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Reducing the Sugar and pH of the Grape (*Vitis vinifera* L. cvs. 'Grenache' and 'Tempranillo') Through a Single Shoot Trimming

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Many vineyards all over the world can easily produce high potential alcohol levels, but the importance of the sugar content in berries has been changing over the past few years. The objective of this work was to reduce the sugar and pH of the grapes, delay berry ripening by decreasing the ratio between the leaf area and yield, perform an intense trimming treatment after berry set and establish the consequences for grapevine productivity in the following year. Severe shoot trimming was done over a three-year period (2010 to 2012). Phenological, vegetative and productive parameters were examined. The date of véraison was delayed by about 20 days. On the same harvesting date, the trim treatment had lower soluble solids (12% to 15 % reduction), lower pH (0.1 to 0.3) and a lower total anthocyanin content (10% reduction). The trim effect was also reflected in berry weight; as a consequence, bunch size and yield were also reduced by around 10%. If the trim treatment does not reduce the leaf area to fruit ratio below 0.50 m²/kg, there is no negative impact on vine capacity in the next year.

INTRODUCTION

Many vineyards throughout the world produce high potential alcohol levels because viticultural techniques have always been designed to produce a higher ripeness. Climatic change has also increased the berry ripeness process naturally (Schultz & Jones, 2010) and, during the last few decades, berry ripeness has been developed earlier. Furthermore, harvesting is taking place later, just into the over-ripeness phase. This situation is the result of the strategic line followed by many wineries to obtain concentrated wines. This global trend is emerging all over the world, and means that wines are being made with a higher alcohol content and the pH also is higher each time. An important percentage of red wines are between 14 and 16 degrees alcohol, and their pH is approximately 4.

The disadvantages of a high alcohol level are difficulties in alcoholic and/or malolactic fermentation, wines with higher volatile acidities, and unbalanced wines, especially when the temperature at which they are served is high. Furthermore, some countries apply higher taxes when wines have a high level of alcohol, and consumers usually refuse wines with a high alcohol content. To tackle this situation, new technical solutions have been developed over the past few years in order to avoid the effects of climate change; these solutions are focused mainly on low-alcohol wines. According to viticultural strategies, the main objective consists of the production of well-balanced grapes of a good quality and with a lower concentration of soluble solids.

In viticulture there are basically are three very different strategies for decreasing the alcohol level in wines: the location of the vineyard, the variety and management practices. This last strategy is the most interesting one because it could be developed in current vineyards without making any substitution of vineyards, as is the case in the first two options. Considering the physiological mechanism of the plant, there are different growing techniques that could delay berry ripening. These techniques should be considered in order to be applied to improve the adaptation of our vineyards and their ripening in a warmer climate.

Several studies have shown earlier stage of development in vine phenology during the last few years (Duchêne & Schneider, 2005; Jones *et al*., 2005). As a result, berry ripening is taking place during the warmer part of the ripening period (Webb *et al*., 2007, 2008). Although many studies have been done on several temperature indexes aimed at determining the most appropriate varietal profile for different viticultural areas (Kenny & Harrison, 1992; Schultz, 2000; Stock *et al*., 2005), it is our opinion that grape-growing techniques have not been analysed well enough. One of the possibilities is the delay in berry ripeness taking place in cooler seasons (Stoll *et al*., 2009). In warm climates, grape varieties achieve sufficient levels of soluble solids to obtain high-quality wines, but the same is not achieved regarding the colour (Iland & Gago, 2002). Temperatures above 30°C after véraison could inhibit anthocyanin synthesis (Mori *et al*., 2007).

The research carried out on ecophysiological

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characterisation all over the world over the last few years has led to the establishment of the leaf area to fruit ratio as one of the most important viticultural indexes to define a well-balanced vineyard that could produce high-quality grapes and wines. The leaf area to fruit ratio should be between 0.8 and 1.2 m^2/kg in order to get good ripeness (Kliewer & Dokoozlian, 2005). Basal leaf removal is one of the most common practices in canopy management (Percival *et al*., 1994; Martínez de Toda, 1995). It is frequently done during the ripening season if the canopy has a very high density, in an attempt to improve the colour intensity and aroma and to decrease the disease impact of pests (Bledsoe *et al*., 1988; Tardáguila *et al*., 2008). In contrast, early leaf removal carried out during the flowering season is a very interesting technique for yield reduction by decreasing bunch weight, berry size and bunch compactness (Tardáguila *et al*., 2010). All these experiments show the high influence of the leaf area to fruit ratio on bunch characteristics. It would be very interesting to take a look at research concerning delayed ripening through the variation of that index.

