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RESEARCH PAPER

Red wine phenolic composition: the effects of summer pruning and cluster thinning

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Abstract

P.M. Cañon, A.S. González, J.A. Alcalde, and E. Bordeu. 2014. Red wine phenolic composition: the effects of summer pruning and cluster thinning. Cien. Inv. Agr. 41(2): 235-248. The quality of red wine is directly associated with its phenolic composition, which can be controlled using several viticultural techniques that affect the vegetative/productive balance of the plants, such as summer pruning and cluster thinning. However, these techniques may also involve high costs and production losses. This study aimed to evaluate the effects of summer pruning and cluster thinning on the phenolic compositions of grapes and wine over three consecutive seasons. The treatments included long (120 cm shoot length) and short (60 cm shoot length) summer pruning and 50% cluster thinning with control treatments conducted in vineyards with cvs. Cabernet-Sauvignon and Carmenere and located in a warm area (Cachapoal, Chile) and cvs. Cabernet-Sauvignon and Pinot Noir located in a cold area (Casablanca, Chile). These treatments generated differences in the microclimatic conditions (radiation and temperature) and the vegetative/productive balance of the plants. Depending on whether the grapevine vigor was high or low, short summer pruning increased or decreased the phenolic composition. The effects of cluster thinning varied according to the natural productivity of each season, increasing the phenolic composition when the natural yields were high and producing no significant effects when they were low. The decision to make these viticultural practices to improve the phenolic composition of the wine depends on the seasonal vineyard vigor and potential productivity. Thus, measures are only applied when a severe imbalance in the vegetative/productive equilibrium occurs or when the microclimatic conditions of the vineyard must be improved.

Key words: Cluster thinning, polyphenols, summer pruning, vegetative/productive balance, *Vitis vinifera* L.

Introduction

Quality and yield of the grapevines for winemaking depends on the balance between fruit load and the properly illuminated leaf area. These two parameters are essential for obtaining a suitable phenolic composition in grapes. Thus, it is important to achieve a proper balance between winter and summer pruning, leaf removal and cluster thinning (Amati *et al*., 1994). Cluster thinning and summer pruning are among the most common agronomic practices that can influence these variables.

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Summer pruning, which consist of the removal of 30 to 60 cm from the shoot tips, is conducted in early summer when the grapevine shoots are still growing, which creates a debilitating effect on the plants (Pszczółkowski, 1971). This technique affects the distribution of vegetative and reproductive growth. Leaves behave like photosynthetic parasites during their first twenty days. Next, the export-import balance becomes positive. In addition, during bloom, the part of the shoot between the apex and the tenth node behaves like a parasitic. Every leaf that is located in any of the ten younger nodes has a greater or lesser degree of parasitism.

Furthermore, the leaf area directly influences the grape microclimate. This influence mainly depends on the amount and distribution of the leaf area in the space or canopy architecture, which affect the exposure of the fruiting zone to sunlight. The external leaves that are directly exposed to sunlight generate the greatest contribution to photosynthesis (Kliewer and Dokoozlian, 2005) and contribute the most to plant productivity.

Regarding the reduction of fruit yield, Reynolds *et al.* (2007) described that cluster thinning can improve the composition of grapes at harvest, which is associated with improved berry maturity, size and color, increased sugar content, a reduction in titratable acidity and an increase in pH (Amati *et al.*, 1994). Palliotti *et al.* (2000) suggested that cluster thinned grapevines produces wines that have higher phenolic contents, which results in a greater aging potential. In this context, Hidalgo (1993) postulated that each plant and variety should not reach a yield that is greater than the yield that can accomplish consistent vigor, quality and development. Moreover, the specific yield that each plant can produce without delay and without affecting the phenolic composition should be obtained. Some evidence suggests that plant load level does not affect sugar accumulation or fruit quality (Freeman and Kliewer, 1983). However, other studies attribute the differences in grape composition to outward differences (*e.g.,* seasonal changes; Keller *et al.*, 2005).

In this study, the effects generated by intensive summer pruning and cluster thinning on microclimate quality and the chemical and phenolic compositions of grapes and wine in vineyards under contrasting soil and climatic conditions are studied, including red Cabernet-Sauvignon and Carmenère cultivars in the warm area of Cachapoal, Chile and cvs. Cabernet-Sauvignon and Pinot Noir in the cold areas of Casablanca, Chile over three vintages (2008, 2009 and 2010).

Materials and methods

Plant material

The experiments were conducted in the Cachapoal Valley (34.40°S; 71.17°W, O'Higgins Region) and the Casablanca Valley (33.32°S; 71.41°W, Valparaiso Region) over three consecutive seasons (2007-2008, 2008-2009 and 2009-2010) in commercial vineyards of *Vitis vinifera* cvs. Cabernet-Sauvignon (located at both valleys), Carmenère (located only at the Cachapoal Valley) and Pinot Noir (located only at the Casablanca Valley).

Plants were grown on a traditional vertical trellis with spur pruning (Cabernet-Sauvignon from Cachapoal and Pinot Noir from Casablanca) and cane pruning (Carmenère from Cachapoal and Cabernet-Sauvignon from Casablanca). All of the plants were non grafted and the planting densities were 2778 (2.4 × 1.5 m), 3333 (3 × 1 m), 2667 (2.5 × 1.5 m) and 3846 (2.6 × 1 m) plants per hectare for the Cabernet-Sauvignon from Cachapoal, the Cabernet-Sauvignon from Casablanca, and the Carmenère and Pinot Noir, respectively.

