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Cluster thinning in cv. Verdejo rainfed grown: Physiologic, agronomic and qualitative effects, in the D.O. Rueda (Spain)

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Abstract. The control of grape yield can be a critical aspect for grape quality of white varieties, moreover in the conditions of high water limitation that occurs in most Spanish growing regions. In the case of Verdejo variety, it is necessary to know its response to the reduction of the number of clusters per vine in order to regulate the production and improve the grape quality. During the period 2012–2014, the application of cluster thinning has been studied, by means of a treatment (A) of removing 27% of clusters, in comparison with a reference treatment (T) without thinning. The trial has been developed with vines of cv. Verdejo on 110R rootstock, planted in 2006 and trellised on bilateral Royat cordon. Vine distances were 2.60 m × 1.25 m (3077 plants/ha). Vineyard growing was developed under rainfed conditions in Medina del Campo (Valladolid, Spain), within the D.O. Rueda. The water and physiological response of vines subjected to thinning has been similar to that of the reference vines. The vegetative growth has not shown significant differences between treatments. However, as expected, the cluster thinning resulted in a substantial reduction of grape yield as a direct consequence of the removal of clusters, although the cluster weight was slightly favored by cluster thinning. The quality of grapes has been modified by cluster thinning, in such a way that the sugar concentration has benefited, while the titratable acidity and tartaric acid have been reduced. However, the malic acid and the pH have hardly been affected by cluster thinning, whereas the potassium concentration has clearly increased as a result of cluster thinning.

1. Introduction

The control of grape yield can be critical for the quality of grapes in white varieties, moreover in the conditions of high water limitation that occurs in most Spanish growing regions. The application of cluster thinning is widespread in grapegrowing areas with Denomination of Origin, governed by quality control agencies or regulatory councils, to correct the excess of crop load. This excess is usually caused by an excessive number of buds retained after pruning or by very mild weather conditions during the flowering and fruit set, which increase the actual fertility with regard to the expectation.

Traditionally, the use of this technique was associated with the idea that a low yield improves the quality of grapes. Even sometimes, the sector transmits this concept to final consumers, who often associate a lower production of grapes per hectare with a higher quality of wine produced, regardless of other aspects of crop. However, it has been known that the initial increase in grape production is accompanied by an increase in grape quality, showing the regression between these two parameters a normal curve, until a point from which the grape quality starts to decrease due to excessive crop load [1]. This balance point depends on the productive capacity of the vineyard, which will be a function of climate, soil, variety, crop management and the desired production goal.

This operation may be necessary or recommended in plants with overload and/or under adverse weather conditions. If it is done early enough before harvest, it can help to achieve the desired status of maturity. The reduction of crop modifies the source–sink ratio and can facilitate the advancement of ripening (around a week) and increase the pH and soluble solids content, anthocyanins, polyphenols and total nitrogen in must [2].

Regarding the homogeneity that this technique gives the grapes finally harvested, there are differing opinions. Intrigliolo and Castel exposed that cluster thinning increases the uniformity in soluble solids [3]. Conversely, Calderon-Orellana et al. wrote that cluster thinning increased uniformity of soluble solids content in clusters during the veraison phase, but in harvest it did not show statistically significant differences between the thinned treatment and the reference, what would indicate that the execution of thinning, looking for the increase of uniformity of ripening at harvest, would not justify its cost [4]. However, both publications agree that changes due to cluster thinning in grape composition and characteristics of the resulting wine, can be modified to some extent depending on the climatic characteristics of the year.

Looking at sensorial aspect, according to Bravdo [1], the score of wine from thinned plants was significantly higher than that from reference plants in a trial with over cropped vines. Contrary, the thinning effect was not statistically significant when evaluating wine from another trial that showed plantas without excess of production. Another sensory evaluation carried out by Berkey et al. [5], with wines obtained from trials of cluster thinning in 2009 and 2010, served to find differences in the first year but not in the second, which highlights the importance of annual climatic conditions regarding the application of this technique.

An extensive number of articles about cluster thinning has been published, as a technique used to regulate the load and increase the quality of grapes, but these publications show differences in results, because they were carried out with different conditions, such as soil, climate, management and variety. Hence the importance that experimentation acquires in each zone with varieties that may require monitoring of the grape yield required or desired.

The purpose of this work is to study the possible effects of the application of cluster thinning in vegetative growth, grape production and quality, on Verdejo variety, grafted onto 110R, and vertical trellis trained, along the period 2012–2014, in an experimental trial located in the Denomination of Origin Rueda (Spain), therefore, in a situation of growing on semi-arid climatic conditions in the center of the Duero river valley.

