AGRONOMIC AND QUALITATIVE EFFECTS OF EARLY LEAF REMOVAL ON cv. VERDEJO IN RAINFED CONDITIONS, IN THE D.O. RUEDA (SPAIN)

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Abstract

Aim: The regulation of the vegetative-reproductive balance of a vineyard is a critical aspect for the quality of grapes. Early leaf removal, generally applied before the phenological stage of flowering, is mainly used as a technique to control yield and improve grape health, aimed at increasing the quality of the wine. The vineyard's response to early leaf removal may depend on the variety, climate, and growing conditions. The aim of this study is to assess the impacts of early leaf removal on the optimisation of the grape ripening process.

Methods and Results: In the D.O. Rueda, Spain, throughout the period of 2015-2018, the application of basal leaf removal was applied at the beginning of flowering. The first eight adult leaves were removed from the base of all the shoots and vine performance assessed. The trial was carried out in a rain fed vineyard of Verdejo, grafted to 110R, planted in 2006, with 2.60 x 1.25 m row and vine spacing, and trained on to a vertical trellis.
Early leaf removal reduced yield by 15%, through a reduction in the bunch weight, affected by a reduction in the number of berries. The weight of the berry and the number of clusters per vine were not affected by early leaf removal. The vegetative development was affected by leaf removal, slightly reducing the leaf area and the pruning weight, in line with the weight of the shoot, also reducing the Ravaz index.
The concentration of sugars increased slightly due to early leaf removal. The pH of must was slightly lower, while the titratable acidity and the tartaric acid increased slightly with the application of leaf removal. The malic acid decreased and the potassium increased slightly due to early leaf removal.

Conclusions: Early leaf removal can be applied to control yield and to favour the maturation and the quality of Verdejo grapes grown under rainfed conditions. However, its application must be considered according to the climatic situation and the type of wine that is intended to be produced.

Significance and Impact of the Study: A benefit of early leaf removal is a reduction in cluster compactness and cluster weight which can improve the grape quality in the cv. Verdejo under rainfed conditions, taking into account the desired grape characteristics.

Keywords: Acidity, grapevine, ripening, sugars, yield

Introduction

The application of leaf removal before flowering aims to control yield and improve grape health and quality, with the ultimate aim of increasing the wine quality. Early leaf removal is based on the immediate effects derived from the functional relationship between the productive potential and the availability of sugars in the flowering phase (Diago, 2010).

The works related to vineyard early defoliation were initially carried out in red varieties, such as Sangiovese (Poni *et al.,* 2006). This work showed that removing four to six leaves from the basal part of the main shoot during flowering limits fruit set and/or the initial development of the berry, and therefore its final size, giving rise to clusters of lower weight and reduced compactness. Higher quality was observed due to an increase in the concentration of sugars, anthocyanins and total polyphenols. In addition, this practice reduced the incidence of *Botrytis cinerea* and other fungal diseases, improving vine health and grape quality (Smith and Centinari, 2019).

This practice has been the subject of various studies in different red varieties and wine-growing areas, having achieved variable results depending on the conditions in which the trials were carried out. Diago (2010) observed that early defoliation in Tempranillo, Graciano and Mazuelo varieties significantly reduced fruit set, cluster weight and grape yield per vine, due to looser clusters, with fewer berries of less or equal weight but with a higher skin / pulp ratio. The vines showed a compensatory vegetative growth, maintaining and even increasing the leaf / fruit ratio, but with higher porosity of the canopy and better exposure of the clusters. Grape quality was improved in terms of phenolic maturity and organoleptic quality.

The magnitude of the effects in the vineyard can vary according to the variety and the conditions of leaf removal application (phenological stage, intensity) and cultivation, as various studies have shown (Arrillaga, 2017; López *et al.,* 2018; Poni *et al.,* 2009; Rodríguez *et al.,* 2015; VanderWeide *et al.,* 2020).