Experimental treatments

The experimental units that were assessed consisted of four contiguous rows and 48 plants. Two rows were left as the borders (one on each side of the experimental unit) of the units where the summer pruning treatment was applied.

The treatments consisted of a combination of the following two levels of summer pruning and two levels of cluster thinning: long summer pruning (120 cm shoot length), short summer pruning (60 cm shoot length), cluster thinning (50% of the clusters) and without cluster thinning. Summer pruning treatments were conducted after fruit-set when the berries were pepper-corn sized with a diameter of approximately 4 mm (E-L 29; Coombe, 1995). In addition, cluster thinning treatments were conducted at the beginning of bunch closure (E-L 31). From each experimental unit, four normal vigor plants were selected for berry sampling from two central rows. Summer pruning treatments were applied across the entire experimental unit and its borders, while cluster thinning was only performed on the four representative grapevines.

Microclimate measurements

Radiation and temperature were measured during the long and short summer pruning treatments using sensors that were connected to an electronic data logger (Watchdog 2000, Model 2475 Spectrum Technologies Inc., Illinois, USA). A linear quantum 10-sensors bar was used to measure the average photosynthetically active radiation (spectral range: 410-655 nm; model SQ-310, Apogee, Logan, Utah) and was placed horizontally inside the canopy above the cordon wire with the sensors oriented upwards. The incident solar radiation above the canopy was measured using a single-sensor Pyranometer (model 3670, Spectrum Technologies Inc., Illinois, USA). The temperature was measured using a micro-sensor (model 3667S, Spectrum Technologies Inc., Illinois, USA) that was located inside the clusters.

Canopy assessments

Leaf Area Index (LAI). The LAIs of the experimental units were estimated according to the methodology described by Caiafa (2008), which was validated by using a Li-COR area meter (model Li3100c, Li-COR Inc., Lincoln, Nebraska USA). Healthy and fully expanded leaves from four normal shoots were sampled from randomly selected plants. Overall, 176, 414 and 449 leaves were sampled for the cvs. Cabernet-Sauvignon, Carmenère and Pinot Noir, respectively.

Point Quadrat. The vineyard canopy was characterized by using the point quadrat procedure according to the methodology described by Smart and Robinson (1998). In addition, the width of the trellis canopy was measured using a graduated rod.

Ravaz index. The description of the vegetative/productive balance was performed by using the Ravaz index, which was calculated as the ratio between the harvested grape weight (kg) and the subsequent pruning weight (kg) of the same plants.

Physico-chemical variables

Approximately 400 grape berry samples were weighed and counted to obtain the average berry weight. A manual press was used to crush the berries and obtain the juice. Twenty mL of the juice were used to measure the total soluble solids content (° Brix) using a digital refractometer (Pocket PAL-1, Atago, Japan), the pH using a potentiometer (Orion 5-Star, Thermo Scientific, Singapore) and the total acidity by titration with NaOH (expressed in g L^{-1} sulfuric acid). The pH and titratable acidities of the wines were measured using a 20 mL sample as described above, and the alcoholic degree was measured using ebulliometry.

Preparation of the berry extracts

Four hundred grape berry samples were ground in a food processor (model BRLY07, Oster) for 1 minute until the skins and seeds were fully broken down and formed a paste. Approximately 2 g (between 1.95 and 2.05 g) of the resulting paste was weighed using a semi-analytical balance and was placed in a 50 mL centrifuge tube. Ten volumes of an aqueous 0.1 M HCl, 50% v/v ethanol solution were added (1:10 dilution) according to the methodology described by Iland *et at.* (2004). This homogenized mixture was shaken for 1 h in a horizontal shaker at 30 rpm. Next, the tubes were centrifuged at 4,000 rpm for 6 min. The resulting supernatant solution was removed and stored at 4 °C until analysis, which was performed within one week.

Winemaking

Winemaking was performed using the cv. Cabernet-Sauvignon grapes from Cachapoal (2008 and 2010) and the cv. Pinot Noir grapes from Casablanca (2010) for all of the biological replicates by employing the traditional red wine fermentation protocol described by Pszczółkowski and Ceppi de Lecco (2011). Twenty-five kilograms of grapes were picked from each experimental unit and were processed by mechanically de-stemming and crushing. Next, sulfur dioxide (0.03 g kg^{-1}) and pectolytic enzymes (0.02 g L^{-1}; Lallzyme C, Lallemand) were applied. Ammonium phosphate was added twice (0.2 g L^{-1}), once before yeast inoculation and once after the density decreased by 10 g mL^{-1}. Fermentation was conducted in plastic containers in a controlled temperature room by using EC-1118 yeast (0.2 g L^{-1}). Fermentation was performed at 28 °C inside an isothermal room. The temperature and density were controlled daily along with the punch down work. Once fermentation was completed (a stable density of 993 g L^{-1} or less for two consecutive days and a residual sugars content of less than 2 g L^{-1}), the free run wine was raked. The wine was transferred to fill 5-L glass containers. These containers were stored in an isothermal chamber (20-24 °C) to promote spontaneous malolactic fermentation and were tested using paper chromatography. Once the malolactic fermentation was completed, sulfur dioxide (50 g L^{-1}) was added to the wine and the filled containers were capped with conical cork stoppers before storing in a cold room (0 °C) for three weeks. At the time of transfer, the free sulfur dioxide concentration was corrected to 35 mg L^{-1}. Finally, the wine was raked, adjusted to a sulfur dioxide content of 35 mg L^{-1}, bottled (0.75 L), and sealed with a cylindrical cork stoppers before storing in a horizontal position at room temperature. In the cluster thinning treatments, winemaking was performed by using 5 kg of grapes from four vines, according to the protocol described above. Fermentation was performed in 5-L glass containers.