2. Material and methods

The trial was carried out throughout the period 2012–2014 in Medina del Campo (Valladolid, Spain), in a vineyard belonging to the winery Yllera Group S.L., located within the D.O. Rueda, in the center of Castilla y León. The coordinates of the trial are 41°21′02″ N, 4°56′16″ W. The vines of the experimental vineyard, planted in 2006, are of cv. Verdejo, grafted onto 110R rootstock.

The vines were trellis trained in bilateral Royat cordon with vertical positioning of vegetation (VSP), with orientation North-South of rows. Pruning load has been 16 buds per vine, with 2-bud spurs. A green pruning operation has been applied each year, after the period of risk of spring frost, to adjust the load of shoots per vine.

The experimental treatments are based on the regulation of the number of clusters, through the application of a cluster thinning treatment (A) compared to a reference treatment (T). The cluster thinning is applied at the beginning of veraison, trying to approach to a reduction of a third part of clusters. This level of reduction has been applied to a greater trial that includes other situations of water regime besides the rainfed one, which is studied in this paper, in such a way that in the present paper, without irrigation, the final adjustment has resulted in an average reduction of 27% of clusters with respect to the reference treatment, so that the reference vines have retained 36% more clusters than the thinned vines.

The vine distances are 2.60 m × 1.25 m, corresponding to a soil area of 3.25 m^2 per vine, that is, at a density of 3077 vines per hectare. The experimental design is of randomized blocks with 4 replications of 20 control vines in each elemental plot. The soil of the trial is deep, with a clay upper horizon and good drainage in general, and slight slope in direction East to West.

The water regime of the trial has been a rainfed growing, without irrigation throughout the period of study.

Measurements of leaf water potential, with pressure chamber, to determine the vine water status, as well as physiologic measurements, of stomatal conductance and net photosynthesis, with an instrument IRGA-6400 (Li-Cor, USA) have been done at 9.00 solar time, every

Table 1. Temperature and rainfall average values of the 2012 season (October 2011/September-2012) recorded in Medina del Campo (Valladolid). T_m: average temperature (°C), T_{max}: average maximum temperature (°C), T_{min}: average minimum temperature (°C), P: precipitation (mm).

	Oct	Nov	Dec	Jan	Feb	Mar	
T_m	13.1	8.2	3.7	2.1	2.4	8.8	
T_{max}	22.5	12.8	9.2	7.0	10.1	17.1	
T_{min}	4.4	4.3	–0.8	–2.1	–4.9	0.1	
P	0.2	0.5	28.5	14.7	1.1	11.0	
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Year**
T_m	8.2	16.3	20.0	21.3	22.5	17.9	12.9
T_{max}	13.2	23.6	27.6	30.0	30.9	25.7	19.2
T_{min}	3.8	8.7	11.4	12.0	13.4	10.4	5.1
P	39.8	10.8	4.8	6.5	1.6	20.6	140.1

Table 2. Temperature and rainfall average values of the 2013 season (October 2012/September-2013) recorded in Medina del Campo (Valladolid). T_m: average temperature (°C), T_{max}: average maximum temperature (°C), T_{min}: average minimum temperature (°C), P: precipitation (mm).

	Oct	Nov	Dec	Jan	Feb	Mar	
T_m	12.3	7.5	5.1	4.5	4.2	7.3	
T_{max}	19.0	12.4	9.4	9.3	9.7	12.1	
T_{min}	6.4	3.0	1.0	0.5	–0.8	2.8	
P	70.8	43.2	14.5	38.9	28.0	98.0	
	Apr	**May**	**Jun**	**Jul**	**Ago**	**Sep**	**Año**
T_m	9.5	11.7	17.2	23.6	21.7	18.2	11.9
T_{max}	15.5	18.1	25.0	32.1	30.6	26.7	18.3
T_{min}	3.5	5.1	9.1	14.6	12.7	10.4	5.7
P	32.9	18.1	9.6	18.5	3.9	42.0	418.4

Table 3. Temperature and rainfall average values of the 2014 season (October 2013/September-2014) recorded in Medina del Campo (Valladolid). T_m: average temperature (°C), T_{max}: average maximum temperature (°C), T_{min}: average minimum temperature (°C), P: precipitation (mm).

