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Impact of thinning level and timing on yield, maturity, and quality of Merlot grapevines under the Big T trellis system

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Abstract: This study evaluated the effects of cluster thinning on yield and quality of 12-year-old Merlot/41B grapevines over the 2019–2020 and 2020–2021 growing seasons. Six phenological stages-before flowering, setting, bunch closure, veraison, half maturity, and before maturity-and three thinning levels (0%, 25%, and 50%) were assessed. Key parameters included total soluble solids (TSS), total acidity (TA), pH, sugar accumulation, maturity indices (TSS/TA, $pH^2 \times$ °Brix), secondary metabolites (total anthocyanins, total tannins, total phenolic content, total polyphenol index), and yield. Cluster thinning significantly enhanced most quality traits, with veraison emerging as the optimal stage for improving phytochemical composition. The highest TSS was observed at setting, while maximum total anthocyanins, tannins, total polyphenol index (TPI), and maturity indices occurred at veraison under 50% thinning. Sugar accumulation was optimised at 25% thinning. Yield decreased proportionally with thinning intensity, with Control vines producing the highest yield and 50% thinning the lowest. Overall, 25% cluster thinning at veraison achieved a balance between improved grape quality and commercial yield, providing a practical management strategy for Merlot production.

Keywords: Merlot; cluster thinning; phenological stages; grape quality; secondary metabolites

Cluster thinning is a key viticultural practice used to balance vegetative and reproductive growth and improve grape quality. Excessive crop load can delay ripening and alter berry composition; therefore, growers regulate canopy structure and remove part of the crop to balance leaf area and fruit load (King et al. 2015). Thinning increases the source–sink ratio and enhances the photosynthetic performance of the remaining foliage. A number of practices are implemented to improve the quality of both table and wine grapes. One of these practices is cluster thinning, which is frequently used in wine grapes (Vanderweide et al. 2024; Čuš et al. 2025). This is especially important for high-

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yielding cultivars where crop control is essential for premium wine production (Reeve et al. 2018).

Wine quality is closely linked to fruit composition, including total soluble solids (TSS), acidity, phenolics, and aroma (Gatti et al. 2012). Thinning generally raises TSS (Choi et al. 2021; Salazar et al. 2021; Aru et al. 2022; Alshallash et al. 2023; Korkutal et al. 2023), though results vary among years and sites (Suklje et al. 2022; Martínez-Lüscher, Kurtural 2023).

Phenolic composition, including anthocyanins and tannins, also tends to improve with thinning, enhancing colour and aroma in cultivars such as 'Syrah', 'Pinot Noir', 'Cabernet Sauvignon', and 'Tempranillo' (Mawdsley et al. 2019; Alba et al. 2022; Artem et al. 2022; XiaoJun et al. 2023). Total phenolic content often rises following thinning (Choi et al. 2021; Salazar et al. 2021; Soltekin et al. 2023), though some studies report negligible effects (Bubola et al. 2017).

Yield reduction is typically proportional to thinning intensity, often 25–50% (Vicente, Yuste 2015; Mesic et al. 2020; Mancha et al. 2021; Copp et al. 2022; Suklje et al. 2022; Alshallash et al. 2023; Janas et al. 2023), and can exceed 40% in some cases (Korkutal, Kaymaz 2016; Mawdsley et al. 2019). Although yield losses may affect economic returns (Bubola et al. 2017; Nistor et al. 2020; Cameron et al. 2024), improved fruit composition can offset this in premium wine production.

Thinning timing also affects results, with applications from flowering to veraison and near harvest (Nistor et al. 2020; Mesic et al. 2020; Carmona-Jiménez et al. 2021; Mancha et al. 2021). Training system influences responses; in Big T systems, vines often carry 10–12 clusters per shoot, increasing yield but potentially diluting berry composition.

This study evaluated cluster thinning at different stages and intensities in a Merlot vineyard trained to the Big T system to determine optimal strategies for balancing yield and grape quality.

MATERIAL AND METHODS

The study was conducted in a Merlot vineyard located at 39°48'3.33''N, 26°22'0.09''E, with vines grafted onto 41B rootstock. Merlot is characterised by large clusters and berries, resulting in high yield potential compared to other wine grape cultivars (King et al. 2015). Vines were planted at 1.5 × 3 m spacing and trained using a double-cane Big T trellis system, with each main cane bearing 7–8 short-pruned annual shoots. Shoots were topped at 40–45 cm, soil was tilled in May and again one month after harvest, and the vineyard was non-irrigated. Fertilisation consisted of organic manure applied to the soil and a 20-20-20 NPK foliar fertiliser before flowering.