Polyphenolic composition

The phenolic compositions of the grapes and wine were determined using a UV/Vis spectrophotometer (Spectronic Genesys 2, Milton Roy, Rochester, NY). The total anthocyanin contents were determined at 520 nm according to the methodology described by Puissant and Leon (1967), the total phenol contents were determined using DO280, and the total tannin contents were determined by precipitation with methyl cellulose (Sarneckis *et al.,* 2006).

Statistical design and analysis

Data from the chemical and phenolic compositions were analyzed using a factorial design with two factors (summer pruning and cluster thinning) on two levels. The analysis of variance and the Fisher's Least Significant Difference (LSD) tests (P = 0.05) were performed using the Statgraphics 5.1 software (Statistical Graphics Corp., Princeton, NJ, USA).

Results

Vegetative/productive balance

The Ravaz index values that were obtained for the 2008, 2009 and 2010 vintages are shown in Figure 1. For all vintages, the short summer pruning without cluster thinning treatments had the higher Ravaz index values, in contrast with

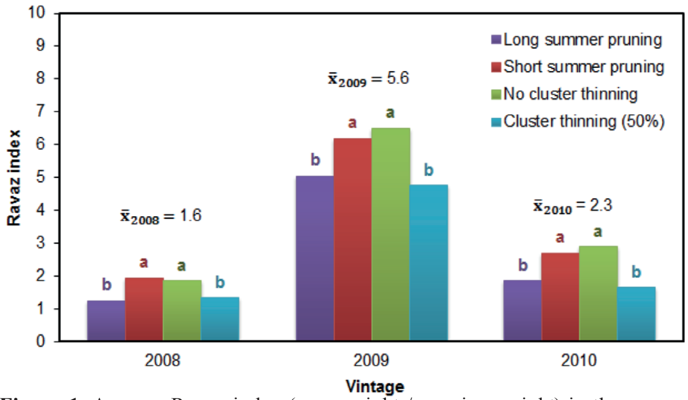

Figure 1. Average Ravaz index (crop weight / pruning weight) in the summer pruning and cluster thinning treatments that were applied in the Cabernet-Sauvignon and Pinot Noir vineyards for the 2008, 2009 and 2010 vintages. The values followed by different letters in the same year are different according to the LSD test (P≤0.05).

Table 1. Crop weight and yield of the different cultivars (only control treatments) for the 2008, 2009 and 2010 vintages. The values followed by different letters in different columns are different according to the LSD test (P≤0.05).

Cultivar / Valley	Yield per plant (kg plant^{-1})	Yield per hectare (t ha^{-1})
2008		
Pinot Noir / Casablanca	1.8	4.7
Cabernet-Sauvignon / Cachapoal	1.2	3.3
Cabernet-Sauvignon / Casablanca	3.2	8.5
Carmenère / Cachapoal	2.2	5.9
Average[1]	2.0 b	5.3
2009		
Pinot Noir / Casablanca	6.3	16.8
Cabernet-Sauvignon / Casablanca	3.2	8.5
Carmenère / Cachapoal	4.8	12.7
Average[1]	5.6 a	14.8
2010		
Pinot Noir / Casablanca	2.7	7.3
Cabernet-Sauvignon / Cachapoal	2.7	7.2
Carmenère / Cachapoal	2.2	5.7
Average[1]	2.5 b	6.5

the long summer pruning with cluster thinning treatments. The lowest calculated Ravaz index values were observed in the 2008 season, with higher values in the 2009 season. Table 1 shows all of the grape yields and pruning weights for the three studied seasons. The seasonal effects were just as important as the treatment effects.

The LAI and leaf area per harvested grape weight (cm^2 g^{-1}) are shown in Table 2. As expected, short summer pruning decreased the leaf area to grape weight ratio. In addition, significant treatment differences were observed for cv. Pinot Noir from Casablanca during the 2008 season and cv. Cabernet-Sauvignon from Cachapoal during the 2008 and 2009 seasons. Furthermore, significantly greater values were observed in the cluster thinning treatments for cv. Carmenère. Despite some significant differences regarding LAI, only the cv. Cabernet-Sauvignon from Cachapoal indicated that the short summer pruning treatment (alone or together with cluster thinning) decreased the LAI.

Table 2. Leaf area per crop weight and leaf area index (LAI) of the vineyards for the 2008 and 2009 vintages under the long or short summer pruning treatments and with or without cluster thinning. The values followed by different letters in the same columns and for the same cultivars are different according to the LSD test (P≤0.05).

