)	Opacity (%)	Tensile (MD) (N/2.54)	Elongation (%)	Mullen burst (kPa)
75.0	1.75	210	96.5	200	18.5	1200

to five basal leaves around the bunch zones on each shoot were removed by hand.

Reflective Mulch (RM) Treatment

Reflective mulch treatments were also implemented at two different phenological stages of grapevine, including pea size period (7 mm diameter) and vérasion period. For this aim, it was benefited from Tyvek® (DuPont™) high density non-woven polyethylene material with high diffusive reflectivity, waterproof and breathable, soft and tough, safe and environmentally friendly as reflective mulch for reflective mulch applications (Table 2).

Grape Harvest and Preparing of Grape Samplings

Grapes of cv. Cabernet Sauvignon were harvested at commercial maturity stage by hand when the grapes on the bunches of Control grapevines roughly reached 22.5–23.0% of total soluble solids content. In the study, 250-grapes were stored for the analyzes of total soluble solids content, titratable acidity, must pH and electrochemical quality assessment of must. In the study, 300-grape samples were also used for determination of total phenolic compounds content and total anthocyanin content. All grape samples were stored at –25 °C up to analyzes of total phenolic compounds content and total anthocyanin content. Prior to these analyzes, grape samples were withdrawn from –25 °C, allowed to thaw overnight at 4 °C and then homogenized in a commercial laboratory blender for 20 s.

Electrochemical Quality Assessment as P-Value

P-value is occasionally used for assessing of electrochemical quality in degrading products. For this purpose, Hoffmann (1991) formulated an equation called as *p*-value, containing redox potential (mV), must pH, *p*-value (µW) and resistivity ('Ω). In available research, *p*-values of grape must sample from different treatments were calculated according to equation mentioned above.

Spectrophotometric Analyzes for Total Phenolic Compounds and Total Anthocyanin Analyses

Finding out of total phenolic compounds contents in grape extracts was conducted in accordance with Folin-Ciocalteu's spectrophotometric method proposed by Singleton et al. (1978). Besides, total anthocyanin content was also determined according to another spectrophotometric method described by Di Stefano and Cravero (1991). All these spectrophotometric measurements were carried out through an UV-VIS spectrophotometer and results of both analyzes were expressed as mg gallic acid equivalent per kg of fresh weight (mg GAE/kg fw).

Statistical Analysis

The research was designed as 4 replicates based on completely randomized block design and all data were subjected to analysis of variance (ANOVA) by using TARIST statistical software. Differences among the treatments were compared by Fisher's Least Significant Difference (LSD) test at 5% level.

Table 3 Effects of treatment timings of basal leaf removal and reflective mulch on physical parameters of cv. Cabernet Sauvignon

Treatments	Grape length (mm)	Grape width (mm)	Grape weight (g)	Bunch length (cm)	Bunch width (cm)	Bunch Weight (g)
C	12.47	12.75	1.41^{c}	14.88	7.86	125.93^{c}
BLR-PSP	13.02	13.14	1.67^{ab}	16.52	9.21	185.40^{ab}
RM-PSP	13.09	13.18	1.75^{a}	16.50	9.52	195.11^{ab}
BLR-PSP + RM-PSP	13.14	13.28	1.79^{a}	17.07	9.88	201.08^{a}
BLR-VP	12.73	12.90	1.55^{bc}	15.63	8.50	154.49^{bc}
RM-VP	12.91	13.03	1.61^{ab}	16.01	8.90	173.08^{ab}
BLR-VP + RM-VP	13.00	13.07	1.65^{ab}	16.17	9.05	182.41^{ab}
$LSD_{5\%}$	NS	NS	0.18	NS	NS	46.04

Different letters in column indicate the significant differences in the mean at 5% level by LSD multiple comparison test

C Control, *BLR-PSP* Basal leaf removal at pea size period, *RM-PSP* Reflective mulch at pea size period, *BLR-PSP + RM-PSP* Basal leaf removal at pea size period + Reflective mulch at pea size period, *BLR-VP* Basal leaf removal at vérasion period, *RM-VP* Reflective mulch at vérasion period, *BLR-VP + RM-VP* Basal leaf removal at vérasion period + Reflective mulch at vérasion period