Experimental design. A two-factor factorial experiment was conducted using a randomised complete block design with six cluster thinning stages and three thinning levels. Each treatment was replicated three times, with three vines per replication, totalling 162 vines. Border vines were left at the beginning, end, and between rows to minimise edge effects. Vines were selected to ensure uniform growth vigour, main cane number, shoot number, and cluster number. Total cluster counts were recorded and equalised to an average of 30–40 clusters per vine.

Cluster thinning application periods. Cluster thinning was applied at six phenological stages, corresponding to EL-15, EL-27, EL-32, EL-35, EL-36, and EL-37 (Lorenz et al. 1995; Table 1).

Table 1. Cluster thinning application dates according to phenological stages

Phenological stage	EL stage	Description	°Brix	2021	2022
Before flowering (BF)	EL-15	leaves separated, shoots elongating rapidly; single flowers in compact groups	–	10.04.	06.04.
Setting (S)	EL-27	fruit set; young berries enlarging (>2 mm diameter), bunch at right angles to the stem	–	25.05.	21.05.
Bunch closure (BC)	EL-32	beginning of bunch closure; berries touching if the bunch is tight	–	20.06.	10.06.
Veraison (V)	EL-35	berry softening and onset of colour development	–	19.07.	16.07.
Half maturity (HM)	EL-36	berries with intermediate sugar accumulation	12–14	17.08.	10.08.
Before maturity (BM)	EL-37	berries not fully ripe	20–22	01.09.	31.08.

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Cluster thinning applications. Control (0%) (C): No clusters were removed.

Cluster thinning (25%) (CT1): 25% of existing clusters were removed from the shoots according to the application periods.

Cluster thinning (50%) (CT2): 50% of clusters on the shoots were removed.

Grape biochemistry, maturity indices, and yield. Grape composition was assessed using standard measurements of TSS, total acidity (TA), and pH (Cemeroğlu 2007). The following parameters were calculated: the sugar concentrations (g/L) corresponding to the °Brix values of the samples were determined from the chart (Bahar et al. 2011). The sugar amount per berry was calculated using the following formula:

$$\text{Sugar amount per berry (mg/berry)} = [1/1.3 \times \times \text{sugar (g/L)}] \times [1/100 \times 100 \text{ berry weight (g)}] \quad (1)$$

Maturity indices such as TSS/TA and $pH^2 \times$ °Brix were also determined (Blouin, Guimberteau 2000). After seed removal, grapes were crushed, centrifuged, and filtered. Total anthocyanin content was determined using the pH differential method (Cemeroğlu 2007). Total tannin content was measured at 760 nm using the Folin-Denis reagent, and total phenolic content (TPC) at 765 nm using the Folin-Ciocalteu reagent (Merck, Darmstadt, Germany) (Waterhouse 2002). The total polyphenol index (TPI) was measured at 280 nm (INRA 2007). Yield (kg/day) was calculated based on the number of vines per decare and the yield per vine.

Data analysis. All data were analysed using the MSTAT-C statistical package (version 1.2, 1986). Differences among treatments were evaluated using the Least Significant Difference test.

RESULTS AND DISCUSSION

Cluster thinning did not significantly affect TSS at $P < 0.05$; however, a clear linear increase was observed with thinning intensity (C: 23.03 °Brix, CT1: 23.36 °Brix, CT2: 23.41 °Brix). TSS was slightly lower in 2022 (23.14 °Brix) than in 2021 (23.39 °Brix). Consistent with Gao and Cahoon (1998), and Soltekin et al. (2023), the highest TSS values were recorded where fewer clusters remained. Among phenological stages, setting (S) yielded the highest TSS.

Analysis of variance indicated significant effects of phenological stage ($P < 0.05$), thinning level, and year on TA. TA decreased with thinning intensity (C: 6.77 g/L, CT1: 6.43 g/L, CT2: 6.30 g/L). Before maturity (BM) (6.95 g/L), before flowering (BF) (6.85 g/L), and bunch closure (BC) (6.71 g/L) showed the highest TA, while veraison (V) had the lowest (5.84 g/L). Year effects revealed higher TA in 2021 (7.25 g/L) than in 2022 (5.75 g/L), likely due to greater rainfall. This inverse relationship between cluster number and TA agrees with Gao and Cahoon (1998) and Palliotti and Cartechini (2000).

pH was significantly affected by phenological stage, thinning level, year, and their interaction (cluster thinning × period interaction; CT × P). It ranged from 3.20 to 3.99, with BC showing the highest (3.77) and V the lowest (3.56) values. Year effects were also evident, with a higher pH in 2022 (3.80) than in 2021 (3.46). The highest interaction effect was observed in CT2 × BC (3.84). Kennedy et al. (2009) similarly reported higher pH in cluster-thinned Merlot vines compared to control treatments.