	2008		2009	
	Leaf≠ area per crop weight (cm^2 g^{-1})	LAI	Leaf area per crop weight (cm^2 g^{-1})	LAI
Pinot Noir (Casablanca)				
Long summer pruning	60 a	2.63 a	14 a	2.63 a
Short summer pruning	29 b	1.84 a	11 a	1.96 a
No cluster thinning	31 b	2.26 a	11 a	2.39 a
Cluster thinning (50%)	57 a	2.20 a	14 a	2.20 a
C. Sauvignon (Casablanca)				
Long summer pruning	121 a	1.45 a	24 a	1.83 a
Short summer pruning	83 a	1.16 a	34 a	1.65 a
No cluster thinning	85 a	1.35 a	28 a	1.71 a
Cluster thinning (50%)	119 a	1.26 a	30 a	1.76 a
C. Sauvignon (Cachapoal)				
Long summer pruning	72 a	1.50 a	140 a	2.72 a
Short summer pruning	22 b	0.71 b	34 b	1.11 b
No cluster thinning	40 a	1.25 a	69 b	2.04 a
Cluster thinning (50%)	54 a	0.96 b	105 a	1.79 b
Carmenère (Cachapoal)				
No cluster thinning	22 b	1.31 a	62 a	3.31 a
Cluster thinning (50%)	54 a	1.63 a	58 a	3.59 a

Microclimatic conditions

The radiation and thermal microclimate characterizations of the cv. Cabernet-Sauvignon from Casablanca and Cachapoal are presented in Figures 2a and 2d. Regarding radiation, the vines with short summer pruning intercepted more solar radiation at the cordon level than those with long summer pruning, with maximal effects at 16 and 17 h at the Casablanca site and between 15 and 16 h at the Cachapoal site. Regarding the temperature, the grapes from the short summer pruning vines at Casablanca had higher temperatures than the grapes from the long summer pruning treated vines. However, at Cachapoal it was not possible to establish any significant differences between these two treatments. Similar radiation effects to those observed for the cv. Cabernet-Sauvignon were shown for the cvs. Pinot Noir and Carmenère (Figures 2e and 2h). The short summer pruning treatments showed higher temperatures, particularly between 9 and 15 hours for the cv. Pinot Noir and between 15 and 21 h for the cv. Carmenère. Nevertheless, the cv. Pinot Noir had higher temperatures in long summer pruning treatment between 15 and 21 h.

Canopy characterization by the point quadrat method for the cvs. Cabernet-Sauvignon, Carmenère and Pinot Noir from both locations during the 2008 season are shown in Figure 3. Only the long summer pruning treatment showed a significant decrease in canopy thickness, and no other significant differences were observed. However, several non-significant tendencies were observed, as follows: the short summer pruning treatments generated wider canopies with a lower percentage of canopy gaps than the long summer pruning treatments (Figure 3a and 3b). Regarding the percentage of internal leaves and clusters, the short summer pruning and cluster thinning treatments resulted in greater canopy gap percentages (Figure 3d and 3e).