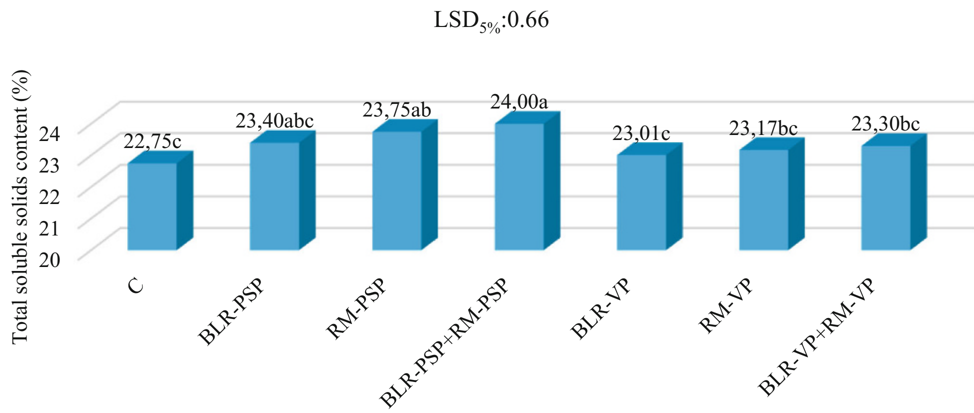

Fig. 1 Effects of treatment timings of basal leaf removal and reflective mulch on total soluble solids content

Results and Discussion

Physical Parameters

Physical characteristics indicated in Table 3 are not significantly influenced by treatment timings of basal leaf removal and reflective mulch except for grape weight and bunch weight ($P \leq 0.05$).

Several factors such as grape cultivar, rootstock, viticultural practices, climatic factors, plant bioregulator treatments can influence the grape and bunch development (Brar et al. 2008; Sonnekus 2015; Kok 2017). Based on grape length depicted in Table 3, treatment timings of basal leaf removal and reflective mulch on have no significant effects on grape length ($P \leq 0.05$) and means of grape length varied from 12.47 (C) to 13.14 mm (BLR-PSP + RM-PSP).

It is clearly seen in results of variance analysis that grape width is not statistically affected by treatment timings of basal leaf removal and reflective mulch ($P \leq 0.05$). While the lowest grape width mean was 12.75 mm for C treatment, BLR-PSP + RM-PSP treatment resulted in the highest grape width (13.28 mm) (Table 3).

With respect to grape weight presented in Table 3, grape weight is significantly influenced by treatment timings of basal leaf removal and reflective mulch ($P \leq 0.05$) and treatments of RM-PSP and BLR-PSP + RM-PSP resulted in the highest grape weight (1.75 and 1.79 g, respectively) when the compared with C treatment (1.41 g).

As shown in Table 3, there are no significant differences between treatment timings of basal leaf removal and reflective mulch in terms of bunch length ($P \leq 0.05$). While the lowest bunch length mean was 14.88 cm for C treatment, the highest bunch length mean was recorded for BLR-PSP + RM-PSP treatment (17.07 cm).

Regarding bunch width presented in Table 3, no significant differences are observed between treatment timings of basal leaf removal and reflective mulch ($P \leq 0.05$) and bunch width means ranged from 7.86 (C) to 9.88 cm (BLR-PSP + RM-PSP).

According to the variance analysis of bunch weight indicated in Table 3, it is obviously seen that treatment timings of basal leaf removal and reflective mulch have considerable roles on bunch weight ($P \leq 0.05$) and the highest bunch weight was recorded for BLR-PSP + RM-PSP treatment (201.08 g) compared to C treatment (125.93 g).

Biochemical Parameters

Figs. 1, 2, 3, 4, 5, 6 and 7 show that there are significant effects of treatment timings of basal leaf removal and reflective mulch on most of biochemical parameters of cv. Cabernet Sauvignon except for titratable acidity ($P \leq 0.05$).

Grape composition at harvest time is one of the most remarkable factors, determining the future quality of wine. Grapes are traditionally harvested based on the concentration of total soluble solids that can be employed for a prediction of sugar content, chiefly glucose and fructose (Gishen et al. 2005; Cozzolino et al. 2006). In current study, treatment timings of basal leaf removal and reflective mulch have crucial roles on total soluble solids content (Fig. 1, $P \leq 0.05$) and BLR-PSP + RM-PSP treatment caused the highest total soluble solids content (24.00%) than C treatment (22.75%).