The application of early defoliation in white varieties has been studied less frequently, focusing mainly on the impact on the aromatic potential of the grape (Vilanova *et al.,* 2018). In La Rioja, the works have been developed with White Tempranillo (García-Escudero *et al.,* 2011), as well as with Viura and Alarije (Martínez *et al.,* 2016), observing that this practice allows the control of the productive potential through the reduction of the berry number per cluster and berry weight, that is, limiting cluster weight. Likewise, an increase in the concentration of sugars, pH and potassium was found, without significantly affecting the level of total acidity. However, these authors draw attention to the possible reduction in fruit quality that may entail in varieties with low acidity potential, especially through malic acid, and the increase in pH, particularly in hotter climates.

Taking into account the possibilities that early defoliation can offer as a tool for controlling yield, as well as for the sanitary improvement of the vineyard, in the absence of previous specific works, its application in the white Verdejo variety was considered, under rainfed cultivation. The work was proposed in the D.O. Rueda, located in the center of the Duero river valley (Castilla y Leon, Spain), with the aim of evaluating its possible vegetative, productive and, particularly, qualitative effects, as basic aspects to optimize the vineyard management.

Materials and Methods

The trial was conducted over the period 2015-2018 in Medina del Campo (Valladolid, Spain), in a vineyard belonging to the Grupo Yllera S.L. winery, located within the D.O. Rueda, in the center of Castilla y Leon region. The geographical coordinates of the vineyard are 41º21'02''N and 4º56'16''O. The vines, planted in 2006, were from cv. Verdejo, grafted onto 110R. The vine distances were 2.60 m x 1.25 m (3,077 vines/ha). The vines were trellis trained to a bilateral Royat cordon and vertical shoot positioning (VSP). Row orientation was NNO (N-25º). The pruning load was 16 buds per vine, with 2 node spurs. A green pruning operation was applied every year, after the spring frost risk period, for the adjustment of the shoot load per vine. The soil of the trial is deep, with a clay upper horizon, and has a slight slope in direction East to West and good drainage in general. The vineyard was not irrigated and climatic conditions are provided in Table 1.

The experimental trial comprised an early leaf removal or defoliation treatment (D) and a control treatment (T), replicated in 4 random blocks, with an elemental plot of 20 vines for evaluation arranged in 2 adjacent rows. The leaf removal (D) was applied at the beginning of the flowering phase, suppressing the first 8 adult leaves, from the base, of all shoots.

Table 1: Data of temperature, ETo and rainfall of seasons 2015, 2016, 2017 and 2018, corresponding to the annual period October (previous year) – September (season year), registered in Medina del Campo (Valladolid). **Tm**: average temperature (ºC), **Tmax**: maximum temperature (ºC), **Tmin**: minimum temperature (ºC), **ETo** 1-apr/30-sep (mm), P: precipitation (mm), **Pa**: Oct 1 / Sep 30, **Pc**: Apr 1/ Sep 30, **Pv**: Jul 1/ Sep 30.

	Tm	Tmax	Tmin	ETo	Pa	Pc	Pv
2015	12.9	19.4	6.8	947	240	122	21.8
2016	12.8	19.1	6.9	830	318	93	0.2
2017	13.2	20.2	6.5	970	167	89	43.0
2018	12.4	19.3	6.0	843	323	139	3.4

The following parameters were measured: grape production (kg/vine), number of bunches per vine and berry weight (g) as yield components; leaf area (Carbonneau, 1976), weight of pruning wood (kg/vine) and number of shoots per vine as vegetative development, subsequently obtaining the Ravaz Index; and concentration of total soluble solids (ºbrix), pH, titratable acidity ($g.L^{-1}$ of tartaric acid), tartaric acid ($g.L^{-1}$), malic acid ($g.L^{-1}$) and potassium ($mg.L^{-1}$), at harvest, as qualitative composition of grapes.

The statistical analysis of results was carried out by simple ANOVA.