Cluster thinning increased sugar concentration (g/L) despite the lack of statistical significance for some parameters. The lowest sugar concentration was in the control, and the highest was in CT2. Phenological stages ranged from 225.75 g/L (BM) to 232.14 g/L (S), with higher values in 2021. Sugar per berry (mg/berry) followed the same trend: CT1 (200.95 mg/berry) > CT2 (187.99 mg/berry) > C (173.74 mg/berry), with maximum values at S and V. Sugar per gram of berry (mg/g) also rose with thinning (CT1: 177.13 mg/g > CT2: 175.02 mg/g > C: 171.31 mg/g), highest at BF (181.99 mg/g). These results corroborate Bahar et al. (2017), Vicente and Yuste (2015), and Korkutal et al. (2023), who reported increased sugar accumulation under cluster thinning.

Maturity indices (TSS/TA and $pH^2 \times$ °Brix) confirmed that CT1 and CT2 accelerated ripening and improved sugar-acid balance compared with Control. V and BC exhibited the highest indices, whereas BM and early thinning showed lower values. Interaction effects were notable for $pH^2 \times$ °Brix, with CT2 × BC reaching the maximum. Higher maturity indices in 2022 further emphasised the role of environmental conditions. These results align with Bahar et al. (2017) and Korkutal et al. (2023) (Figures 1 and 2).

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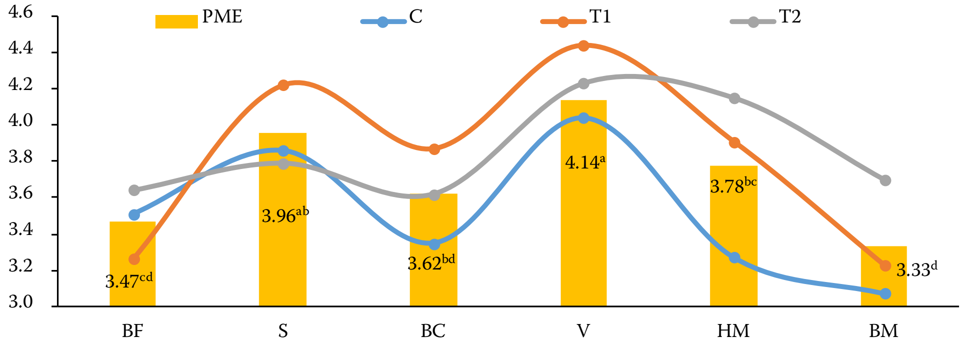

Figure 1. Maturity index (TSS/TA) values according to the application periods and thinning levels

TSS – total soluble solids; TA– total acidity; PME – period main effect; BF – before flowering; S – setting; BC – bunch closure; V – veraison; HM – half maturity; BM – before maturity; C – control; T1 – thinning 1; T2 – thinning 2; TME $P < 0.05$: 0.25; PME $P < 0.05$: 0.35; YME $P < 0.05$: 0.20; T×Y $P < 0.05$: 0.50

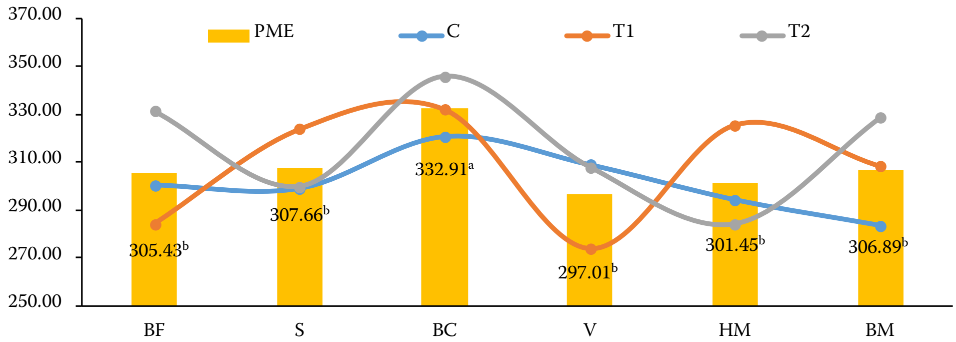

Figure 2. Maturity index (pH^2 × °Brix) values according to the application periods, and thinning levels