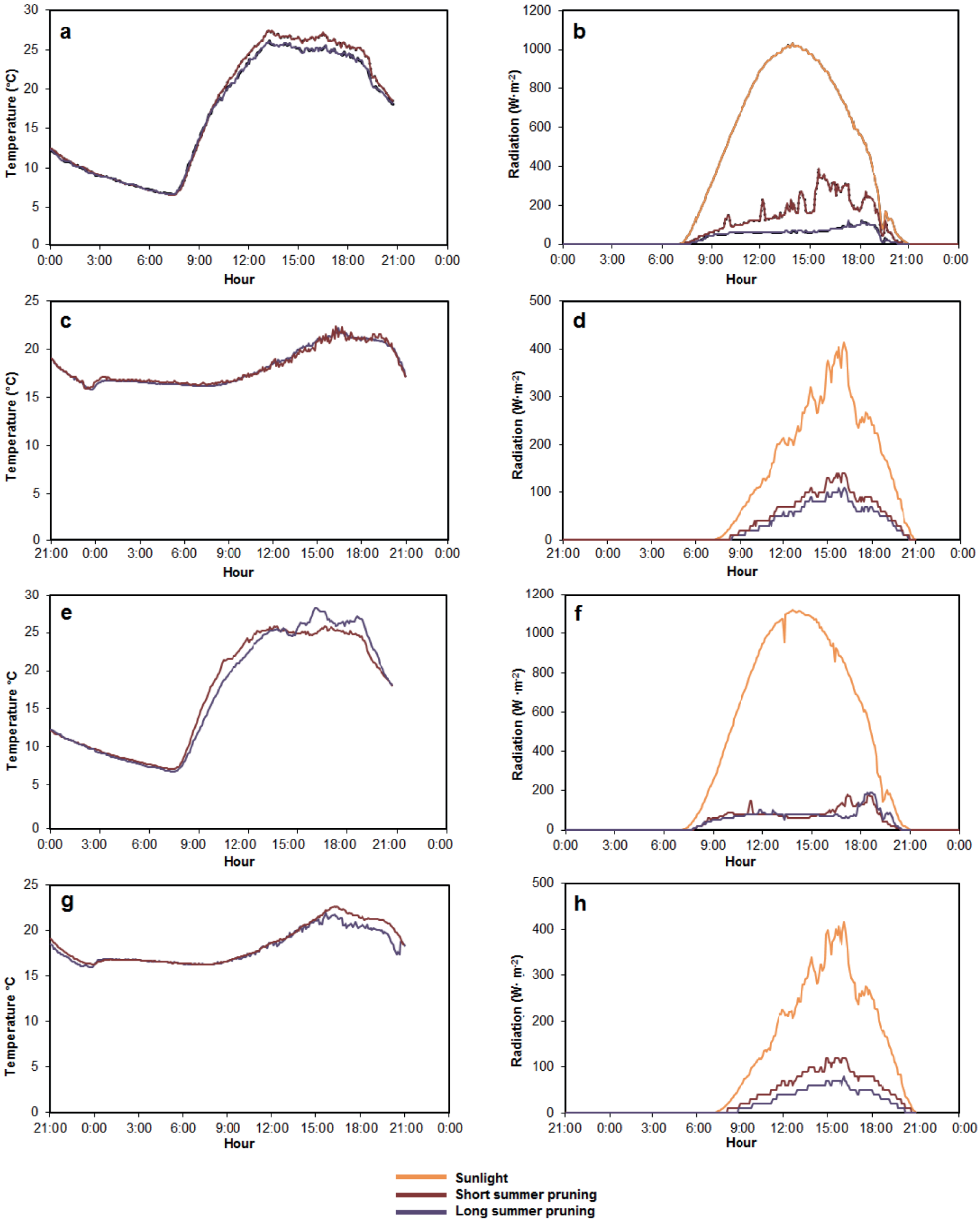

Figure 2. Microclimatic measurements of temperature (Figures a, c, e and g) and radiation (Figures b, d, f and h) with day for the Cabernet-Sauvignon vineyard in Casablanca (Figures a and b), the Cachapoal (figures c and d) and Pinot Noir vineyards in Casablanca (Figures e and f) and the Carmenère vineyard in Cachapoal (Figures g and h) for the 2008 vintage.

Chemical compositions of the grapes and wines

All of the evaluated grape parameters showed no significant differences during the 2008 season for the cvs. Cabernet-Sauvignon and Pinot Noir from Casablanca and the cvs. Cabernet-Sauvignon and Carmenère from Cachapoal (Table 3). In addition, no significant differences were observed for the wines of the cv. Cabernet-Sauvignon from Cachapoal (Table 4). Regarding the chemical

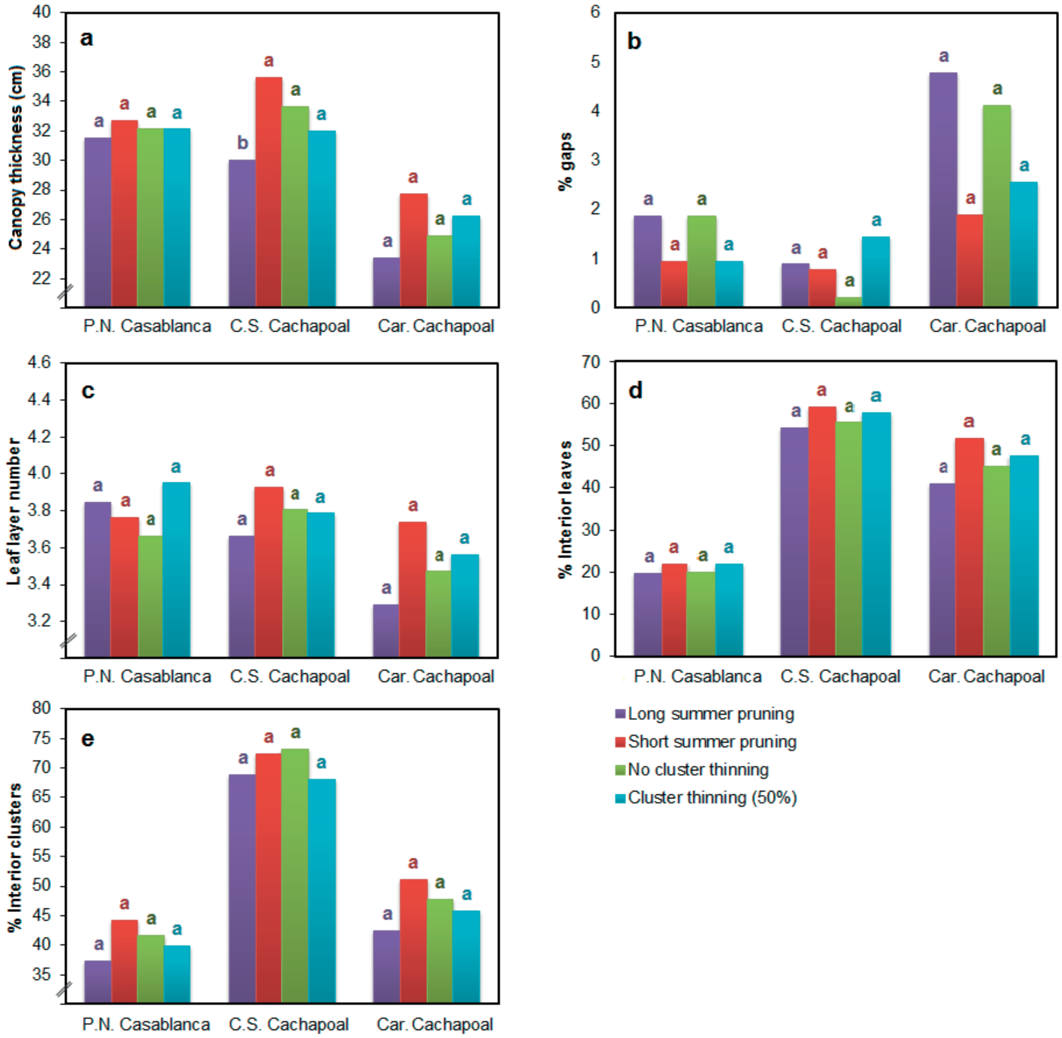

Figure 3. Vine characterization using the quadrant method for the three cultivars studied in Casablanca and Cachapoal during 2008. Here, a corresponds with canopy thickness; b corresponds with the percentage of gaps; c corresponds with leaf layer number; d corresponds with the percentage of the interior leaves; and e corresponds to the percent of interior clusters. The values followed by different letters in the bars of the same cultivar are different according to the LSD test (P≤0.05).

compositions of the wines, the short summer pruning and cluster thinning treatments increased the total soluble solids contents and pH, which was consistent with a reduction in the total acidity, with the exception of the cv. Carmenère, for which no significant differences were observed. The phenolic compositions responded in the same way, with the total polyphenol, anthocyanin and tannin concentrations increasing in the short summer pruning and cluster thinning treatments. The average berry weight was approximately 0.92 g, without significant differences between the treatments.