Titratable acidity is a substantial parameter to assess the quality characteristics of both grape juice and wine (Lamikanra et al. 1995; Kok 2017; Kok and Bal 2017a). As illustrated in Fig. 2, there are no significant differences between treatment timings of basal leaf removal and reflective mulch ($P \leq 0.05$). But the lowest titratable acidity mean was obtained from BLR-PSP + RM-PSP treatment (9.00 g/L) when the compared with C treatment (10.69 g/L).

pH of grape must is another important factor, affecting wine quality and must pH range is between 2.9 and 4.2 (Robinson and Harding 2015). In present study, it is evidently monitored in Fig. 3 that treatment timings of basal

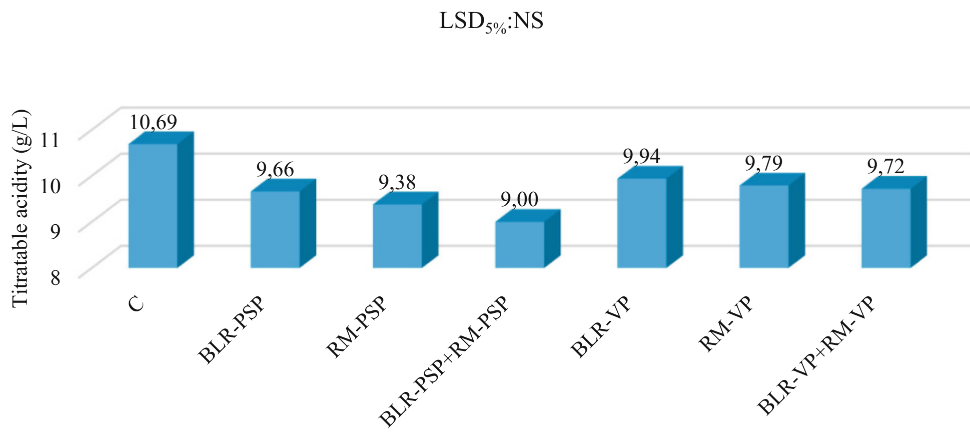

Fig. 2 Effects of treatment timings of basal leaf removal and reflective mulch on titratable acidity

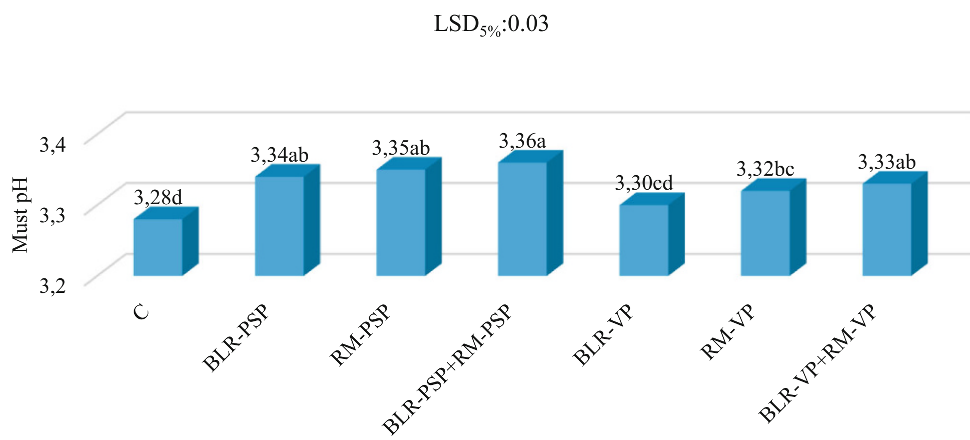

Fig. 3 Effects of treatment timings of basal leaf removal and reflective mulch on must pH