PME – period main effect; BF – before flowering; S – setting; BC – bunch closure; V – veraison; HM – half maturity; BM – before maturity; C – control; T1 – thinning 1; T2 – thinning 2; PME $P < 0.05$: 21.06; YME $P < 0.05$: 12.16; CT × P $P < 0.05$: 36.48

Table 2. Total anthocyanin values according to application periods, thinning levels, and year

CTA	Year	Application periods						Main effects	
		BF	S	BC	V	HM	BM	TME	YME
C	2021	357.20	430.34	389.51	355.73	388.92	323.71	352.13^{C}	
	2022	324.00	308.73	353.67	330.76	319.30	343.69		
	CT × P	340.60^{de}	369.58^{ce}	371.59^{ce}	343.24^{de}	354.11^{de}	333.70^{de}		
CT1	2021	469.12	383.93	473.52	314.90	468.82	294.33	392.55^{B}	2021: 408.44; 2022: 380.80
	2022	371.89	377.61	448.26	452.64	311.96	343.69		
	CT × P	420.50^{bd}	380.77^{ce}	460.89^{bc}	383.77^{ce}	390.39^{ce}	319.01^{e}		
CT2	2021	470.88	357.20	464.71	624.51	452.96	331.64	439.18^{A}	
	2022	379.23	410.95	529.92	606.88	314.89	326.35		
	CT × P	425.05^{bd}	384.07^{ce}	497.31^{b}	615.70^{a}	383.93^{ce}	329.00^{de}		
PME		395.38^{ab}	378.13^{bc}	443.26^{a}	447.57^{a}	376.14^{bc}	327.23^{c}		

CTA – cluster thinning applications; C – control, CT1 – 25% cluster thinning, CT2 – 50% cluster thinning; PME – period main effect; BF – before flowering; S – setting; BC – bunch closure; V – veraison; HM – half maturity; BM – before maturity; TME – thinning main effect; YME – year main effect; CT × P – cluster thinning × period interaction; PME $P < 0.05$: 57.09; TME $P < 0.05$: 40.38; CT × P $P < 0.05$: 98.89; uppercase letters – TME; lowercase-italic letters – PME; lowercase letters – CT × P

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Table 3. Total tannin content according to application periods, thinning levels, and year

CTA	Year	Application periods						Main effects		
		BF	S	BC	V	HM	BM	TME	YME	
	2021	1.26	1.51	1.35	1.33	1.20	1.29			
C	2022	1.28	1.36	1.42	1.23	1.27	1.12	1.30^{c}		
	CT × P	$1.27^{\mathbf{fg}}$	$1.44^{\mathbf{cg}}$	$1.39^{\mathbf{dg}}$	$1.28^{\mathbf{fg}}$	$1.23^{\mathbf{fg}}$	$1.20^{\mathbf{g}}$			
	2021	1.43	1.45	1.17	1.39	1.32	1.32			
CT1	2022	1.92	1.73	1.50	1.98	1.37	1.27	1.49^{b}	2021 1.40^{B}	2022 1.60^{A}
	CT × P	$1.67^{\mathbf{be}}$	$1.59^{\mathbf{bf}}$	$1.33^{\mathbf{dg}}$	$1.68^{\mathbf{be}}$	$1.34^{\mathbf{dg}}$	$1.30^{\mathbf{eg}}$			
	2021	1.53	1.30	1.38	2.40	1.50	1.09			
CT2	2022	2.25	2.12	2.23	2.24	1.26	1.32	1.72^{a}		
	CT × P	$1.89^{\mathbf{b}}$	$1.71^{\mathbf{bd}}$	$1.80^{\mathbf{bc}}$	$2.32^{\mathbf{a}}$	$1.38^{\mathbf{dg}}$	$1.20^{\mathbf{g}}$			
PME		1.61^{ab}	1.58^{ab}	1.51^{bc}	1.76^{a}	1.32^{cd}	1.23^{d}			

CTA – cluster thinning applications; C – control, CT1 – 25% cluster thinning, CT2 – 50% cluster thinning; PME – period main effect; BF – before flowering; S – setting; BC – bunch closure; V – veraison; HM – half maturity; BM – before maturity; TME – thinning main effect; YME – year main effect; CT × P – cluster thinning × period interaction; TME $P < 0.05$: 0.16; PME $P < 0.05$: 0.22; YME $P < 0.05$: 0.13; CT × P $P < 0.05$: 0.38; uppercase letters – YME; lowercase-italic letters – PME; lowercase letters – TME; lowercase-bold letters – CT × P

Cluster thinning significantly increased anthocyanin content (Table 2). CT2, especially at V and BC, produced the highest levels, with CT2 × V reaching 615.70 mg/kg. These results are in agreement with Palliotti and Cartechini (2000), González-Neves and Ferrer (2008), and Mawdsley et al. (2019), who reported greater anthocyanin accumulation under more intense thinning.