Stoll *et al*. (2009) argue that leaf area reduction through severe trimming or leaf removal treatments (0.8 to 1.4 m^2/kg against 1.9 m^2/kg in the control) delay berry ripening in Riesling for a period of between 15 and 20 days. Intrieri and Filippetti (2009) also consider this reduction in leaf area as a very interesting technique to delay berry ripening. On the other hand, some studies have indicated that reducing carbohydrate production during the growing season by defoliation decreased the concentrations of overwintering carbohydrate reserves, mostly starch, in both the roots and trunks (Bennett *et al*., 2005; Zufferey *et al*., 2012). Yield in the following season, shoot growth and total vine pruning weight were also decreased in vines in which carbohydrate reserves had been reduced (Bennett *et al*., 2005). These findings suggest that restricted carbohydrate reserve accumulation as a consequence of defoliation may have a negative impact on subsequent grapevine productivity.

The main objective of this work was to evaluate leaf area reduction by trimming as a growing technique to the reduce sugar and pH of the grape, and to establish the consequences for grapevine productivity in the next year.

MATERIALS AND METHODS

This study was conducted in 2010 in two commercial vineyards of *Vitis vinifera* cv. 'Grenache' and 'Tempranillo' located in Badarán (42.36 N, -2.81 W, 615 m) and San Vicente (42.56 N, -2.75 W, 503 m) respectively. The vineyards were in the Rioja appellation, Northern Spain, and had a planting density of 2.7 m x 1.2 m. The study was continued in 2011 and 2012, but only in the 'Grenache' vineyard. Both vineyards were planted in 1998 as bush vines, without trellises; the vine rows had a North–South orientation and the vines were pruned to twelve buds per vine on spurs of two buds each. The vineyards were managed, without irrigation, to standard practices according to the Rioja appellation.

A severe manual trim was performed, cutting the shoot on the node located above the last bunch. The treatment was carried out after berry set, when the diameter of the berry was 3 to 4 mm (close to 1 July every year). Each year, two rows were selected and a completely randomised design consisting of three replicates of ten vines per treatment was made: control (non-trimmed vines) and trimmed vines after berry set. The two rows selected were different each year. The date of véraison was established in the 'Grenache' vineyard when the grapes reached 50% colour change, stage 35 of Eichorn-Lorenz (Coombe, 1995), on six vines of each experimental treatment; two vines per replicate.

To determine the leaf area of the shoot, the Smart method based on the disc technique (Smart & Robinson, 1991) was used. The leaf area of the shoot at harvest time was measured on 15 shoots per treatment, removing the petioles in order to measure the weight according to the leaf surface. Subsequently, that weight was compared with the weight of one hundred discs of known surface, and the leaf area surface per shoot was obtained. The leaf area surface per vine was obtained by multiplying the leaf area surface per shoot and the number of shoots per vine.

At harvest time, between 25 and 30 October for the three years, the yield per vine was determined on five vines of each replicate (15 vines per treatment), as was the number of shoots and the number of bunches. Berry weight was measured for 200 berries of each replicate. After that, each 200-berry sample was crushed manually to obtain the must for the chemical analysis. The soluble solids, pH and titratable acidity were analysed by OIV standard methods (OIV, 2013). Total anthocyanins and phenols were analysed by the Iland method (Iland *et al*., 2004).

The effect of the trim treatment on vine capacity in the next year was also studied in the 'Grenache' vineyard. The vegetative and productive data from the two treatments (control and trimmed) performed in 2010 and 2011 were examined again in 2011 and 2012 respectively, one year after the treatments.