	Oct	Nov	Dec	Jan	Feb	Mar	
T_m	13.4	6.5	2.6	6.1	5.5	8.8	
T_{max}	19.6	11.9	8.1	10.2	10.0	15.8	
T_{min}	8.2	1.7	–2.1	1.8	1.2	2.0	
P	70.8	43.2	14.5	38.9	28.0	98.0	
	Abr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Year**
T_m	13.2	14.6	19.0	21.1	21.3	18.6	12.6
T_{max}	20.3	22.1	26.6	28.7	29.1	25.8	19.0
T_{min}	6.5	7.1	10.7	13.2	13.3	12.3	6.3
P	18.6	17.0	12.5	5.6	0.0	49.5	328.8

two weeks, from cluster thinning application to harvest time. Also, several parameters of vegetative development, grape production and grape quality, were determined as it is shown in the part of Results and discussion.

The statistical analysis of results was performed using analysis of variance (ANOVA) with the STATISTICA 7.0 program.

The monthly average rainfall and temperature data, for the period 2012–2014, are detailed in Tables 1–3.

3. Results and discussion

3.1. Grape production

The grape yield of thinning treatment has shown a significant reduction compared with the reference treatment, resulting in an average difference of 22% lower than the reference, but with variations depending on the year between 12%, in 2014, and 29%, in 2013, in such a way that the differences became statistically significant in 2012 and 2013 (Table 4).

The cluster weight has shown a tendency to increase in the thinned treatment, to a greater or lesser extent depending on the year, with variations between 3.2%, in 2013, and 9.1%, in 2012, with an annual average increase above 6%, having found statistically significant differences between treatments only in 2012 (Table 5).

The cluster weight therefore partially would explain some compensation in grape production, since the number of clusters per vine has been reduced directly, to around 27% on interannual average, by applying the thinning treatment (Table 6).

Table 4. Grape yield (t/ha). Treatments: reference (T), cluster thinning (A). Statistical significance: * = $p < 5\%$ (for all tables).

Treat.	2012	2013	2014	Aver.
T	7.44	11.40	9.78	9.54
A	5.72	8.01	8.56	7.43
Sig.	*	*	–	

Table 5. Cluster weight (g).

Treat.	2012	2013	2014	Aver.
T	122	160	155	146
A	133	165	166	155
Sig.	*	–	–	

Table 6. Clusters/vine.

Treat.	2012	2013	2014	Aver.
T	19.8	23.1	20.5	21.1
A	14.0	15.8	16.8	15.5
Sig.	*	*	*	

Table 7. Berries/cluster.

Treat.	2012	2013	2014	Aver.
T	108	112	102	108
A	113	116	99	109
Sig.	–	–	–	

Table 8. Berry weight (g).

Treat.	2012	2013	2014	Aver.
T	1.13	1.43	1.52	1.36
A	1.18	1.43	1.68	1.43
Sig.	–	–	–	

Regarding the cluster weight, the number of berries per cluster has shown an inconsistent trend of thinning treatment to have slightly higher values than the reference treatment, with an average increase of 1.5% (Table 7), having found no statistically significant differences between treatments. As to berry weight, it has been observed certain tendency in thinning treatment to produce slightly larger berries, with a mean value of 1.43 g vs. 1.36 g corresponding to the reference treatment, although the differences were not found statistically significant in any case (Table 8).

The real fertility, expressed as number of clusters per vine, has obviously shown the same trend as the number of clusters, given the shoot load adjustment applied. Therefore, the observed differences were statistically significant all years (Table 9).

3.2. Vegetative growth

The weight of pruning wood per unit area of soil has not been practically modified by the reduction of crop load, showing a mean value along the study period slightly higher (around 1.5%) in the thinning treatment than in the reference. This average value comes from the favorable values to one or another treatment depending on the year of study. In the first two years, the amount of pruning wood was lower for thinning treatment (7.4% and 1.2% respectively). However, in the last year this treatment showed an increase of pruning wood of more than 11%, although no statistically significant differences were found in any year (Table 10).

The weight of shoot neither has been altered by the application of cluster thinning, with a mean value of 40.8 g for vines of reference treatment and 41.8 g for thinned vines (Table 11).

The number of shoots per vine has not changed significantly between treatments, logically, given the shoot load

Table 9. Clusters/shoot.

Treat.	2012	2013	2014	Aver.
T	1.29	1.45	1.24	1.33
A	0.92	1.00	1.02	0.98
Sig.	*	*	*	

Table 10. Pruning wood weight (t/ha). Treatments: reference (T), cluster thinning (A). Statistical significance: * = $p < 5\%$ (for all tables).

Treat.	2012	2013	2014	Aver.
T	1.54	2.31	2.17	2.01
A	1.42	2.28	2.42	2.04
Sig.	–	–	–	

Table 11. Shoot weight (g).

