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RESEARCH PAPER

Effects of Berry Thinning and Leaf Removal on Yield and Fruit Quality of Prima (*Vitis vinifera* L.) Grapevines Grown in Hot-Warm Climate

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Abstract

In viticulture, growing techniques affect fruit quality and yield, depending on environmental conditions and the characteristics of varieties. In this study, the effects of leaf removal ($LR_{1(ABS)}$, $LR_{1(V)}$, $LR_{2(BF/ABS)}$, and $LR_{2(BF/V)}$) and berry thinning (BT) treatments ($BT_{(+)}$ and $BT_{(-)}$) in the Prima early table grape variety were examined. Leaf removal treatments at different periods in shoots increased cluster width ($LR_{1(V)}$ and $LR_{2(BF/ABS)}$) and cluster size ($LR_{1(V)}$). In terms of berry characteristics, no significant effect of leaf removal was determined. Berry color index (CIRG) values were higher in the $LR_{2(BF/ABS)}$ and $LR_{2(BF/V)}$ treatments compared to the single-period leaf removal treatments ($LR_{1(ABS)}$, $BT_{(-)}$, $LR_{1(ABS)}$, $BT_{(+)}$, $LR_{1(V)}$, $BT_{(-)}$, $LR_{1(V)}$, $BT_{(+)}$). It was observed that performing leaf removal once at the berry set ($LR_{1(ABS)}$) increased acidity content, while performing it at the veraison ($LR_{1(V)}$) raised pH and maturity index values. While Photosystem II (PSII) and SPAD values of leaves in the leaf removal treatments were found to be similar, the highest PSII value of lateral shoot leaves was found in the $LR_{1(V)}$ treatment. Berry thinning at the rate of 1/3 in the cluster significantly increased cluster width, cluster homogeneity, berry length, 100-berry weight, and CIRG values compared to the control plants. Consequently, due to the partially observed different effects of leaf removal and berry thinning, it was concluded that investigating the effects of these treatments on some yield, quality, and canopy microclimate characteristics considering the timing and method of treatments together with varieties and changing climate characteristics would be beneficial.

1. Introduction

The Mediterranean Region is a prominent region in the cultivation of early table grapes, as in many other agricultural products in Türkiye. In the region, early harvesting is a significant advantage with the preference for varieties with low effective temperature sums in cultivation. This advantage can be further enhanced by prioritizing certain cultural practices necessary to improve grape quality and increase market value in table grape cultivation. Achieving optimal grape quality is closely related to vine vigor and yield levels, and it is possible through advisable activities within the vegetation period for vegetative and generative balance (Poni et al., 2018). In this sense, summer pruning has effects such as improving the canopy microclimate, advancing grape ripening, and reducing favorable conditions for pathogen development (Di Lorenzo et al., 2011). The growth of grape berries involves many biological, physiological, and chemical changes. Each growth stage may vary depending on the variety and environmental conditions (Burger et al., 2005).

Desired quality in table grapes represents a combination of medium-sized clusters of uniformly large, perfect berries with the characteristic color, pleasing flavor, and texture of the variety (Winkler et al., 1974).

Leaf removal (LR) in grapevines, also known as defoliation, is a canopy management technique that provides cost-effective and high-quality grape yield (Bakhsh et al., 2021). This technique is usually defined as the removal of the leaves from the basal portion of the shoots where clusters are also located. Traditionally, this intervention is carried out on dense canopies between fruit set and veraison with the aim of improving light penetration and air circulation around the clusters (Poni et al., 2018). This process can affect the microclimate around the cluster, and therefore, the cluster and berry characteristics (cluster length, cluster mass, rachis mass, number of berries, berry mass, and cluster compactness index) (Würz et al., 2020). To understand the multiple benefits that defoliation may provide, several studies have been conducted on the removal of leaves around grape clusters at different phenological stages of the vine (Yu et al., 2021). It is stated that the effects of leaf removal on grape quality are relatively consistent. This situation manifests itself in the total photosynthesis capacity depending on the shading intensity of the canopy at the basal part of the shoots, the timing of leaf removal, and the degree of leaf removal. Different results have been obtained in various studies regarding the interaction of the variety and the environment with this process (Poni et al., 2018). In one study on the Pinot Noir variety at the full flowering or EL-20 phenological stage, as a result of five different leaf removal levels (control, four, six, eight, and ten basal nodes of leaf removal), leaf removal from eight basal nodes caused low fruit set, and the removal of eight or ten leaves reduced cluster compactness (Acimovic et al., 2016). In the Cabernet Sauvignon and Marselan varieties, removing leaves in the cluster zone generally reduced titratable acidity in both varieties, but it did not affect the total soluble solid (TSS) content of grape berries, while it increased the anthocyanin and flavanol content of berries (Yao et al., 2024). Basal leaf removal after fruit set, compared to removal performed at the veraison stage, delayed ripening by reducing TSS values at harvest and increasing anthocyanin contents (Fernández-Zurbano et al., 2024). Early leaf removal (before flowering), compared to the control, partially reduced cluster compactness, decreased cluster rot by 61%, and increased TSS content by 5.2% (VanderWeide et al., 2021).