Tannin content (Table 3) was significantly influenced by thinning level, phenological stage, year, and their interactions. CT2 consistently produced the highest tannin levels, peaking at V, while BM had the lowest. Greater tannin content in 2022 supports findings of Wang et al. (2022) and Korkutal et al. (2023), who observed proportional increases in tannins with cluster thinning intensity.

TPC (Table 4) was highest in CT2 (1634.02 mg/kg), followed by CT1 (1313.76 mg/kg) and Control (1094.11 mg/kg). Stages S (1595.63 mg/kg) and V

Table 4. Total phenolic content values according to application periods, thinning levels, and year

CTA	Year	Application periods						Main effects		
		BF	S	BC	V	HM	BM	TME	YME	
	2021	$1\,128.33^{ho}$	$1\,520.75^{cg}$	882.87^{mp}	844.99^{op}	916.21^{lp}	869.24^{np}			
C	2022	998.03^{kp}	$1\,101.06^{io}$	$1\,107.12^{io}$	$1\,251.06^{fm}$	$1\,123.79^{ho}$	$1\,385.89^{ej}$	$1\,094.11^{\mathbf{c}}$		
	CT × P	$1\,063.18^{\boldsymbol{fh}}$	$1\,310.90^{\boldsymbol{cf}}$	$994.99^{\boldsymbol{gh}}$	$1\,048.02^{\boldsymbol{gh}}$	$1\,020.00^{\boldsymbol{gh}}$	$1\,127.56^{\boldsymbol{eh}}$			
	2021	$1\,184.39^{go}$	$1\,791.97^{cd}$	988.94^{kp}	654.24^{p}	$1\,022.27^{jp}$	832.88^{op}			
CT1	2022	$1\,132.88^{ho}$	$1\,192.73^{go}$	$1\,822.27^{bc}$	$2\,307.12^{a}$	$1\,457.12^{ci}$	$1\,378.33^{ej}$	$1\,313.76^{\mathbf{b}}$	2021 $1\,242.32^{B}$	2022 $1\,452.28^{A}$
	CT × P	$1\,158.63^{\boldsymbol{dh}}$	$1\,492.35^{\boldsymbol{c}}$	$1\,405.60^{\boldsymbol{cd}}$	$1\,480.68^{\boldsymbol{c}}$	$1\,239.69^{\boldsymbol{cg}}$	$1\,105.60^{\boldsymbol{eh}}$			
	2021	$1\,437.42^{di}$	$2\,326.82^{a}$	$1\,485.91^{ch}$	$2\,190.45^{ab}$	$1\,614.70^{cf}$	669.39^{p}			
CT2	2022	$1\,216.21^{gn}$	$1\,640.45^{ce}$	$2\,169.24^{ab}$	$2\,272.27^{a}$	$1\,332.88^{ek}$	$1\,252.57^{fl}$	$1\,634.02^{\mathbf{a}}$		
	CT × P	$1\,326.82^{\boldsymbol{ce}}$	$1\,983.63^{\boldsymbol{ab}}$	$1\,827.57^{\boldsymbol{c}}$	$2\,231.36^{\boldsymbol{a}}$	$1\,473.79^{\boldsymbol{c}}$	$960.98^{\boldsymbol{h}}$			
PME		$1\,182.87^{\mathit{cd}}$	$1\,595.63^{\mathit{a}}$	$1\,409.39^{\mathit{b}}$	$1\,586.69^{\mathit{a}}$	$1\,244.49^{\mathit{c}}$	$1\,064.72^{\mathit{d}}$			

CTA – cluster thinning applications; C – control, CT1 – 25% cluster thinning, CT2 – 50% cluster thinning; PME – period main effect; BF – before flowering; S – setting; BC – bunch closure; V – veraison; HM – half maturity; BM – before maturity; TME – thinning main effect; YME – year main effect; CT × P – cluster thinning × period interaction; TME $P < 0.05$: 106.44; PME $P < 0.05$: 150.52; YME $P < 0.05$: 86.89; CT × P $P < 0.05$: 260.69; T × Y × P $P < 0.05$: 368.69; uppercase letters – YME; lowercase-italic letters – PME; lowercase-bold letters – TME; lowercase-bold-italic letters – CT × P; lowercase letters – T × Y × P

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Table 5. Total polyphenol index values according to application periods, thinning levels, and year