Results and Discussion

Grape Production

Yield was reduced by an interannual average of 15% as a consequence of leaf removal, showing statistically significant differences between treatments in two years of the study. The control treatment reached an average of 9.18 t/ha versus 7.78 t/ha collected in the leafless treatment. The differences in grape production were due to the reduction in cluster weight, which showed statistically significant differences favourable to the control treatment every year, with an average of 131 g versus 109 g of the leafless treatment. The number of berries per cluster was the component affected by leaf removal that decisively reduced the cluster weight, showing statistically significant differences in most years, which resulted in an average reduction of 16% with respect to the control treatment. The berry weight was not affected in a defined way by the application of leaf removal, showing variable differences between treatments, some of which were significant, depending on the year, finally giving rise to a very similar interannual mean value between treatments, around to 1.26 g. The number of clusters per vine was not affected in general by leaf removal over the years, presenting a similar interannual average value between both treatments, around 23 clusters per vine.

Table 2. Grape production: grapes weight ($kg.vine^{-1}$), yield ($t.ha^{-1}$), clusters per vine, cluster weight (g), berries per cluster and berry weight (g), of control (T) and leaf removal (D) treatments, in the period 2015-2018. Statistical significance level: *, p<0,1; **, p<0.05.

Treat.	Grape weight / vine					Yield					Clusters / vine				
	2015	**2016**	**2017**	**2018**	***Ave.***	**2015**	**2016**	**2017**	**2018**	***Ave.***	**2015**	**2016**	**2017**	**2018**	***Ave.***
T	2.90	3.48*	1.97**	3.59	*2.98*	8.9	10.7*	6.1**	11.0	*9.18*	23.1	26.4	22.1	20.5	*23.0*
D	2.54	3.13	1.39	3.06	*2.53*	7.8	9.6	4.3	9.4	*7.78*	22.5	25.9	22.1	21.7	*23.1*
	Cluster weight					**Berries / cluster**					**Berry weight**				
T	126*	132*	89**	175**	*131*	109	128**	80**	99	*104*	1.16	1.04	1.12	1.77**	*1.27*
D	113	121	62	140	*109*	99	104	55	90	*87*	1.14	1.17**	1.13	1.56	*1.25*

Vegetative Growth

The total leaf area (LAI) measured in the maturation phase was only slightly reduced due to the early leaf removal, the LAI index going from an average of 1.65 in the control to 1.57 in the leafless treatment, that is, decreasing by 5%, without resulting statistically significant differences in any case. The external leaf surface (SA) was also slightly reduced due to early defoliation, by 5%, resulting in statistically significant differences between both treatments in some of the years.

A tendency to reduce the weight of pruning wood derived from early leaf removal was observed, with the interannual average decreasing by 9%, although the differences compared to the control treatment were not statistically significant in any case. Shoot weight was slightly higher in the control than in the leaf removal treatment in general, but the differences did not were statistically significant. The average interannual reduction due to leaf removal was almost 9%, thus contributing, in a major way, to the reduction in the weight of pruning

wood compared to the control treatment. The number of shoots per vine did not show differences between treatments, resulting in an interannual mean of 15.2 in the control and 15.0 in the leafless treatment.
The Ravaz index was slightly reduced with the leaf removal, going from a mean value of 5.6 in the control to 5.1 in the leafless treatment, although the differences were only statistically significant in the third year of study.

Table 3. Vegetative growth: pruning wood weight (g.vine^{-1}), shoots per vine, shoot weight (g), leaf area index (LAI), surface area (SA) and Ravaz index, of control (T) and leaf removal (D) treatments, in the period 2015-2018. Statistical significance level: *, p<0,1; **, p<0.05.