Berry thinning (BT) is one of the most important practices in the management of high-quality table grapes (Du and Liu, 2023). In table grapes, cluster weight, shape, and compactness, berry color, homogeneity, size, firmness, and total soluble solids (TSS), as well as the TSS/acidity ratio, are among the main quality characteristics (Domingos et al., 2016). Berry thinning is a common viticultural practice performed to improve cluster and fruit quality by reducing the number of berries in each cluster (Jia et al., 2023). Berry thinning is carried out after fruit set by cutting off a certain portion of the lower part of the cluster, with the aim of obtaining a greater number of grape clusters of the same size and quality on the vine (Zabadal, 2002). El-Salhy et al. (2022) reported that 25% berry thinning performed after fruit set in the Superior Seedless grape variety slightly reduced cluster weight and vine yield compared to the control, whereas it significantly increased berry weight and the concentration of some chemical components of grape juice. In another study conducted under greenhouse conditions (Jia et al., 2023), berry thinning treatment increased berry weight, TSS, fructose/glucose ratio, and anthocyanin content in two table grape varieties (Baoguang and Cuiguang). In the Crimson Seedless grape variety, berry thinning at different berry development stages effectively reduced cluster compactness but did not significantly affect yield, and early berry thinning (in 4-6 mm diameter) led to an increase in berry size (17.04 mm) and improvements in quality parameters such as color intensity (6.63%), total phenolic content (1.17 mg 100 g^{-1}), and anthocyanin content (22.41 mg 100 g^{-1}) (Kakade et al., 2025).

Berry thinning and leaf removal are important techniques in viticulture for achieving high-quality grape harvest (Devi et al., 2024). Climate change necessitates the re-evaluation of viticultural practices to manage grape quality (Assefa et al., 2025). In this study, under the conditions of the Eastern Mediterranean region in Türkiye, the effects of leaf removal at different times and degrees in the basal part of shoots and berry thinning treatments in clusters on grape quality and yield in Prima early table grape variety were investigated.

2.Material and Methods

This study was conducted in 2020 in the vineyard area of Hatay Mustafa Kemal University (36º26.566'N, 36º18.096'E). In the study, 3-year-old Prima vines grafted onto 1613C rootstock planted at 2.0 m × 1.5 m intervals were used. The soil in the trial area was determined as clay-loamy, non-saline, mildly alkaline, and calcareous, and its organic matter content was close to medium. Vines were trained with a vertical cordon training system, and short pruning was applied. During the trial, temperature and humidity values were recorded at hourly intervals in the study area with a datalogger (42270-EXTECH). Depending on growth levels, 13-16 shoots per vine were left.

Leaf removal and berry thinning treatments were performed in the study. The leaf removal treatments were performed by removing leaves and lateral shoots together. In these treatments, all leaves and lateral shoots from the lowest node to the node where the uppermost cluster was located on shoots were removed once after berry set (ABS) or at veraison (V). In some vines, leaf removal performed before flowering (BF) from the lowest node to the node where the first cluster was located was completed by a second removal on the same shoots up to the node where the last cluster was located, after fruit set or at veraison. The leaf removal treatments were carried out on April 27-28 for pre-flowering, May 23-26 for post-berry set, and June 15-17 for veraison. In half of the vines subjected to leaf removal, berry thinning (cutting 1/3 of the cluster tips) was performed, while berry thinning was not performed in the other half. Abbreviations and explanations of the 8 treatments included in the trial are given in Table 1.