The reserves were estimated through the "vine capacity", or dry matter production of the vine, without taking into account growth of the roots and trunk. It is defined as the addition of dry weight of clusters, pruning weight, and leaves. The dry weight of the clusters was calculated as the product of yield × 0.23 (cluster dry weight/cluster fresh weight) (Martínez de Toda, 1985). Pruning dry weight was determined as the product of pruning weight × 0.47 (dry weight/pruning weight) (Martínez de Toda, 1991). Leaf dry weight was calculated as the product of total leaf area per vine (m^2) × 65 g/m^2 (specific foliar weight) (Martínez de Toda, 1985). During dormancy, vines were pruned according to the standard bush vine system as described before, and the pruning weight was determined on five vines per replicate (15 vines per treatment).

Mean comparisons were performed using Student's t-test ($p = 0.05$). The statistical analysis was performed using the statistical package SPSS 15.0 for Windows.

RESULTS

Leaf area to fruit ratio and yield

As shown in Table 1 , the leaf area to fruit ratio for 'Grenache' ranges from 0.63 to 1.83 m^2/kg in the control to 0.50 to 0.80 m^2/kg in the trim treatment. The decrease in bunch weight in the trim treatment was similar to berry weight decrease, amounting to about 10%. The results obtained for 'Tempranillo' are shown in Table 2. The leaf area to fruit

TABLE 1
Leaf area, yield per vine, bunch weight and berry weight for control and trimming treatment of 'Grenache' in the years 2010, 2011 and 2012.

		Control	Trimming
2010	Leaf area per vine (m^2)	7.49 a	4.05 b
	Leaf area/yield (m^2/kg)	1.33 a	0.80 b
	Bunch weight (g)	309 a	283 b
	Berry weight (g)	1.62 a	1.48 b
2011	Leaf area per vine (m^2)	7.96 a	3.35 b
	Leaf area/yield (m^2/kg)	1.83 a	0.82 b
	Bunch weight (g)	271 a	255 b
	Berry weight (g)	1.46 a	1.37 b
2012	Leaf area per vine (m^2)	3.72 a	2.76 b
	Leaf area/yield (m^2/kg)	0.63 a	0.50 b
	Bunch weight (g)	388 a	364 b
	Berry weight (g)	1.57 a	1.46 b

Different letters across a row show significant differences between values according to Student's t-test (P = 0.05)

TABLE 2
Yield components and grape composition of control and trimming treatment of 'Tempranillo' in the year 2010.

	Control	Trimming
Leaf area by vine (m^2)	8.49 a	2.45 b
Leaf area/yield (m^2/kg)	1.88 a	0.64 b
Bunch weight (g)	214 a	181 b
Berry weight (g)	2.18 a	1.86 b
Soluble solids (°Brix)	24.9 a	21.4 b
pH	3.60 a	3.30 b
Total acidity (g tar/L)	5.10 b	5.62 a
Total anthocyanins (mg/g)	1.79 a	1.65 b
Total phenols (AU/g)	4.23	4.21

Different letters across a row show significant differences between values according to Student's t-test (P = 0.05)

ratio decreased from 1.88 m^2/kg to 0.64 m^2/kg. Berry weight decrease was in the same proportion as the bunch weight decrease; it was reduced by 15% in the trim treatment.

Date of véraison
Table 3 shows significant differences at véraison every year between trim treatment and the control. The date of véraison was delayed by 18 to 20 days in the trim treatment.

Grape composition
Table 4 shows the results obtained from the grape analyses of 'Grenache' for the three years. Every year, the soluble solids decreased by about 3°Brix for the trim treatment, which means an average reduction of 12%. The pH was also reduced by 0.10 for the trim treatment. No significant differences were found in the total acidity. The total anthocyanins were reduced by about 10% in the trim treatment. The content of total phenols showed no significant differences in any of the years.

In 'Tempranillo' (Table 2), the decrease in soluble solids was around 15% for the trim treatment. The pH also was reduced by 0.30. Total acidity was increased. The total anthocyanins were reduced by around 10% in the trim treatment, but the total phenol content showed no significant differences.