Compared with the observations from the 2008 harvest, the grape yields for the 2009 harvest were significantly higher (Table 1). The most important significant effects of this last harvest resulted from the cluster thinning treatments, as shown in the cv. Cabernet-Sauvignon from Cachapoal (Table 3), where short summer pruning significantly reduced the total soluble solids contents and pH

Table 3. Chemical analysis of the grapes harvested in 2008 and 2009 that underwent summer pruning (60 cm), long summer pruning (120 cm), 50 percent cluster thinning or no cluster thinning. The values followed by different letters for the same cultivars are different according to the LSD test ($P \leq 0.05$).

	Soluble solids [°Brix]	Total Acidity [g H_2SO_4 L^{-1}]	pH	Polyphenols [AU (g berry)$^{-1}$]	Anthocyanins [mg (g berry)$^{-1}$]	Tannins [mg (g berry)$^{-1}$]
2008						
C. Sauvignon (Casablanca)						
Long summer pruning	21.0 b	3.83 a	3.34 b	13.7 b	232 b	374 b
Short summer pruning	21.7 a	3.41 b	3.52 a	17.0 a	267 a	454 a
No cluster thinning	21.0 b	3.73 a	3.40 b	14.3 b	238 b	390 b
Cluster thinning (50%)	21.7 a	3.51 b	3.51 a	16.3 a	261 a	437 a
Pinot Noir (Casablanca)						
Long summer pruning	24.0 b	3.63 a	3.58 b	9.4 b	95 b	316 b
Short summer pruning	25.8 a	3.14 b	3.76 a	15.8 a	115 a	464 a
No cluster thinning	24.2 b	3.55 a	3.61 b	12.0 b	99 b	352 b
Cluster thinning (50%)	25.6 a	3.21 b	3.72 a	13.2 a	111 a	428 a
C. Sauvignon (Cachapoal)						
Long summer pruning	23.7 b	2.74 a	3.43 b	17.9 b	177 b	525 b
Short summer pruning	24.5 a	2.29 b	3.50 a	20.9 a	235 a	633 a
No cluster thinning	23.9 b	2.63 a	3.44 b	18.4 b	188 b	535 b
Cluster thinning (50%)	24.2 a	2.39 b	3.49 a	20.3 a	224 a	623 a
Carmenère (Cachapoal)						
Long summer pruning	24.7 b	2.33 a	3.93 b	13.5 b	214 b	320 b
Short summer pruning	25.9 a	1.79 b	4.00 a	15.0 a	248 a	404 a
No cluster thinning	24.8 b	1.94 a	3.94 b	13.1 b	224 a	333 b
Cluster thinning (50%)	25.7 a	2.18 a	3.99 a	15.4 a	238 a	391 a
2009						
C. Sauvignon (Cachapoal)						
Long summer pruning	24.0 a	2.09 a	3.61 a	124 a	1250 a	4.76 a
Short summer pruning	22.9 b	2.18 a	3.53 b	119 a	1280 a	5.08 a
No cluster thinning	23.2 b	2.20 a	3.54 b	113 b	1250 b	4.61 b
Cluster thinning (50%)	23.8 a	2.07 b	3.61 a	130 a	1290 a	5.23 a
Pinot Noir (Casablanca)						
Long summer pruning	22.7 a	3.38 a	3.56 a	170 a	870 a	4.05 a
Short summer pruning	22.2 a	3.48 a	3.54 a	155 b	750 b	3.88 a
No cluster thinning	21.9 a	3.54 a	3.52 a	162 a	770 b	3.87 a
Cluster thinning (50%)	23.0 a	3.32 b	3.59 a	162 a	850 a	4.06 a
Carmenère (Cachapoal)						
No cluster thinning	24.3 a	2.19 a	3.93 a	169 a	1829 a	4.53 a
Cluster thinning (50%)	25.0 a	2.10 a	3.92 a	162 a	2304 a	4.66 a

values. Regarding the cv. Pinot Noir during the 2009 season, cluster thinning had a positive effect on several parameters, such as total acidity and the total anthocyanin contents. However, the short summer pruning treatment had a negative effect on the anthocyanin and total polyphenol contents, in contrast with the effects observed for the 2008 vintage. The cv. Carmenère showed no significant differences, but a trend toward higher total polyphenol, anthocyanin and tannin contents was observed with cluster thinning.

The 2010 harvest (Table 4) had an intermediate yield when compared with the 2008 and 2009 harvests. The wines from this 2010 harvest of the cv. Cabernet-Sauvignon from Cachapoal only showed significant differences for the total anthocyanin content and color intensity; however, there was a significant interaction between both factors (summer pruning and cluster thinning). In addition, the short summer pruning with cluster thinning treatments generated a positive effect on the color intensity and total anthocyanin contents. For the wines from the cv. Pinot Noir, a few significant differences were observed. These results matched the performance of the treatments during the 2009 season (*i.e.,* a positive effect of cluster thinning and a negative effect of short summer pruning).