The vegetative and generative plant parts removed during summer pruning are shown in Tables 2 and 3, respectively, for similar treatments (mean±standard deviation). Vegetatively, the number of leaves removed from summer shoots and lateral shoots that were cut off are given as total values per vine (Table 2). Generatively, in 4 treatments where berry thinning was performed, berry counts were made, and rachis lengths were measured in a total of 120 randomly taken 1/3 cluster tip parts. In 12 groups of 50 grape berries each (unripe) formed randomly, diameter and weight measurements were made (Table 3).

Harvested mature clusters were weighed on a digital scale, and yield values per vine (g vine^{-1}) and per unit area (kg ha^{-1}) were calculated. Five clusters were randomly taken from each vine, while in 15 clusters per replication, weight (g), width (cm), and length (cm) were measured, and cluster sizes (cm^2) were calculated. Clusters were visually evaluated according to berry size, and homogeneity ratios (%) were determined. In 20 berries taken from the middle 1/3 part of clusters, width (mm) and length

Table 1. Applications included in the experiment.

Application number	Abbreviations of applications	Description of applications
1	$LR_{1(ABS)}$, $BT_{(-)}$	LR: Leaf Removal
2	$LR_{1(ABS)}$, $BT_{(+)}$	BT: Berry Thinning
3	$LR_{1(V)}$, $BT_{(-)}$	1: One term
4	$LR_{1(V)}$, $BT_{(+)}$	2: Two term
5	$LR_{2(BF/ABS)}$, $BT_{(-)}$	BF: Before Flowering
6	$LR_{2(BF/ABS)}$, $BT_{(+)}$	ABS: After Berry Set
7	$LR_{2(BF/V)}$, $BT_{(-)}$	V: Veraison
8	$LR_{2(BF/V)}$, $BT_{(+)}$	-: Control, +: Application

Table 2. Values related to the removed vegetative parts in summer pruning (n/vine).

Application	Number of leaves (Mean±SD)	The total number of leaves of axillary shoots (Mean±SD)
$LR_{1(ABS)}$, $BT_{(-)}$, $LR_{1(ABS)}$, $BT_{(+)}$	66.2±8.6	94.1±14.5
$LR_{1(V)}$, $BT_{(-)}$, $LR_{1(V)}$, $BT_{(+)}$	61.7±6.1	135.8±19.7
$LR_{2(BF/ABS)}$, $BT_{(-)}$, $LR_{2(BF/ABS)}$, $BT_{(+)}$	*28.2±1.4	**92.5±4.5
$LR_{2(BF/V)}$, $BT_{(-)}$, $LR_{2(BF/V)}$, $BT_{(+)}$	*24.8±2.2	**120.7±27.2

LR: Leaf Removal, BT: Berry Thinning, BF: Before Flowering, ABS: After Berry Set, V: Veraison, 1: One term, 2: Two term, -: Control, +: Application. *: Excluding leaves cut from summer shoots before flowering, **: Excluding for the leaves on the axillary shoots cut before flowering.

Table 3. In berry thinning applications, berry number, berry weight, berry diameter and rachis length in 1/3 cluster parts.

Application		Features	Mean±SD
	$LR_{1(ABS)}$, $BT_{(+)}$ $LR_{1(V)}$, $BT_{(+)}$ $LR_{2(BF/ABS)}$, $BT_{(+)}$ $LR_{2(BF/V)}$, $BT_{(+)}$	Total berry number (n)	22.58±1.40
		Full-sized berries (n)	18.10±1.92
		Number of shot berries (n)	4.48±1.12
		Berry weight (g)	0.82±0.02
		Berry diameter (mm)	10.05±0.03
		1/3 rachis tip length (cm)	7.47±0.21

(mm) were measured, and 100 berries were weighed (g). Berry skin color (L, a*, b*) was measured with a Minolta CR 300 device. CIRG=(180−H)/(L+C) values were calculated (Carreño et al., 1996).