Impact on the next year
Table 5 shows the effects of vine trimming in the previous season on vegetative parameters, yield and vine capacity of 'Grenache' in the following year. No differences were found for any yield parameter, leaf area per vine or vine capacity of the trim treatment in the next year.

DISCUSSION

Leaf area to fruit ratio and yield
In 2012 there was less leaf area than in 2010 and 2011 (Table 1), probably due to lower rainfall in 2012. The yield was not affected as much as the leaf area as a consequence of the trim treatment; as a result, the leaf area to fruit ratio was modified mainly by the leaf area lost. It is expected that this important ratio decrease should affect the grape ripening process (Kliewer & Dokoozlian, 2005; Stoll *et al*., 2009). The reduction of berry and bunch weight (between 10% in 'Grenache' and 15% in 'Tempranillo') was similar to that found in the experiments carried out by Stoll *et al.* (2009). Just as was concluded by Rombola *et al*. (2011),

the trim treatment appeared to be an attractive approach for controlling yield and a possible alternative to expensive techniques, such as bunch thinning or early defoliation; the latter of which often enhances fruit sugar concentration (Tardáguila *et al*., 2010).

TABLE 3
Véraison dates for control and trimming treatment of 'Grenache'.

	Control	Trimming
2010	Sep 1st a	Sep 19th b
2011	Aug 28th a	Sep 15th b
2012	Sep 5th a	Sep 24th b

Different letters across a row show significant differences between values according to Student's t-test (P = 0.05)

Delaying ripening

Ripening in the control vines started at the beginning of September (Table 3), when mean temperatures were 20°C and maximum temperatures were 33°C (for the area of Rioja Alta). Nevertheless, in the trim treatment the ripening period began during the second half of September, when mean temperatures reached 14°C and the maximum temperatures were 25°C. The delay in ripening due to the practice of trimming meant that ripeness took place later, when temperatures were cooler. Therefore the decrease in leaf area as a consequence of the trim treatment could be useful to obtain a delay in ripening. When berry ripeness developed during cooler periods, phenol development and aroma synthesis were more adequate (Stoll *et al*., 2009). This hypothesis is very important in relation to warm wine regions.

TABLE 4
Grape composition for control and trimming treatment of 'Grenache' in the years 2010, 2011 and 2012.

		Control	Trimming
2010	Soluble solids (°Brix)	24.4 a	21.2 b
	pH	3.10 a	3.01 b
	Total acidity (g tar/L)	7.27	7.11
	Total anthocyanins (mg/g)	0.92 a	0.83 b
	Total phenols (AU/g)	2.34	2.46
2011	Soluble solids (°Brix)	25.7 a	23.1 b
	pH	3.24 a	3.14 b
	Total acidity (g tar/L)	6.00	5.88
	Total anthocyanins (mg/g)	0.98 a	0.88 b
	Total phenols (AU/g)	1.80	1.78
2012	Soluble solids (°Brix)	24.5 a	21.4 b
	pH	3.17 a	3.07 b
	Total acidity (g tar/L)	6.70	6.70
	Total anthocyanins (mg/g)	1.05 a	0.93 b
	Total phenols (AU/g)	1.30	1.15

Different letters across a row show significant differences between values according to Student's t-test (P = 0.05)

TABLE 5
Effect of vine trimming in the previous season on vegetative and productive parameters and vine capacity in the years 2011 and 2012.

		Control	Trimmed in the previous season
2011	Leaf area per vine (m^2)	7.96	7.72
	Yield per vine (kg)	4.06	4.20
	Bunch number per vine	15.0	15.0
	Bunch weight (g)	271	280
	Berry weight (g)	1.46	1.52
	Vine capacity (kg)	2.11	1.97
2012	Leaf area per vine (m^2)	3.72	3.80
	Yield per vine (kg)	5.82	5.65
	Bunch number per vine	15.5	14.5
	Bunch weight (g)	388	374
	Berry weight (g)	1.57	1.60
	Vine capacity (kg)	1.88	1.72

Different letters across a row show significant differences between values according to Student's t-test (P = 0.05)

This delay of 18-20 days on the veraison date compensates for the phenological advancement that has occurred in the last thirty years in most of the wine growing regions (Duchêne & Schneider, 2005; Jones *et al*., 2005; Stoll *et al*., 2009).