Discussion

Smart and Robinson (1998) proposed that separate thinning and summer pruning can regulate the Ravaz index components to obtain a good balance between vegetative growth and production, with an optimal ratio obtained at values between 5 and 10, an excess load or insufficient foliage obtained above a value of 12 and a poor yield or excessive vigor obtained at values of less than 3. According to this information, the 2009 season was the only one in which the plants were balanced, and the 2008 vintage was characterized by a marked imbalance in favor of vegetative plant growth, which agrees with the low production of this vintage in Chile (National Association of Enologists of Chile, 2008, 2009 and 2010) and was more relevant than the applied treatments. Previous evidence has suggested that cluster thinning decreases the Ravaz index by reducing crop load, which results in a difference of between 27 and 43%. In turn, the short summer pruning treatment leads to a higher Ravaz index that varies from 19 to 36% due to the decreased foliage. Furthermore, the leaf areas per gram of fruit were relatively high relative to those recommended (8-12 cm^2 g^{-1}) by Smart and Robinson (1998), but the LAIs were adequate (approximately 2.1). This result confirmed that the balanced productive vegetative results from the low yielding plants.

Microclimatic measurements have shown that short summer pruning improves cluster exposure to solar radiation. This result agrees with the much lower radiation in the center of the canopy relative to its surface due to the strong absorption of light by the leaves. Smart and Robinson (1998) indicated that for a light intensity of 2000 µE m^{-2} sec^{-1}, only 120 µE m^{-2} sec^{-1} are transmitted to the next layer of leaves, and only 7 µE m^{-2} sec^{-1} are left to go through to the next layer. In addition, the lower differences found in temperature can be explained by the moderating effects of the leaves through transpiration, which cools down

Table 4. Chemical analysis of the 2008 and 2010 vintage wines that underwent the short summer pruning (60 cm), long summer pruning (120 cm), 50 percent cluster thinning and no cluster thinning treatments. The values followed by different letters for the same cultivars are different according to the LSD test ($P \leq 0.05$).

	Alcohol [°GL]	Total Acidity [g H_2SO_4 L^{-1}]	pH	Polyphenols [AU (g berry)$^{-1}$]	Anthocyanins [mg (g berry)$^{-1}$]	Tannins [mg (g berry)$^{-1}$]
2008						
C. Sauvignon (Cachapoal)						
Long summer pruning	12.9 b	3.84 a	3.02 b	46.2 b	352 b	6.25 b
Short summer pruning	13.5 a	3.47 b	3.43 a	56.6 a	436 a	7.55 a
No cluster thinning	12.9 b	3.76 a	3.13 b	45.8 b	369 b	6.12 b
Cluster thinning (50%)	13.5 a	3.55 b	3.32 a	57.0 a	419 a	7.68 a
2010						
C. Sauvignon (Cachapoal)						
Long summer pruning	12.8 a	5.09 a	3.54 a	70.6 a	339 a	1.24 a
Short summer pruning	12.6 a	5.21 a	3.49 a	71.4 a	346 a	1.28 a
No cluster thinning	12.8 a	5.10 a	3.51 a	75.6 a	364 a	1.34 a
Cluster thinning (50%)	12.6 a	5.19 a	3.52 a	66.6 a	321 b	1.19 a
Pinot Noir (Casablanca)						
Long summer pruning	13.4 a	3.91 a	3.66 a	29.6 a	209 a	0.16 a
Short summer pruning	13.3 a	3.83 a	3.57 a	27.2 b	201 a	0.15 a
No cluster thinning	13.7 a	3.82 a	3.60 a	27.9 a	206 a	0.14 a
Cluster thinning (50%)	13.0 a	3.92 a	3.64 a	28.8 a	204 a	0.17 a

the foliage. The reduction in the number of spaces with no leaves or bunches in the short summer pruning treatment, which were measured using the point quadrant method, potentially occurred because the shoots were not trapped by the higher wires, which resulted in a canopy that was less dense and explains the better illumination and higher temperatures of the bunches.

It is very important for the wine industry to determine the factors that affect the biosynthesis of polyphenolic compounds under the prevailing conditions in the country. Among these factors, light, temperature, soil, water supply, nutrition, pathogens, growth regulators and other factors are important (Downey *et al*., 2006). In this research, the effects of summer pruning and bunch thinning were studied, which are both frequently used in viticulture, are expensive and result in high production losses when thinning is used. Thus, these factors should be evaluated in terms of their impacts on wine, especially the phenolic compositions of wine.

Considering that the 2008 vintage had low yields (Table 1), the positive effects of the short summer pruning treatment could be explained by the excess of unnecessary leaves due to the low amount of bunches. Eliminating part of the foliage improved the microclimate and the phenolic compositions of the grapes. In 2009, the plants had more bunches of grapes, so the number of leaves was most likely limiting for adequate ripening. In this case, bunch thinning improved the berry composition, particularly its phenolic composition. The negative effect of the short summer pruning treatment on the anthocyanin and total phenol contents in the Pinot Noir in 2009 could be explained by a deficit in the foliar surface relative to the higher fruit load. The effects of the short summer pruning treatment in 2008 on the increasing polyphenol concentration cans be understood from the prospective of improved plant physiology when a low fruit load occurs relative to the plants potential. Pérez and Montenegro (1982) propose that vigorous vegetative growth not only generates a poor microclimate for bunches, but also for the entire physiology of the plant. Several effects are attributed to summer pruning, such as better light penetration to the bunch area, better ventilation for the bunches and a reduced incidence of *Botrytis cinerea*. The results of the 2009 season were similar to those described by Smith *et al*. (1988) for defoliation in Cabernet-Sauvignon between berry set and veraison, which resulted in increased anthocyanin and phenol contents. In addition, Hunter *et al.* (1991) observed defoliation in the Cabernet-Sauvignon when greater anthocyanin concentrations were found in the berry skin.