Cluster width and length were measured with a ruler, berry width and length were measured with calipers, and cluster and berry weights were measured with a precision scale. In grape juice obtained by squeezing with a cloth, TSS (%) was measured using a hand refractometer (Atago digital hand-held refractometer), pH was measured with a pH meter (pH330-WTW), and acidity (%) was calculated in terms of tartaric acid using the titration method with a 0.1N NaOH solution. According to each treatment, maturity index values (TSS/acidity) of the grapes were determined. Harvesting was carried out in the first week of July (Figure 1).

On each vine, in one marked shoot, SPAD (Minolta Co. Ltd. Japan) measurements of relative chlorophyll content (Brunetto et al., 2012) and photosystem II (PSII) activity (Murchie and Lawson, 2013) measurements conducted with a fluorimeter (FluorPen FP100, Photon System Instruments Ltd, Drasov, Czech Republic) were taken from the leaf located at the node just above the part where leaf removal was performed and from the leaf in the middle part of the lateral shoot after veraison.

During the study, when required, cultural practices such as soil tillage, spraying, sucker removal, shoot tying, weed control, irrigation, and fertilization were carried out. The trial was planned according to a factorial randomized plots design with three replications and three vines in each replication. Analyses of variance and Tukey's tests of the results obtained during the trial were performed at a significance level of 5% using the SAS 8.02 package program.

3.Results and Discussion

The weekly mean value plot of temperature and humidity data taken hourly in the area where the trial was conducted is given in Figure 2. During the 110-day vegetation period between budburst (March 21) and ripening date (July 8) for Prima grape variety, the effective temperature sum was calculated as 1450.5 degree-days. According to the records taken, during the period between budburst and grape harvest, temperature varied between 14.8°C and 30.8°C, and relative humidity varied from 35.8%

Figure 1. Grape maturity and fruit sampling.

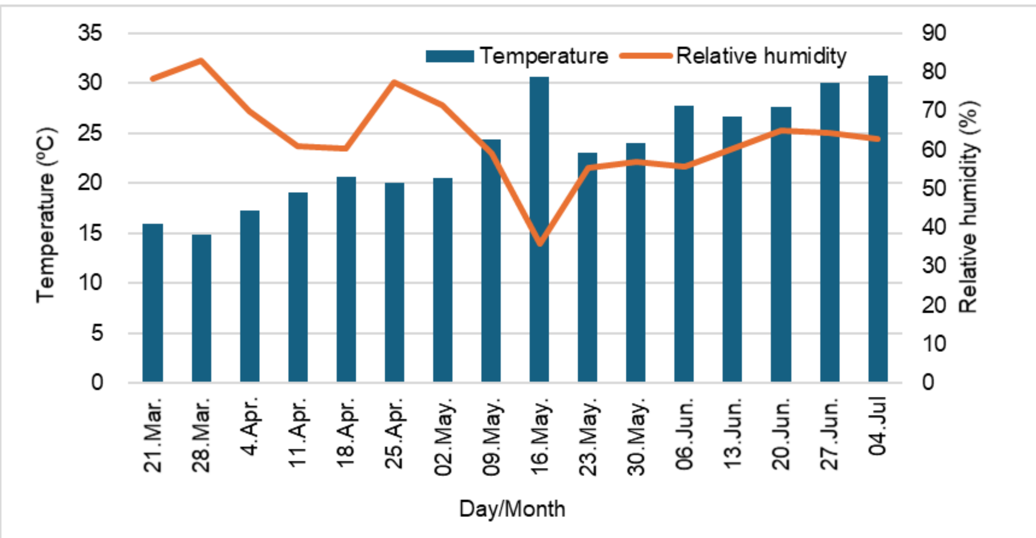

Figure 2. Weekly temperature (°C) and relative humidity (%) values of the experiment area.

to 83.1%. Between May 16 and 22, an increase above normal in air temperature and a decrease in relative humidity were determined.