CTA	Year	Application periods						Main effects		
		BF	S	BC	V	HM	BM	TME	YME	
C	2021	4.03	7.62	6.88	7.29	6.27	6.60	6.40^{c}		
	2022	6.27	7.16	6.24	5.74	6.28	6.47			
	CT × P	5.15$^{\mathbf{g}}$	7.39$^{\mathbf{df}}$	6.56$^{\mathbf{fg}}$	6.52$^{\mathbf{fg}}$	6.27$^{\mathbf{fg}}$	6.54$^{\mathbf{fg}}$			
CT1	2021	8.16	8.82	10.53	7.91	7.50	7.07	8.08^{b}	2021 8.06^{A}	2022 7.47^{B}
	2022	6.61	7.76	8.45	9.72	7.13	7.35			
	CT × P	7.38$^{\mathbf{df}}$	8.29$^{\mathbf{ce}}$	9.49$^{\mathbf{bc}}$	8.81$^{\mathbf{cd}}$	7.31$^{\mathbf{ef}}$	7.21$^{\mathbf{ef}}$			
CT2	2021	9.66	9.66	10.77	11.86	7.34	7.15	8.81^{a}		
	2022	6.89	8.51	9.88	10.34	6.44	7.18			
	CT × P	8.28$^{\mathbf{ce}}$	9.09$^{\mathbf{bc}}$	10.32$^{\mathbf{ab}}$	11.10$^{\mathbf{a}}$	6.89$^{\mathbf{ef}}$	7.17$^{\mathbf{ef}}$			
PME		6.93$^{\mathit{b}}$	8.25$^{\mathit{a}}$	8.79$^{\mathit{a}}$	8.81$^{\mathit{a}}$	6.82$^{\mathit{b}}$	6.97$^{\mathit{b}}$			

CTA – cluster thinning applications; C – control, CT1 – 25% cluster thinning, CT2 – 50% cluster thinning; PME – period main effect; BF – before flowering; S – setting; BC – bunch closure; V – veraison; HM – half maturity; BM – before maturity; TME – thinning main effect; YME – year main effect; CT × P – cluster thinning × period interaction; TME $P < 0.05$: 0.58; PME $P < 0.05$: 0.83; YME $P < 0.05$: 0.48; CT × P $P < 0.05$: 1.44; uppercase letters – YME; lowercase-italic letters – PME; lowercase-bold letters – CT × P; lowercase letters – TME

(1586.69 mg/kg) recorded the highest TPC, BM the lowest (1064.72 mg/kg). CT × P interaction was significant, with CT2 × V reaching 2231.36 mg/kg. These results agree with Korkutal and Kaymaz (2016), who reported that phenolic content increases as cluster load decreases. However, Göksel et al.(2024) report that phenolic compounds in grapes can be affected by many factors, especially the variety itself and ecological characteristics.

Similarly, the TPI (Table 5) was highest in CT2 (8.81) and at V (8.81), with CT2 × V peaking at 11.10, whereas C × BF showed the lowest value (5.15). These results corroborate Artem et al. (2022), who found higher TPI in thinned vines.

Cluster thinning reduced yield in proportion to thinning intensity (C: 777.00 kg/daa > CT1: 702.20 kg/daa > CT2: 514.30 kg/daa). The highest yield was observed at S (769.11 kg/daa). These results confirm previous reports that thinning effectively regulates crop load and lowers yield (Mancha et al. 2021).

CONCLUSION

This study evaluated the effects of cluster thinning at six phenological stages and three thinning levels on yield and grape quality in a 12-year-old Merlot vineyard. Cluster thinning improved most phytochemical parameters, including sugar accumulation, anthocyanin, tannin, TPI, and maturity index, with the highest values generally observed at veraison. The optimal thinning intensity for quality enhancement was 25%, while 50% thinning maximised secondary metabolites but substantially reduced yield. Yield decreased proportionally with thinning intensity, with the lowest yields recorded in early and heavy-thinned treatments. Considering both grape quality and commercial yield, 25% cluster thinning at veraison is recommended as the most practical management practice for balancing quality and productivity.

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REFERENCES

Alba V., Natrella G., Gambacorta G., Crupi P., Coletta A. (2022): Effect of over crop and reduced yield by cluster thinning on phenolic and volatile compounds of grapes and wines of Sangiovese trained to Tendone. Journal of the Science of Food and Agriculture, 102: 7155–7163.

Alshallash K.S., Fahmy M.A., Tawfeeq A.M., Baghdady G.A., Abdrabboh G.A., Hamdy A.E., Kabsha E.B.A. (2023): GA_3 and hand thinning improves physical, chemical characteristics, yield and decrease bunch compactness of Sultanina grapevines (*Vitis vinifera* L.). Horticulturae, 9: 160.