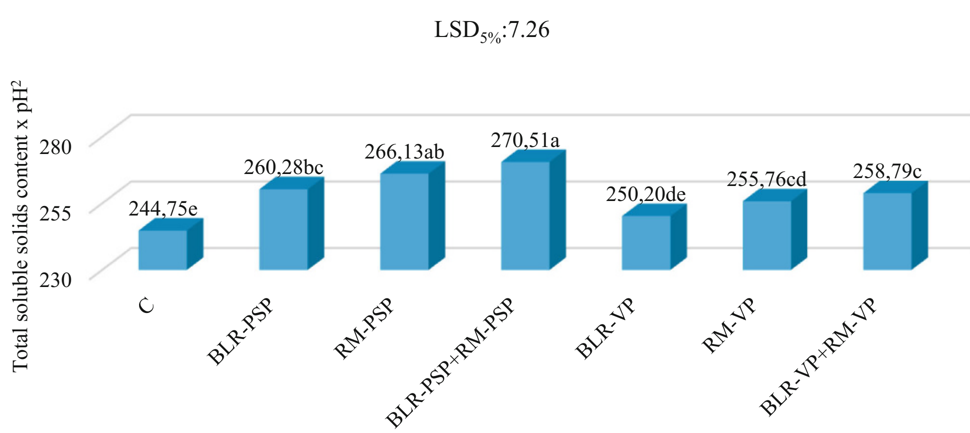

Fig. 4 Effects of treatment timings of basal leaf removal and reflective mulch on total soluble solids content × pH^2

leaf removal and reflective mulch significantly affect must pH ($P \le 0.05$) and means of must pH differed from 3.28 (C) to 3.36 (BLR-PSP + RM-PSP).

Parameter of total soluble solids content × pH^2 is accepted as considerable indicator of optimum maturity for wine grapes and its equation value varies from 200 to 270 (Coombe et al. 1980). It is plainly seen in Fig. 4 that treatment timings of basal leaf removal and reflective mulch have key roles on total soluble solids content × pH^2 ($P \le 0.05$). In available study, the highest total soluble solids content × pH^2 mean was recorded for BLR-PSP + RM-PSP treatment (270.51) compared to C treatment (244.75).

In recent times, electrochemical quality assessment by calculating p-value has been remarkable tool employed to determine quality characteristics of foods (Kok 2017; Kok and Bal 2017b) and low p-values point out better product quality (Wolf and Rey 1997). As shown in Fig. 5, treatment timings of basal leaf removal and reflective mulch on have crucial effects on electrochemical quality assessment ($P \le 0.05$) and means of electrochemical quality as-

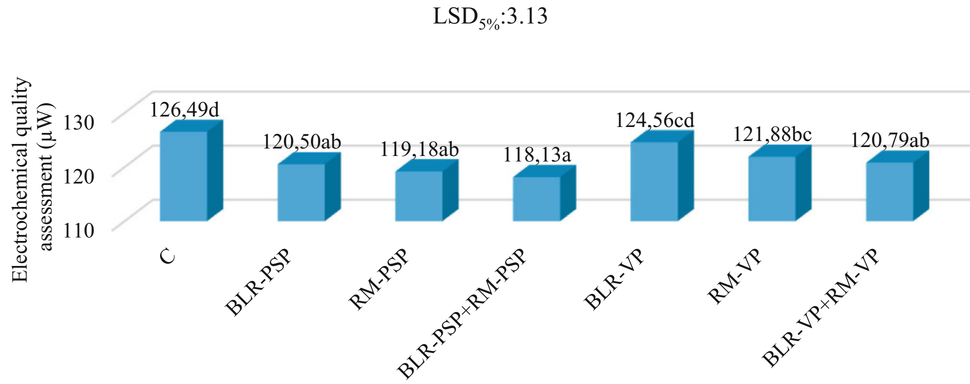

Fig. 5 Effects of treatment timings of basal leaf removal and reflective mulch on electrochemical quality assessment

