Influence of the irrigation period in Tempranillo grapevine, under the edaphoclimatic conditions of the Duero river valley

Influence de la période d'irrigation dans le cv. Tempranillo, dans les conditions édaphoclimatiques de la Vallée de Duero

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Abstract

Irrigation of vineyards is a matter of controversial arguments at areas of high quality wine production. Besides, the effects of the water in the plant are closer related to the water availability than to the irrigation regime. In this way, the criteria for irrigation timing can reach very important physiologic and productive consequences to optimize the vineyard management on each environmental situation.
An experimental trial has been carried out along the period 2005-2007 in the province of Valladolid (Spain), focused on the study of modification of plant water status (leaf water potential), soil water content, physiologic activity, vegetative-productive behavior and quality expression (berry weight, sugar concentration, pH, total acidity, poliphenols concentration) of the Tempranillo variety in the Duero river valley, through the application of a moderate irrigation doses in two different periods of the vegetative cycle, on a concrete edaphic situation. The treatments applied were the following: 20% ETo from vegetative Growth stopping (G20) and 20% ETo from Veraison (V20), both irrigated until one week before harvest. The vines, planted in 1993, were grafted onto 110R and vertical trellised trained, as a bilateral Royat cordon. Vine spacing is 2.70 m x 1.40 m (2645 vines/ha).
The results have shown some differences due to the irrigation period treatments on the effects related to vine water status and soil water content, physiologic activity, vegetative development, productivity and grape quality in Tempranillo variety. In general, the earlier application of irrigation has favoured vine physiologic activity and leaf development, through the improvement of plant water status, estimated by means of leaf water potential measurement, which have consequently provoked certain increase of yield. On the contrary, the delay of irrigation until veraison stage has shown certain tendency in grape composition to increase sugar concentration, pH and poliphenols index.

Key words: LAI, leaf water potential, quality, veraison.

Introduction

The irrigation management is an important viticultural aspect where the rainfall is not enough during the vegetative cycle (Mullins *et al*. 1992), since when the evaporative atmospheric demand is higher than the available water in the soil the water stress happens (Wample 2000, in Sánchez-Llorente 2004). Irrigation plays a direct roll in some stages of the vegetative cycle, as in the flower initiation, and also in its development, modifying the future yield (Pérez 2002). In this way, as flowering and berry set are critical stages for vines due to the cellular divisions that take place, the water stress in this period can drive the vine to poor berry set and small berry size (McCarthy *et al*. 1992). Ojeda *et al*. (2001) said that an early water deficit can cause the decrease of the volume of cell when it happens from flowering to veraison, becoming this situation irreversible for the vine, since one of the yield components, the berry size, is more influenced by the water stress when this happens between flowering and veraison than between veraison and maturity. According to these authors, when there is available water for vines through the ripening season (stage III), the stressed berries can recover their partial or complete size. As Cuevas *et al*. (2006) said, under deficit irrigation conditions, as it can happen due to the delay of the irrigation beginning until the veraison stage, the stomatal closure reduces the CO_2 uptaking and modifies the relation between net photosynthesis rate (A) and stomatal conductance (g_s).

The own vine is the best indicator of its water status and its irrigation requirements (Sánchez-Llorente 2004), since the measurements done on its own organs include edaphic and atmospheric factors which determine the hydric balance (availability of water in the soil, evaporative atmospheric demand) and intrinsic vine factors (leaf area, drought tolerance) (Choné *et al*. 2000; Van Leeuwen *et al*. 2001). Definitively, for the success of any irrigation strategy it is necessary that all decisions are based on sensitive and reliable hydric indicators (Yuste *et al*. 2004) and take into account that the excess of water stress after veraison stage should be avoid because this could provoke the delay in the accumulation of sugar (McCarthy 1998).
The aim of this work is to study the effect of the irrigation period modification along the vegetative cycle, in vegetative, productive and qualitative development of Tempranillo variety, as well as in soil water content, vine water status and its physiologic activity.

Material and methods

The trial was carried out in Valladolid (central-northern Spain), along the period 2005-2007, in a Tempranillo/110 Richter vineyard planted in 1993. Vine spacing was 2.70 x 1.40 m (2645 vines.ha^{-1}). Vines were vertical trellis trained in a bilateral Royat cordon (VSP) and 2-bud spur pruned for 39600 shoots/ha. Row orientation was north-south (+25º). ET daily average was 4.50 mm in 2005, 4.87 mm in 2006 and 4.64 mm in 2007 during the irrigation period. Annual rainfall was 301 mm in 2005, 454 mm in 2006 and 550 mm in 2007.
Experimental irrigation treatments applied were 20% ETo from vegetative Growth stopping (G20) and 20% ETo from Veraison (V20), both irrigated until one week before harvest. Water for irrigation was drip applied weekly and the total doses were 77.8 mm, 66.1 mm and 63.5 mm for G20 and 50.3 mm, 37.4 mm and 25.8 mm for V20 in 2005, 2006 and 2007 respectively. The irrigation started for G20 and V20 respectively in 2005 the 4th of July and the 1st of August, in 2006 the 3rd of July and the 1st of August and in 2007 the 2nd of July and the 6th of August. The randomised block design consisted of 4 replications with an elemental plot of 11 control vines On the soil profile of the trial there are three distinguishable lays which main characteristics are exposed on table 1. It is a rocky soil, without physic nor chemical limitations in deep lays, which allows the soil a good drainage and a high speed of water infiltration. The main part of the root system is located on the first 60 cm of soil depth.