Artem V., Antoce A.O., Geana E.I., Ionete R.E. (2022): Study of the impact of vine cultivation technology on the Feteasca Neagra wine phenolic composition and antioxidant properties. Journal of Food Science and Technology, 59: 1715–1726.

Aru V., Nittnaus A.P., Sorensen K.M., Engelsen S.B., Toldam-Andersen T.B. (2022): Effects of water stress, defoliation and crop thinning on *Vitis vinifera* L. cv. Solaris: Part I: Plant responses, fruit development and fruit quality. Metabolites, 12: 363.

Bahar E., Carbonneau A., Korkutal I. (2011): The effect of extreme water stress on leaf drying limits and possibilities of recovering in three grapevine (*Vitis vinifera* L.) cultivars. AJAR, 6: 1151–1160.

Bahar E., Korkutal İ., Kabataş İ.E. (2017): Farklı yaprak su potansiyeli (Ψ_{yaprak}) ve salkım seyreltme uygulamalarının Sangiovese üzüm çeşidinin fitokimyasal özellikleri üzerine etkileri. Iğdır Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 7: 11–18.

Blouin J., Guimberteau G. (2000): Maturation et Maturite des Raisins. Feret, Bordeaux, France.

Bubola M., Sivilotti P., Janjanin D., Poni S. (2017): Early leaf removal has a larger effect than cluster thinning on grape phenolic composition in cv. Teran. American Journal of Enology and Viticulture, 68: 234–242.

Cameron W., Petrie P.R., Bonada M. (2024): Effects of vineyard management practices on winegrape composition. A Review using meta-analysis. American Journal of Enology and Viticulture, 75: 0750022.

Carmona-Jiménez Y., Palma M., Guillen-Sanchez D.A., Garcia-Moreno M.V. (2021): Study of the cluster thinning grape as a source of phenolic compounds and evaluation of its antioxidant potential. Biomolecules, 11: 227.

Cemeroğlu B. (2007): Gıda analizleri. Gıda Teknolojisi Derneği Yayınları, 34: 168–171.

Choi K.O., Im D., Park S.J., Lee D.H., Kim S.J., Hur Y.Y. (2021): Effects of berry thinning on the physicochemical, aromatic, and sensory properties of Shine Muscat grapes. Horticulturae, 7: 487.

Copp C.R., Achala N.KC., Levin A.D. (2022): Cluster thinning does not improve fruit composition in grapevine Red Blotch virus-infected *Vitis vinifera* L. American Journal of Enology and Viticulture, 73: 56–66.

Čuš F., Krebelj A.J., Potisek M. (2025): Influence of vineyard location, cluster thinning and spontaneous alcoholic fermentation on wine composition. Foods, 14: 1101.

Gao Y., Cahoon G.A. (1998): Cluster thinning effects on fruit weight, juice quality and fruit skin characteristics in Reliance Grapes. Research Cicular Ohio Agricultural Research and Development Center, USA, 299: 87–93.

Gatti M., Bernizzoni F., Civardi S., Poni S. (2012): Effects of cluster thinning and preflowering leaf removal on growth and grape composition in cv. Sangiovese. American Journal of Enology and Viticulture, 63: 325–332.

González-Neves G., Ferrer M. (2008): Effects of training system and cluster thinning on the composition of Merlot grapes. Agrociencia Uruguay, 12: 10–18.

Göksel Z., Kayahan S., Atak A., Şen A., Tunçkal C. (2024): Phenolic contents of some disease-resistant raisins (*Vitis* spp.). Acta Horticulturae, 1385: 119–126.

INRA (2007): Determination d'anthocyanes en echantillons de raisin. Mode operatiore. Ref: MO-LAB-23. Version: 1, Septembre 2007. UE Pech Rouge, France.

Janas M., Benesova L., Ailer S., Levicka M. (2023): Utilization of different yield regulation methods of the vine for production of wines of higher designation protected of origin. Slovak Journal of Food Sciences, 17: 231–241.

Kennedy U., Learmonth R., Hassal T. (2009): Effects on grape and wine quality of bunch thinning of Merlot under Queensland conditions. Queensland Wine Industry Association. 18 May 2009, Project Number: RT 06/05-2, Australia.

King P., Smart R.E., McClellan D.J. (2015): Timing of crop removal has limited effect on Merlot grape and wine composition. Agricultural Sciences, 6: 456–465.