The results for grape composition (Tables 2 and 4) confirm the initial hypothesis about the effects of the trim: heavy decrease in leaf area, lower leaf area to fruit ratio, delay in the ripening process, and a decrease in soluble solids, pH and total anthocyanin level (Kliewer & Dokoozlian, 2005; Intrieri & Filippetti, 2009; Stoll *et al*., 2009).

Regarding the quality of the wine, it should be noted that the methodology used in this study did not allow us to determine whether there just was delayed ripening or incomplete maturation. To resolve this issue, it would be interesting to harvest each treatment at a different time and even make wine with some of the grapes to assess the final quality of the wines. It also would be interesting to do further research on other trimming intensities, as well as other times of intervention.

Impact in the next year

Bennett *et al*. (2005) suggest that the restricted accumulation of carbohydrate reserves as a consequence of defoliation may have a negative impact on subsequent grapevine productivity over two seasons. Zufferey *et al*. (2012) found that higher leaf to fruit ratios resulted in increased carbohydrate reserves, which attained maximum values when the leaf to fruit ratio approached 2.0 m^2/kg.

Our results suggest that the trim treatment maintained a leaf area to fruit ratio (0.50 to 0.80 m^2/kg; Tables 1 and 2) that was high enough not to have a negative effect on vine capacity in the next year. These results seem to indicate that, if the trim treatment does not reduce the leaf area to fruit ratio below 0.50 m^2/kg, there will be no negative impact on the vine capacity in the next year (Table 5).

CONCLUSIONS

The decrease in leaf area to fruit ratio through a severe trim treatment after berry set produced an important delay in grape ripening in the 'Grenache' and 'Tempranillo' varieties. The véraison stage was delayed by about 20 days. On the same harvesting date, the trim treatment had lower levels of soluble solids, lower pH and less total anthocyanin content. The trim effect was also reflected in berry weight, leading to reduced bunch size and yield. It was also found that, if the trim treatment did not reduce the leaf area to fruit ratio below 0.50 m^2/kg, there was no negative impact on the vine capacity in the next year.

It would be very interesting to study other trimming intensities, as well as other times of intervention. Further research could also be done to determine whether it just was delayed ripening, or whether the grapes did in fact not mature completely, and to harvest each treatment at a different time and even transform grapes into wine to assess the final quality of the wines.

LITERATURE CITED

Bennett, J., Jarvis, P., Creasy, G.L. & Trought, M.C.T., 2005. Influence of defoliation on overwintering carbohydrate reserves, return bloom, and yield of mature Chardonnay grapevines. Am. J. Enol. Vitic. 56, 386-393.

Bledsoe, A.M., Kliewer, W.M. & Marois, J.J., 1988. Effects of timing and severity of leaf removal on yield and fruit composition of Sauvignon Blanc grapevines. Am. J. Enol. Vitic. 1, 49-54.

Coombe, B.G., 1995. Growth stages of the grapevine. Aust. J. Grape and Wine Res. 1, 100-110.

Duchêne, E. & Schneider, C., 2005. Grapevine and climatic changes: A glance at the situation in Alsace. Agron. Sust. Dev. 25, 93-99.

Iland, P. & Gago, P., 2002. Australia wines. Styles and tastes. Patrick Iland Wine Promotions, Campbelltown, South Australia.

Iland, P., Bruer, N., Ewart, A., Markides, A. & Sitters, J., 2004. Monitoring the winemaking process from grapes to wine: Techniques and concepts. Patrick Iland Wine Promotions, Campbelltown, South Australia.

Intrieri, C. & Filippetti, I., 2009. Matturazione accelerata delle uve ed eccessivo grado alcolico dei vini: Cosa può fare la ricerca se cambia il clima? Rivista di frutticoltura e di ortofloricoltura 71, 60-62.

Jones, G.V., Duchêne, E., Tomasi, D., Yuste, J., Braslavska, O., Schultz, H.R., Martinez, C., Boso, S., Langellier, F., Perruchot, C. & Guimberteau, G., 2005. Changes in European winegrape phenology and relationships with climate. Proc. XIV GESCO Symposium, Vol. I, Geisenheim, Germany. pp. 55 – 61.