In this study, the effects of the leaf removal and berry thinning treatments on yield parameters were not statistically significant. Single-period leaf removal treatments were observed to partially reduce grape yield per vine (g) and per hectare (kg), which may be attributed to the timing of leaf removal Table 4). The early removal of active leaves up to the uppermost cluster, when photosynthetic activity is still high following fruit set, or late removal (veraison), when photosynthetic efficiency declines, can both lead to a reduction in assimilate availability and consequently affect yield. However, two-stage leaf removal was associated with maintaining more active leaves in the cluster zone for a longer time and better light penetration and photosynthetic activity. Indeed, Somkuwar et al. (2024) reported that PAR (Photosynthetically Active Radiation) values and photosynthesis efficiency could increase depending on optimum leaf management in the cluster zone. Furthermore, Harner et al. (2024) observed a gradual decrease in yield in vines exposed to increased early-season leaf removal intensity (3 to 12 leaves per shoot). Under cultivation conditions, the grape yield values in the treatments were found in the range of 36-46 tonnes ha^{-1}. Berry thinning caused an insignificant reduction (1200 kg ha^{-1}) in grape yield in terms of general mean values. Dardeniz (2014) reported that in the Uslu and Cardinal varieties, when berry diameters were 5-7 mm, cutting cluster tips at 1/3, 1/6, and 1/12 ratios had no significant effect on grape yield. Kakade et al. (2025) stated that berry thinning at different berry development stages (4-6 mm, 6-8 mm, 8-10 mm, and 10-12 mm in diameter) in the Crimson Seedless variety did not significantly affect yield, while El-Salhy et al. (2022) also observed that berry thinning in Superior Seedless vines slightly reduced yield compared to the controls. The results of their study supported our results. The leaf removal treatments at different periods did not create significant effects on cluster homogeneity, cluster length, or cluster weight, while the $LR_{1(V)}$ and $LR_{2(BF/ABS)}$ treatments raised cluster width, and the $LR_{1(V)}$ treatment increased cluster size. In the berry thinning treatments, cutting 1/3 of cluster tips shortened cluster length values by approximately 7.5 cm. The shortened clusters continued to develop until ripening time, and the difference between this treatment and the control was statistically significant. In the berry thinning treatments, cluster width also increased, but cluster size was significantly lower compared to that in the control. The result in our study that cluster weight was not significantly affected by berry thinning was in parallel with those obtained in the Uslu and Cardinal varieties by Dardeniz (2014). Choi et al. (2021) reported that increasing berry thinning ratios (30% and 50%) in the Shine Muscat grape variety reduced cluster weight. Based on these results, it is understood that the effects of berry thinning may vary depending on the variety, the degree of thinning, and the development stage of berries.

While the effects of the leaf removal treatments on berry characteristics were not statistically significant, berry thinning caused significant increases in berry length and 100-berry weight (Table 5). Jia et al. (2023) determined that medium (30%) and severe (50%) berry thinning treatments significantly increased berry weight in the Baoguang and Cuiguang varieties. Han et al. (2019) also found that berry thinning in the Cabernet Sauvignon grape variety caused a significant increase in 100-berry weight compared to the controls. In the Superior Seedless grape variety, berry thinning at a ratio of 25% in the lower or upper parts of clusters increased berry weight compared to the control, and this increase was associated with reduced competition for basic nutrients among berries (El-Salhy et al., 2022).

Table 4. Effects of leaf removal and berry thinning applications on yield of Prima.

Leaf removal (LR)	Berry thinning (BT)	Yield (g $vine^{-1}$)	Yield (kg ha^{-1})
$LR_{1(ABS)}$	BT (-)	12255.56	40811.0
	BT (+)	11771.78	39200.0
	Mean	12013.67	40005.5
$LR_{1(V)}$	BT (-)	10811.89	36003.6
	BT (+)	11442.78	38104.5
	Mean	11127.33	37054.0
$LR_{2(BF/ABS)}$	BT (-)	13962.22	46494.2
	BT (+)	12216.11	40679.7
	Mean	13089.17	43586.9
$LR_{2(BF/V)}$	BT (-)	12675.33	42208.9
	BT (+)	12818.11	42684.3
	Mean	12746.72	42446.6
Berry thinning	(-)	12426.25	41379.4
	(+)	12062.19	40167.1
HSD 5% LR		NS*	NS
HSD5% BT		NS	NS
HSD%5 LR × BT		NS	NS

LR: Leaf Removal, BT: Berry Thinning, BF: Before Flowering, ABS: After Berry Set, V: Veraison, 1: One term, 2: Two term, - : Control, + : Application, *NS: Nonsignificant

Table 5. Effects of leaf removal and berry thinning applications on cluster and berry characteristics of Prima.