Korkutal İ., Kaymaz Ö. (2016): Viognier (*Vitis vinifera* L.) üzüm çeşidinde farklı sıra yönleri ve salkım seyreltme uygulamalarının kalite ve verim ve özellikleri üzerine etkileri. Bahçe, 45(Özel Sayı): 599–606.

Korkutal İ., Bahar E., Koskosoğlu B. (2023): Cabernet Franc üzüm çeşidinin fitokimyasal özelliklerine eğimdeki konumun, anacın ve salkım seyreltmenin etkisi. Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 28: 536–556.

Lorenz D.H., Eichhorn K.W., Bleiholder H., Klose R., Meier U., Weber E. (1995): Phenological growth stages of the grapevine (*Vitis vinifera* L. ssp. vinifera) codes and descriptions according to the extended BBCH scale. Australian Journal of Grape and Wine Research, 1: 100–103.

Mancha L.A., Uriarte D., Valdes E., Moreno D., Henar Prieto M. (2021): Effects of regulated deficit irrigation and early cluster thinning on production and quality parameters in a vineyard cv. Tempranillo under semi-arid conditions in Southwestern Spain. Agronomy, 11: 34.

Martínez-Lüscher J., Kurtural S.K. (2023): Source-sink manipulations have major implications for grapevine berry and wine flavonoids and aromas that go beyond the changes in berry sugar accumulation. Food Research International, 169: 112826.

Mawdsley P., Peterson J.C., Casassa L. (2019): Multi-year study of the effects of cluster thinning on vine performance, fruit and wine composition of Pinot Noir

https://doi.org/10.17221/109/2025-HORTSCI

(Clone 115) in California's Edna Valley AVA (USA). Scientia Horticulturae, 256: 108631.

Mesic J., Obradovic V., Svitlica H.M.B., Malcic I., Soldo T. (2020): Impact of cluster thinning on Merlot and Cabernet Sauvignon (*Vitis vinifera* L.) must quality. In: Proc. 55th Croatian and 15th Int. Symp. Agriculture, Vodice-Croatia, Feb 16–21, 2020: 506–509.

Nistor E., Dobrei A., Dobrei A., Ciorica G. (2020): Climate variability and canopy management influence on grape berries quality in Merlot and Pinot Noir varieties. Scientific Papers. Series B, Horticulture, 64: 299–306.

Palliotti A., Cartechini A. (2000): Cluster thinning effects on yield and grape composition in different grapevine cultivars. Acta Horticulturae, 512: 111–120.

Reeve A.L., Skinkis P.A., Vance A.J., McLaughlin K.R., Tomasino E., Lee J., Tarara J.M. (2018): Vineyard floor management and cluster thinning inconsistently affect Pinot Noir crop load, berry composition, and wine quality. HortScience, 53: 318–328.

Salazar D.M., Velázquez-Marti B., Lopéz-Cortés I. (2021): Vine architecture and production control measures to improve the quality of the wine from Shiraz variety (*Vitis vinifera* L.). Spanish Journal of Agricultural Research, 19: e0908.

Soltekin O., Teker T., Güler A., Candemir A. (2023): Farklı ürün seviyelerinin Syrah üzüm çeşidinde fizyolojik faaliyetler, tane özellikleri ve şarap kalitesi üzerine etkileri. Bahçe, 52(Özel Sayı 1): 332–338.

Suklje K., Jez Krebeli A., Vaupotic T., Cus F. (2022): Effect of cluster thinning within the grapevine variety Welschriesling on yield, grape juice and wine parameters. Mitteilungen Klosterneuburg, Rebe und Wein, Obstbau und Früchteverwertung, 72: 118–129.

Vanderweide J., Nasrollahiazar E., Schultze S., Sabbatini P., Castellarin S.D. (2024): Impact of cluster thinning on wine grape yield and fruit composition: A review and meta-analysis. Australian Journal of Grape and Wine Research, 2024: 2504396.

Vicente A., Yuste J. (2015): Cluster thinning in cv. Verdejo rainfed grown: Physiologic, agronomic and qualitative effects, in the D.O. Rueda (Spain). BIO Web of Conferences, 5: 01020.

Wang W., Liang Y., Quan G., Wang X., Xi Z. (2022): Thinning of cluster improves berry composition and sugar accumulation in Syrah grapes. Scientia Horticulturae, 297: 110966.

Waterhouse A.L. (2002): Determination of total phenolics. Current Protocols in Food Analytical Chemistry, 6: I1–1.

XiaoJun Xi., Qian Zha., Xiangjing Yin., AiLi J. (2023): Changes in sugar, anthocyanin, and ABA accumulation in response to cluster thinning and girdling in Jumeigui grape. American Journal of Enology and Viticulture, 74: 0740006.

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