Another probable explanation for the effects of short summer pruning is the occurrence of leaf renewal from the secondary shoots, which would improve maturation and generate a higher acidity. Magalhães (2008) states the period of the vegetative cycle should be considered with the age and number of leaves that will be eliminated when considering summer pruning. When leaves are old, it is advisable to use summer pruning because new leaves from secondary shoots will have a considerably higher photosynthetic rate.

The results obtained in 2008 and 2009 from bunch thinning agree with the description that vineyards with low yields have better phenolic compositions than vineyards with high yields (Reynolds *et al.*, 2007). The adjustment of production through bunch thinning in Syrah (McCarthy and Cirami, 1987) accelerates the ripening of grapes and significantly increases the anthocyanin content and color intensity. The effects of yield reduction on faster maturation and improved wine quality depends on the period when bunch thinning is performed, being more effective during the veraison period. From the veraison period, the bunches are prioritized for sugar distribution due to reduced vegetative growth, which improves the final berry composition (as observed in the 2008 and 2009 seasons).

The decrease in the phenol content that was observed with the short summer pruning in

2009 potentially resulted from an imbalance between the foliar surface and the high yield load of that season because the number of leaves is important for providing enough photosynthesis for sugar accumulation. The levels of production are used to understand the increase in the anthocyanin contents when the bunches were thinned by 50% when considering that the high yield load observed 2009 favored the distribution of photosynthates to the remaining bunches. These results correspond with the results that are described in cold climate grapevines that are subjected to bunch thinning and basal leaf removal during veraison. (Di Profio *et al.*, 2011). Bunch thinning alone or bunch thinning combined with leave removal had the highest anthocyanin and phenol levels and the greatest color intensity when only the leaves that produced a slight increase of these parameters were removed.

Howell (2001) reported a foliar surface range of 7 to 14 cm^2 g^{-1} of fresh grapes, with equilibrium occurring at 7 for a hot viticulture and at 14 for a cold viticulture that was associated with a shorter season. For the 2008 season, all of the values for the ratio foliar area of the fresh fruit were much higher than 14, with minimum values of approximately 40 in the Pinot Noir in Casablanca and a maximum of nearly 100 in the Cabernet-Sauvignon controls in Casablanca. For the 2009 season, the values of this ratio were generally much lower, with values of approximately 11 and 19 in the Pinot noir and Cabernet-Sauvignon from Casablanca, respectively, and 69 in the Carmenère from Cachapoal. These lower values mainly resulted from the higher production during the 2009 season (Table 1) rather than from higher foliar areas. No information is available for the 2010 season.

This study was not intended to determine the effects of soil on the vegetative/productive equilibrium, but only attempted to characterize the effects of this equilibrium under two Chilean viticulture conditions. Thus, when considering the three varieties that were studied over the three seasons, it was possible to state that summer pruning and bunch thinning may modify the physiology of the plants by balancing or unbalancing the vegetative/productive equilibrium, which will depend on the natural productivity of the plant defined for that specific season.

In conclusion, this study showed that bunch thinning did not affect or improve the phenolic composition, whereas summer pruning resulted in contrasting effects over the three studied seasons. This phenomenon is potentially explained by the availability of photosynthates for the bunches and from the improvement of the microclimatic radiation and temperature conditions, which are aspects that can have opposite effects.

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Resumen

P.M. Cañón, A.S. González, J.A. Alcalde y E. Bordeu. 2014. Composición fenólica del vino tinto: efecto de chapoda de brotes y raleo de racimos. Cien. Inv. Agr. 41(2): 235-248. La calidad del vino tinto está directamente relacionada con su composición fenólica, la cual puede ser manejada en el viñedo mediante técnicas vitícolas que afectan el equilibrio vegetativo-productivo de las plantas, pero que a la vez pueden implicar elevados costos y pérdidas de producción. Este estudio tuvo como objetivo evaluar en tres temporadas consecutivas, el efecto de las técnicas vitícolas de chapoda de brotes y raleo de racimos, sobre la composición fenólica de las uvas y el vino, bajo las condiciones vitícolas de Chile. Se aplicaron tratamientos de chapodas cortas (brotes de 60 cm) y largas (brotes de 120 cm) y raleo del 50% de los racimos y sin raleo, en viñedos de las variedades Cabernet-Sauvignon y Carmenere ubicados en una localidad cálida (Cachapoal, Chile), así como Cabernet-Sauvignon y Pinot noir ubicados en una localidad fría (Casablanca, Chile). Estos tratamientos generaron diferencias en las condiciones microclimáticas (radiación y temperatura) y en el equilibrio vegetativo/productivo de las plantas. Dependiendo si el vigor del viñedo era alto o bajo, la chapoda corta generó incrementos o disminuciones en la composición fenólica. El efecto del raleo de racimos sobre la composición fenólica se mostró dependiente de la productividad natural de cada temporada, presentando incrementos cuando los rendimientos eran altos y ausencia de efectos significativos cuando estos eran bajos. La decisión vitícola de realizar estas prácticas vitícolas con el fin mejorar la composición fenólica del vino dependerá del vigor y la productividad potencial que presente el viñedo en cada temporada, justificándose su aplicación solo cuando existan fuertes desbalances en el equilibrio vegetativo-productivo, o cuando se requiera mejorar las condiciones microclimáticas de las vides.

Palabras clave: Chapoda de brotes, equilibrio vegetativo-productivo, polifenoles, raleo de racimos, *Vitis vinifera* L.

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