LR	BT	BHC (%)	CL (cm)	CW (cm)	CS (cm^2)	CWe (g)	BW (mm)	BL (mm)	100 BW (g)
$LR_{1(ABS)}$	BT (-)	90.78 (72.45)	21.64	13.57	293.84	494.33	19.08	20.10	470.82
	BT (+)	90.00 (71.60)	17.31	13.46	232.55	483.22	19.42	20.53	492.76
	Mean		19.47	13.51 ab	263.19 ab	488.78	19.25	20.32	481.79
$LR_{1(V)}$	BT (-)	90.56 (72.40)	22.37	13.44	301.15	484.37	18.56	20.24	458.42
	BT (+)	95.13 (77.28)	18.62	14.40	268.01	525.00	19.38	20.69	500.29
	Mean		20.50	13.92 a	284.58 a	504.68	18.97	20.47	479.36
$LR_{2(BF/ABS)}$	BT (-)	86.67 (68.86)	21.10	13.30	280.95	480.29	18.83	20.22	434.81
	BT (+)	95.13 (77.46)	18.77	14.49	272.60	543.09	18.89	20.38	495.10
	Mean		19.94	13.89 a	276.78 ab	511.69	18.86	20.30	464.95
$LR_{2(BF/V)}$	BT (-)	91.58 (73.20)	20.48	11.87	243.39	420.69	19.16	20.63	473.89
	BT (+)	92.71 (74.58)	18.71	13.14	245.73	458.22	19.32	20.87	482.24
	Mean		19.60	12.51 b	244.56 b	439.46	19.24	20.75	478.06
BT	(-)	89.89 (71.73) B[x]	21.40 A	13.04 B	279.83 A	469.92	18.91	20.30 B	459.48 B
	(+)	93.24 (75.23) A	18.35 B	13.87 A	254.72 B	502.38	19.25	20.62 A	492.60 A
HSD 5% LR		NS[y]	NS	*	*	NS	NS	NS	NS
HSD5% BT		*	*	*	*	NS	NS	*	*
HSD%5 LR × BT		NS	NS	NS	NS	NS	NS	NS	NS

LR: Leaf Removal, BT: Berry Thinning, BF: Before Flowering, ABS: After Berry Set, V: Veraison, 1: One term, 2: Two term, -: Control, +: Application, BHC: Berry homogeneity in cluster, CL: Cluster length, CW: Cluster width, CS: Cluster size, CWe: Cluster weight, BW: Berry width, BL: Berry length, 100BW: 100 berry weight.
[x] Different letters within the columns indicate significant differences among means (*P≤0.05*). [y] NS, Nonsignificant.

Table 6. Effects of leaf removal and berry thinning applications on berry colour and must characteristics of Prima.