Kenny, G.J. & Harrison, P.A., 1992, The effects of climate variability and change on grape suitability in Europe. J. Wine Res. 3, 163-183.

Kliewer, W.M. & Dokoozlian, N.K., 2005. Leaf area/crop weight ratios of grapevines: Influence on fruit composition and wine quality. Am. J. Enol. Vitic. 56, 170-181.

Martínez de Toda, F., 1985. Estudio de los efectos del despunte en la vid mediante la utilización de radisótopos. Ed. I.E.R. La Rioja.

Martínez de Toda, F., 1991. Biologia de la vid. Fundamentos biologicos de la viticultura. Ed. Mundi-Prensa, Madrid.

Mori, K., Goto-Yamamoto, N., Kitayama, M. & Hashizume, K., 2007. Loss of anthocyanins in red-wine grape under high temperature. J. Exp. Bot. 58, 1935-1945.

OIV, 2013. Compendium of international methods of analysis of wines and musts. OIV, Paris.

Percival, D.C., Fisher, K.H. & Sullivan, J.A., 1994. Use of fruit zone leaf removal with *Vitis vinifera* L. cv. Riesling grapevines. II. Effect on fruit composition, yield, and occurrence of bunch rot (*Botrytis cinerea* Pers.: Fr.). Am. J. Enol. Vitic. 45, 133-139.

Rombola, A., Covarrubias, J., Boliani, A., Marodin, G., Ingrosso, E. & Intrieri, C., 2011. Post-véraison trimming practices for slowing down berry sugar accumulation and tuning technological and phenolic maturity. Proc. 17th GiESCO Symposium, Asti-Alba, Italy. pp. 567 – 570.

Schultz, H.R., 2000. Climate change and viticulture: A European perspective on climatology, carbon dioxide and UV-B effects. Aust. J. Grape Wine Res. 6, 2-12.

Schultz, H.R. & Jones, G.V., 2010. Climate induced historic and future changes in Viticulture. Journal of Wine Research 21(2), 137-145.

Smart, R. & Robinson, M., 1991. Sunlight into wine: A handbook for winegrape Canopy management. Winetitles, Adelaide.

Stock, M., Gerstengarbe, F.W., Kartschall, T. & Werner, P.C., 2005. Reliability of climate change impact assessments for viticulture. Acta Horticulturae 689, 29-39.

Stoll, M., Scheidweiler, M., Lafontaine, M. & Schultz, H.R., 2009. Possibilities to reduce the velocity of berry maturation through various leaf area to fruit ratio modifications in *Vitis vinifera* L. Riesling. Proc. XVI GESCO Symposium, Davis, USA. pp. 93 – 96.

Tardáguila, J., Diago, M.P., Martínez de Toda, F., Poni, S. & Vilanova. M., 2008. Effects of timing of leaf removal on yield, berry maturity, wine composition, and sensory properties of Grenache wines grown in dry farmed conditions. J. Int. Sci. Vigne Vin. 42, 221-229.

Tardáguila, J., Martínez de Toda, F., Ponie, S. & Diago, M.P., 2010. Early leaf removal impact on yield components, fruit, and wine composition of Graciano and Carignan (*Vitis vinifera* L.) grapevines. Am. J. Enol. Vitic. 61, 372-381.

Webb, L.B., Whetton, P.H. & Barlow, E.W.R., 2007. Modelled impact of future climate change on the phenology of grapevines in Australia. Australian Journal of Grape and Wine Research 13, 165-175.

Webb, L.B., Whetton, P.H. & Barlow, E.W.R., 2008. Climate change and wine grape quality in Australia. Climate Research 36, 99-111.

Zufferey, V., Murisier, P., Vivin, P., Belcher, S., Lorenzini, F., Spring, J.L. & Viret, O., 2012. Carbohydrate reserves in grapevine (*Vitis vinifera* L. 'Chasselas'): The influence of the leaf to fruit ratio. Vitis 51(3), 103-110.