Treat.	2012	2013	2014	Aver.
T	32.5	47.0	42.8	40.8
A	30.7	46.9	47.9	41.8
Sig.	–	–	–	

Table 12. Shoots/vine.

Treat.	2012	2013	2014	Aver.
T	15.4	16.0	16.5	15.9
A	15.1	15.8	16.5	15.8
Sig.	–	–	–	

Table 13. Ravaz index.

Treat.	2012	2013	2014	Aver.
T	4.93	4.97	5.28	5.06
A	4.05	3.52	3.35	3.64
Sig.	–	*	*	

adjustment applied each year after the period of risk of spring frost (Table 12).

The Ravaz index has shown a clear reduction in thinned vines with respect to reference vines, resulting from the yield decrease of thinning treatment, so that statistically significant differences have been observed in 2013 and 2014 (Table 13).

3.3. Water status and physiology

The values of leaf water potential (Table 14) did not allow to distinguish the two treatments applied, showing in both cases a high level of water stress in plants that were rainfed grown, with values between 1.13 and 1.71 MPa.

The stomatal conductance (Table 15) has not shown a clear trend resulting from cluster thinning, not having found statistically significant differences between treatments. In the second half of August 2013 higher values than in the other measurements were found, which could be reflecting a luxury use of the available water, possibly due to a lower level of water stress experienced by plants in such summer meteorological conditions observed that were abnormally soft at that time. In the second half of July 2012 the situation was the opposite, according with a situation observed under conditions of high stress at that time.

The net assimilation (Table 16) has shown a parallel behavior as the stomatal conductance, with values that do not reflect significant differences between treatments and were at a fairly low level according to the remarkable water stress suffered each year by plants, in rainfed growing conditions.

Despite the clear modification of the source/sink balance achieved by means of the reduction of crop load, the plants affected by this reduction showed no changes in physiological behavior compared to the reference plants. These results are in agreement with those obtained by other authors that have worked with cv. Tempranillo [6], who suggest that plants under severe water stress may be less physiologically sensitive to the influence of the crop load as a sink than plants with enough watering supply.

Table 14. Leaf water potential (MPa). Statistical significance: * = $p < 5\%$ (for all tables).

Year	Date	T	A	Sig.
2012	**18-Jul**	–1.13	–1.24	–
	16-Aug	–1.44	–1.61	–
	30-Aug	–1.71	–1.69	–
	12-Sep	–1.67	–1.64	–
2013	**28-Aug**	–1.39	–1.39	–
	11-Sep	–1.47	–1.53	–
	26-Sep	–1.61	–1.70	
	9-Oct	–0.58	–0.64	–
2014	**13-Aug**	–1.41	–1.43	–
	27-Aug	–1.53	–1.57	–
	10-Sep	–1.50	–1.55	–

Table 15. Stomatal conductance (mmol H_2O. m^{-2}. s^{-1}).

Year	Date	T	A	Sig.
2012	**18-Jul**	11.00	3.47	–
	16-Aug	44.88	42.98	–
	30-Aug	35.92	43.66	–
	12-Sep	37.84	39.86	–
2013	**28-Aug**	82.73	82.12	–
	11-Sep	39.48	42.43	–
	26-Sep	33.00	42.85	–
2014	**13-Aug**	28.53	34.18	–
	27-Aug	25.63	23.63	–
	10-Sep	21.56	26.51	–

Table 16. Net photosynthesis (μmol $CO_2.m^{-2}.s^{-1}$).

Year	Date	T	A	Sig.
2012	18-Jul	3.28	3.36	–
	16-Aug	7.14	6.19	–
	30-Aug	6.58	7.27	–
	12-Sep	5.84	6.57	–
2013	28-Aug	10.19	12.46	–
	11-Sep	11.51	12.02	–
	26-Sep	11.08	11.52	–
2014	13-Aug	12.82	13.45	–
	27-Aug	7.92	7.13	–
	10-Sep	7.43	8.33	–

3.4. Grape composition

The concentration of total soluble solids (°brix) increased slightly in favor of thinning treatment every year, according with authors that have worked with other varieties [7,8], having found statistically significant differences between treatments in 2012 and 2013 (Table 17). In 2012, the plants suffered a major water stress and the cluster thinning got to rise the accumulation of sugars, advancing the date of harvest in a week compared to the reference treatment, which is in accordance with some authors in other varieties [2]. Conversely, in 2013 the environmental conditions exerted lower water stress in plants and, additionally, heavy rainfalls marked the end of maturation. Nevertheless, in this case the technological maturity was also accelerated. It is remarkable that higher levels of sugar were achieved, thanks to the thinning operation applied, in the treatment of cluster thinning in two years that were climatologically opposite.