LR	BT	L	a*	b*	CIRG	TSS (%)	pH	Acidity (%)	Maturity index
$LR_{1(ABS)}$	BT (-)	26.08 a[x]	2.39	1.09 a	5.59	14.62	3.51	0.74	19.89
	BT (+)	25.06 ab	2.30	0.82 ab	5.92	14.88	3.55	0.73	20.41
	Mean	25.57 a	2.35	0.96	5.76 b	14.75	3.53 c	0.73 a	20.15 b
$LR_{1(V)}$	BT (-)	25.32 ab	1.87	0.72 a	5.82	15.17	3.63	0.62	24.50
	BT (+)	26.39 a	2.06	0.59 ab	5.77	15.10	3.63	0.67	22.70
	Mean	25.86 a	1.97	0.65	5.80 b	15.14	3.63 a	0.64 b	23.60 a
$LR_{2(BF/ABS)}$	BT (-)	24.17 bc	2.37	0.86 ab	6.07	14.58	3.56	0.63	23.23
	BT (+)	22.73 c	2.62	0.82 ab	6.46	14.25	3.53	0.64	22.26
	Mean	23.45 b	2.49	0.84	6.26 a	14.41	3.55 bc	0.63 b	22.75 ab
$LR_{2(BF/V)}$	BT (-)	24.95 ab	2.81	0.65 b	6.04	13.36	3.59	0.62	21.70
	BT (+)	23.36 c	1.98	0.84 a	6.27	15.25	3.65	0.66	23.28
	Mean	24.15 b	2.39	0.75	6.15 a	14.30	3.62 ab	0.64 b	22.49 ab
BT	(-)	25.13 A	2.36	0.83	5.88 B	14.43	3.57	0.65 B	22.33
	(+)	24.39 B	2.24	0.77	6.11 A	14.87	3.59	0.67 A	22.16
HSD 5% LR		*	NS[y]	NS	*	NS	*	*	*
HSD5% BT		*	NS	NS	*	NS	NS	*	NS
HSD%5 LR × BT		*	NS	*	NS	NS	NS	NS	NS

LR: Leaf Removal, BT: Berry Thinning, BF: Before Flowering, ABS: After Berry Set, V: Veraison, 1: One term, 2: Two term, -: Control, +: Application, CIRG: Berry color index, TSS: Total soluble solids.
[x] Different letters within the columns indicate significant differences among means (*P≤0.05*). [y] NS, Nonsignificant.

The berry color development of the variety was affected significantly (except for a* values) by the leaf removal and berry thinning treatments. The highest values in the L color parameter were obtained in the $LR_{1(V)BT(+)}$ treatment and in $BT_{(-)}$ cases in other LR treatments. In terms of the b* color parameter, $LR_{2(BF/V)}BT_{(+)}$ displayed high values, while among other LR treatments, $BT_{(-)}$ resulted in high values. The LR x BT interaction was significantly effective on these two characteristics. CIRG values were significantly higher in the $LR_{2(BF/ABS)}$ and $LR_{2(BF/V)}$ treatments compared to the $LR_{1(ABS)}$ and $LR_{1(V)}$ treatments. According to the color scale of Carreño et al. (1996), when leaf removal was performed in a single period in our study, red-black (5.76-5.80) color formation was prominent, and when it was performed in two periods, blue-black (6.15-6.26) color formation was prominent. Devi et al. (2024) also reported that clusters should be exposed to sunlight during ripening for berries to color best. In this study, compared to clusters without berry thinning, darker (blue-black) color formation occurred in those with berry thinning (Table 6). Kakade et al. (2025) observed that berry thinning in the Crimson Seedless variety caused significant differences in color intensity (5.34-6.63). In grapes harvested at ripening time, differences were determined in juice pH, acidity, and maturity index values according to mean values in the leaf removal treatments, but not in TSS. The highest pH and maturity index values were found in the $LR_{1(V)}$ treatment, followed by the $LR_{2(BF/V)}$ treatment. In the $LR_{1(ABS)}$ treatment performed early and once, acidity content was the highest, while pH and maturity index values were the lowest (Table 6). In this study, the TSS contents of the treatments were determined to be in the range of 14.25-15.25% (except for $LR_{2(BF/V)}BT_{(-)}$), and maturity index values were determined as 19.89 and above. These values were within the classification of table grape ripening defined by Poni et al. (2018), where TSS values were 14.0%≤ … <16.0%, and TSS/acidity ratios were ≥18:1. Defoliation at different periods did not affect TSS contents in the Merlot variety (Sivilotti et al., 2016). On the other hand, in the Cabernet Sauvignon variety, increasing degrees of leaf removal at the fruit set stage caused higher acidity (Cataldo et al., 2021). These results were considered to support our results.