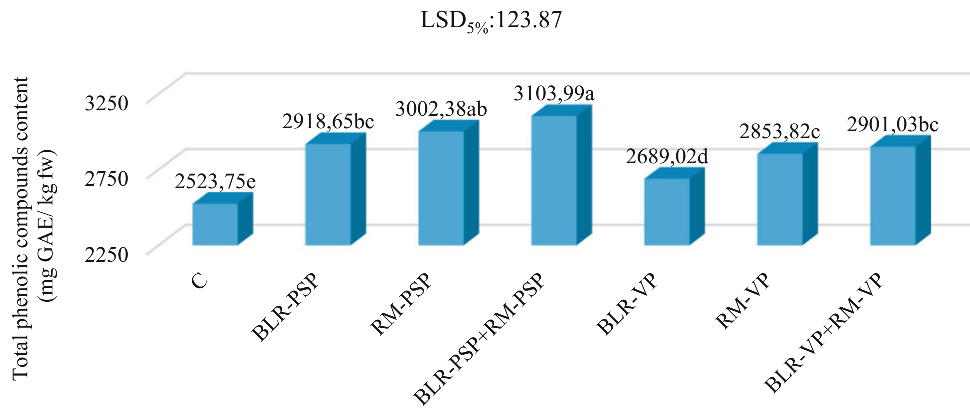

Fig. 6 Effects of treatment timings of basal leaf removal and reflective mulch on total phenolic compounds content

sessment changed from 118.13 (BLR-PSP + RM-PSP) to 126.49 µW (C).

Phenolic compositions of wine grapes are immensely important for wine quality (Cristea 2014) and phenolic compounds contribute to the organoleptic characteristics of wine, including color, astringency and body (Brighenti et al. 2017). As depicted in Fig. 6, treatment timings of basal leaf removal and reflective mulch give rise to significant differences in total phenolic compounds content ($P \leq 0.05$) and BLR-PSP + RM-PSP treatment led to the highest total phenolic compounds content (3103.99 mg GAE/kg fw) when the compared with C treatment (2523.75 mg GAE/kg fw).

Anthocyanins are responsible for the red color of grape skins and wine and are normally found in grape skins (Ribereau-Gayon et al. 2001). As figured out in Fig. 7, treatment timings of basal leaf removal and reflective mulch have of great importance on total anthocyanin content ($P \leq 0.05$) and means of total anthocyanin content ranged from 1342.20 (C) to 1926.59 mg GAE/kg fw (BLR-PSP + RM-PSP).

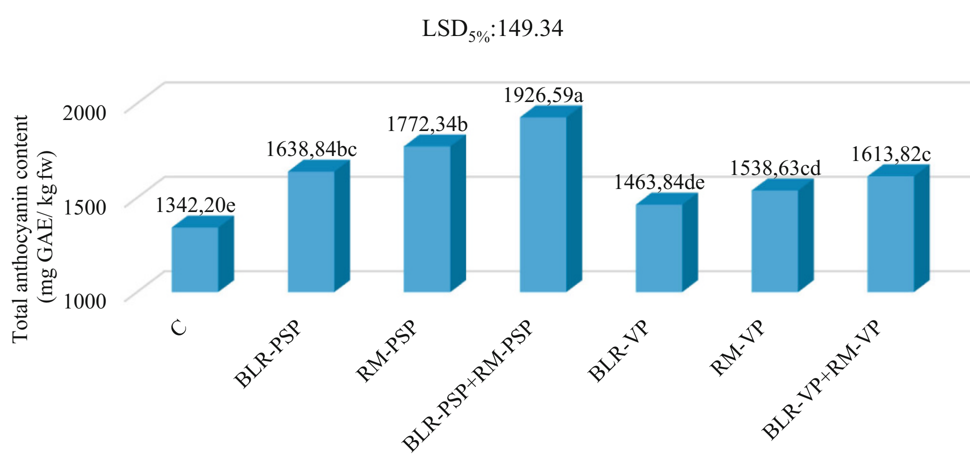

Fig. 7 Effects of treatment timings of basal leaf removal and reflective mulch on total anthocyanin content

Conclusions

Total soluble solids × pH^2, electrochemical quality assessment, total phenolic compounds content and total anthocyanin content are major wine grapes quality characteristics depending on grape cultivar, environmental conditions, growing location and different viticultural practices, as well as treatment timings of viticultural practices. Findings of present study indicate that the inductions of phenolic compounds and anthocyanins syntheses from the important quality characteristics seem to be associated with the treatment timings of basal leaf removal and reflective mulch. As a result, basal leaf removal plus reflective mulch treatment at pea size period were quite superior for increasing wine grape quality characteristics of cv. Cabernet Sauvignon.

Conflict of interest D. Kok declares that he has no competing interests.

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