The pH values have been quite similar in both treatments, without remarkable annual differences which naturally have not been statistically significant (Table 18).

The titratable acidity (g/L TH_2) has shown a reduction of concentration in the treatment of cluster thinning compared to the reference, with an annual average of 7%. The reduction was higher in the driest year (2012, with 9%) and lower in the wettest year (2013, with 5%), but founding statistically significant differences between treatments all years of study (Table 19).

The tartaric acid (g/L) has presented the same annual trend as titratable acidity, with a reduction of values achieved by the thinning treatment with respect to the reference treatment. Still, the differences were only statistically significant in 2012 (Table 20).

The malic acid (g/L) has scarcely shown differences between treatments, with very low values in both treatments all years of study, but highlighting the first year, the driest one (Table 21).

The potassium concentration (mg/L) has been higher in the treatment of thinning every year, especially in the two years that had greater water availability (2013 and 2014), in such a way that the differences were statistically significant in both years (Table 22).

Table 17. Total soluble solids (ºBrix). Treatments: reference (T), cluster thinning (A). Statistical significance: * = $p < 5\%$ (for all tables).

Treat.	2012	2013	2014	Aver.
T	22.3	20.7	22.5	21.8
A	22.9	22.0	22.8	22.6
Sig.	*	*	–	

Table 18. pH of must.

Treat.	2012	2013	2014	Aver.
T	3.45	3.34	3.40	3.40
A	3.50	3.40	3.43	3.44
Sig.	–	–	–	

4. Conclusions

The application of cluster thinning has logically had effect on grape production, since the thinning treatment has clearly shown lower grape yield than the reference

Table 19. Titratable acidity (g/L TH_2).

Treat.	2012	2013	2014	Aver.
T	5.27	5.27	5.50	5.34
A	4.79	4.99	5.14	4.97
Sig.	*	*	*	

Table 20. Tartaric acid (g/L).

Treat.	2012	2013	2014	Aver.
T	9.34	8.01	8.84	8.73
A	8.63	7.88	8.31	8.27
Sig.	*	-	-	

Table 21. Malic acid (g/L).

Treat.	2012	2013	2014	Aver.
T	0.55	1.06	1.03	0.88
A	0.61	0.97	1.01	0.86
Sig.	–	–	–	

Table 22. Potassium (mg/L).

Treat.	2012	2013	2014	Aver.
T	1778	1313	1213	1435
A	1795	1558	1600	1651
Sig.	–	*	*	

treatment, with an average reduction of about 22%. This reduction has been slightly lower than that of number of clusters per vine (caused directly by the operation), due to the fact that the cluster weight compensated partially the final grape yield. The number of berries per cluster has not been remarkably affected, while the berry weight has shown an increasing trend due to the cluster thinning, which has favored the slight increase of cluster weight.

The pruning wood weight per unit area of soil has not been significantly modified by reducing of crop load, since, obviously, neither the shoot weight has shown any substantial variation. The Ravaz index has shown a clear reduction, derived directly from yield reduction in the thinning treatment.

The water status and physiological response of vines subjected to cluster thinning have been similar to those of the reference vines, not having found significant differences between both treatments.

The concentration of total soluble solids has been favored consistently by reducing of crop load. The pH of must has not shown a clear tendency to increase in the thinning treatment. Nevertheless, the titratable acidity has been reduced by reducing crop load, especially when the water stress was higher. The tartaric acid has been also reduced with cluster thinning, mainly when the water stress was higher, although with less intensity than the titratable acidity. The malic acid has shown low values, without practically differences in favor of any treatment. The potassium concentration was clearly higher in the treatment of thinning than in the reference treatment in all years of study.

Definitely, the application of cluster thinning has remarkably reduced grape yield, through the number of clusters, despite the slight increase of berry and cluster weight. The vegetative growth, however, has hardly been modified by this technique applied in an advanced phase of the grape growth cycle. The increase of sugar accumulation makes remarkable the usefulness of this operation in abnormally dry or rainy vintages, in which there can be a ripening delay, in order to optimize the harvest date and the grape quality. However, this technique can cause a reduction of titratable acidity and increase the potassium concentration in grapes. For all that, there should be considered together the oenological and productive implications derived from this operation, always according to the productive and economic targets of each wine estate.

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