The physiological responses to the treatments were assessed based on photosynthetic potential and photosynthetic efficiency, as determined by SPAD and PSII measurements, which indirectly influence grape yield and quality. Chlorophyll fluorescence shows changes in linear electron flow and CO_2 assimilation with PSII in the monitoring of photosynthetic performance in plants (Baker, 2008). As a result of the leaf removal treatments in this study, PSII values in leaf measurements were found similar, while in lateral shoot leaf measurements, the $LR_{1(V)}$ treatment provided the highest value, and the $LR_{2(BF/V)}$ treatment provided the lowest value. This difference among the treatments was statistically significant. SPAD measurements were not affected by different leaf removal treatments in this study (Table 7). The finding that leaf removal at berry set in the Cabernet Sauvignon grape variety did not cause significant differences in PSII and SPAD values compared to the controls (Cataldo et al., 2021) was similar to our results. In vines subjected to berry thinning, compared to those not subjected to this treatment, no statistically significant differences were observed in PSII and SPAD measurements of both shoot and lateral shoot leaves.

4. Conclusion

In this study, the potential effects of leaf removal and berry thinning treatments in the cluster zone of Prima grape variety were investigated. In general, in the methods and strategies of summer pruning practices in Mediterranean sub-regions, leaf removal treatments are now applied much more carefully and conservatively, particularly under the influence of changing climate conditions (Poni et al., 2023). Planning leaf removal gradually according to photosynthetic activity and light requirements in the cluster zone can have positive effects on grape yield and quality. Indeed, in our study, leaf removal performed twice caused a partial increase in yield. In leaf removal treatments performed during different periods, $LR_{1(V)}$ and $LR_{2(BF/ABS)}$ increased cluster width, and $LR_{1(V)}$ increased cluster size. Grape berry characteristics did not respond to leaf removal treatments to a significant extent. Berry color index (CIRG) values were found higher in the two-period leaf removal treatments ($LR_{2(BF/ABS)}$ and $LR_{2(BF/V)}$) compared to the single-period treatments. The $LR_{1(ABS)}$ treatment, which was performed early and once, increased acidity contents, while the $LR_{1(V)}$ treatment performed at veraison increased pH and maturity index values. The PSII and SPAD measurement values of leaves were similar among the leaf removal treatments, while the highest PSII values of lateral shoot leaves were found in the $LR_{1(V)}$ treatment. Berry thinning at the rate of 1/3 in clusters showed effects that increased cluster width, cluster homogeneity, berry length, 100-berry weight, and berry color index values.

Table 7. Effects of leaf removal and berry thinning applications on leaf PSII and SPAD values of Prima.

LF	BT		Main leaf		Lateral leaf	
			PSII	SPAD	PSII	SPAD
$LR_{1(ABS)}$	BT (-)		0.76	47.62	0.76	38.71
	BT (+)		0.75	50.18	0.75	40.24
		Mean	0.76	48.90	0.75 ab[x]	39.48
$LR_{1(V)}$	BT (-)		0.78	47.76	0.77	38.81
	BT (+)		0.77	48.29	0.77	39.47
		Mean	0.78	48.02	0.77 a	39.14
$LR_{2(BF/ABS)}$	BT (-)		0.76	50.11	0.73	41.34
	BT (+)		0.78	48.67	0.75	39.93
		Mean	0.77	49.39	0.74 ab	40.64
$LR_{2(BF/V)}$	BT (-)		0.78	50.59	0.74	39.74
	BT (+)		0.74	47.90	0.73	39.08
		Mean	0.76	49.24	0.73 b	39.41
BT	(-)		0.77	49.02	0.75	39.65
	(+)		0.76	48.76	0.75	39.68
HSD 5% LR			NS[y]	NS	*	NS
HSD5% BT			NS	NS	NS	NS
HSD%5 LR × BT			NS	NS	NS	NS

LR: Leaf Removal, BT: Berry Thinning, BF: Before Flowering, ABS: After Berry Set, V: Veraison, 1: One term, 2: Two term, -: Control, +: Application, PSII: Photosystem II.
[x] Different letters within the columns indicate significant differences among means (*P≤0.05*). [y] NS, Nonsignificant.

In conclusion, since the treatments showed different effects considering some of the examined parameters, it was determined that it would be beneficial to investigate in detail the effects of leaf removal and berry thinning practices on yield, quality, and ripening time in terms of timing and method together with varieties and changing climate characteristics.

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