Treat.	**Pruning Wood weight**					**Shoots / vine**					**Shoot weight**				
	2015	**2016**	**2017**	**2018**	***Ave.***	**2015**	**2016**	**2017**	**2018**	***Ave.***	**2015**	**2016**	**2017**	**2018**	***Ave.***
T	482	606	358	724	*543*	16.1*	15.3	14.9	14.5	*15.2*	29.8	39.6	23.9	49.8	*35.8*
D	477	557	309	624	*492*	15.3	15.3	14.7	14.8	*15.0*	31.2	36.3	20.9	42.3	*32.7*
	LAI					**SA**					**Ravaz index**				
T	1.39	1.88	1.33	2.02	*1.65*	0.83	1.09**	0.93**	1.08	*0.98*	6.05	5.76	5.62**	5.01	*5.61*
D	1.34	1.83	1.22	1.88	*1.57*	0.84	0.99	0.82	1.07	*0.93*	5.35	5.67	4.56	4.91	*5.12*

Grape Composition
The influence of leaf removal on grape composition was variable. Thus, the concentration of soluble solids showed a slight tendency to increase in the leaf removal treatment, the average increase being 0.3 ºbrix with respect to the control treatment, although the differences were not statistically significant every year. The pH was slightly lower in the leaf removal than in the control treatment, resulting in statistically significant differences in two of the four years. Titratable acidity and tartaric acid showed a slightly increasing trend in the leaf removal treatment compared to the control one, although the difference was only statistically significant in the first year of the study. On the contrary, malic acid showed lower values in the leaf removal than in the control treatment, every year, resulting in statistically significant differences in two of the four years. The potassium concentration in the grape must was slightly higher in the leafless than in the control treatment, although the difference was only statistically significant in the second year of the study.

Table 4. Grape composition: total soluble solids (ºbrix), pH, titratable acidity (g.L^{-1} tartaric acid), tartaric acid (g.L^{-1}), malic acid (g.L^{-1}) and potassium (mg.L^{-1}), of control (T) and leaf removal (D) treatments, in the period 2015-2018. Statistical significance level: *, p<0,1; **, p<0.05.

Treat.	**Soluble solids**					**pH**					**Titratable acidity**				
	2015	**2016**	**2017**	**2018**	***Ave.***	**2015**	**2016**	**2017**	**2018**	***Ave.***	**2015**	**2016**	**2017**	**2018**	***Ave.***
T	23.1	22.7	22.5	22.9	*22.8*	3.39	3.45**	3.43	3.44**	*3.43*	5.20	5.79	5.75	5.27	*5.50*
D	23.6**	22.4	23.1*	23.3	*23.1*	3.34	3.33	3.38	3.42	*3.37*	5.49	5.62	5.91	5.41	*5.61*
	Tartaric acid					**Malic acid**					**Potassium**				
T	8.82	9.83	10.23	8.35	*9.31*	0.87**	1.08	1.06	1.61*	*1.16*	1998	1940	1687	1383	*1752*
D	9.49**	9.43	10.50	8.50	*9.48*	0.57	0.90	1.02	1.42	*0.97*	2080	2008*	1690	1415	*1798*

Conclusions

Early leaf removal reduced yield by 15%, through a reduction in cluster weight, as a result of a 16% reduction in the number of berries compared to the control treatment. Neither the berry weight nor the number of clusters per vine had an impact on the yield reduction caused by early leaf removal, despite the fluctuating annual variations observed in berry weight.

Vegetative development was affected by early leaf removal, with a reduction in leaf area and a 9% decrease in pruning weight, due to a reduction in the shoot weight. The Ravaz index also showed a tendency to decrease with leaf removal.

The concentration of soluble solids was slightly favoured by early leaf removal. The pH was slightly lower in leaf removal vines, while total acidity and tartaric acid were slightly higher with leaf removal. Malic acid was reduced as a consequence of leaf removal, while the potassium concentration was slightly higher when leaf removal was applied compared to the control treatment.

Early leaf removal allows efficient and healthy yield control for the vineyard, as well as improving the structure of the cluster, being able to favour ripening and grape quality of the cv. Verdejo grown in rainfed conditions. However, its application, in terms of intensity and timing, must be considered paying attention to the climatic situation and the type of wine to be made.

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