Depth (cm)	Thick elements (%)	U.S.D.A. texture			Textural type
		Sandy	Lime	Clay	
0-20	70.7	45.3	19.4	35.3	AcAr
20-45	68.8	47.4	19.5	33.1	FrAcAr
45-100	74.8	61.4	9.5	29.1	FrAcAr

Table 1 Physic characteristics of the soil profile in the experimental vineyard, in Valladolid.

Experimental determinations have been orientated to measure vegetative development (pruning weight, shoot vigour and number), grape production (yield, number of clusters and berry weight), grape quality (sugar concentration, total acidity, pH and total poliphenols index), vine physiologic activity (net photosynthesis and stomatal conductance), soil water content and vine water status (leaf water potential). The soil water content was determined every fortnight through volumetric measurements in the first 60 cm of soil depth, by means of *Time Domain Reflectometry* (TDR), with a commercial Trase System model 6050X1 (Soil Moisture corp. California, USA). The electromagnetic transmission lines were two 0.63 cm diameter and 60 cm lenght probes, vertically buried into the soil and separated 5 cm one from each other. The probes were installed 10 cm far away from the dripper vertical line.
Net photosynthesis (A) and stomatal conductance (g_s) were measured at 9:00 (solar time) by means of a portable LI-6400 IRGA (Li-COR, USA) on 6 leaves per treatment from June to September: After each gas interchange measurement, the leaf was detached to immediately measure leaf water potential (LWP) using a Scholander pressure bomb.

Grape productivity and quality of the grape were determined at harvest, which date was: 21st of September, 2005; 12th of September, 2006; 3rd of October, 2007. Before harvest, a sampling was done in order to analyse the basic components of the must. The total poliphenols index was measured by spectrophotometry absorbance at 280 nm, on the must obtained without maceration of must with the skins, in order to simplify the operation and to establish the most standardized comparison.

Results

Vegetative development

Total shoots number of G20 and V20 treatments has been very similar in the 3 years, due to the same pruning load applied to both treatments and also to the similar number of watershoots developed, which have provoked no differences between treatments. There were no statistically significant differences in the shoots number neither in the watershoots number, in the 3 years of study. Pruning weight has maintained the same tendency the 3 years, with G20 treatment values lightly higher than those of V20 treatment, although without statistically significant differences (table 2). This light increase has been partially due to the slightly higher vigour observed in G20 than in V20. G20 treatment obtained 11.7%, 5.6% and 7.4% higher pruning weight than V20 in 2005, 2006 and 2007 respectively.

Year	Treatment	Pruning weight	Total shoots	Counted shoots	Watershoots	Shoot weight
2005	**G20**	0.99	17.5	14.3	3.18	57.1
	V20	0.88	17.2	14.0	3.20	50.9
	S.L.	-	-	-	-	-
2006	**G20**	0.92	16.1	13.4	2.86	57.6
	V20	0.87	15.9	14.1	2.30	54.9
	S.L.	-	-	-	-	-
2007	**G20**	1.56	16.3	13.7	2.74	95.6
	V20	1.52	16.2	13.9	2.41	94.3
	S.L.	-	-	-	-	-

Table 2 Pruning weight (kg/vine), number of total shoots per vine, number of counted shoots per vine, number of watershoots per vine and shoot weight (g) of treatments: 20% ETo irrigation from vegetative Growth stopping (G20) and from Veraison (V20), in 2005, 2

Definitively, the vegetative development have been slightly sensitive to the irrigation timing period and, consequently, to the water deficit provoked by V20 treatment until veraison. The vines irrigated from the vegetative growth stop (G20) have had a bigger vegetative development than the vines irrigated from veraison (V20), being the differences between treatments smaller in 2007 than in 2005 and 2006.

Total leaf area

The application of the irrigation treatments has provoked some differences in the vine total leaf area (LAI), which have not been statistically significant (table 5). In general, total leaf area of G20 vines was superior than that of V20 vines, except in 2005, when measurement was done after the vegetative growth stop but earlier than the 2 following years. The observed differences in 2005 were caused, especially, by higher proportion of leaf area of laterals related to the total leaf area in V20 than in G20 treatment. In 2006 and 2007, the total leaf area of G20 treatment was near 0.5 m^2/m^2 higher than V20, although the differences were not statistically significant. The leaf area of laterals was higher than the leaf area of principal shoot in both treatments in 2007, with a contribution of laterals around 55% in G20 and 57% in V20 to the total leaf area of the vine (table 5). In spite of the differences observed, these were not statistically significant. Definitively, the variation of irrigation timing period has provoked a tendency of the total leaf area to increase in G20 with respect to V20, especially related to the laterals leaf area with respect to the principal shoot leaf area.

Soil water content

In 2005, the soil water content in both treatments was around 15% (v/v) at the beginning of the vegetative cycle, but when the water demand of vines was higher (from June to September) the soil water content decreased to 10% (v/v) or lower values (figure 1). The limitation of available water was higher in 2005 than in the two next years (which were more rainy) due to the scarce rainfall from the beginning of the year and a very low water refill of the soil during the previous winter. From the last days of June (just close to the beginning of the irrigation in G20) until the first days of August (beginning of the irrigation in V20), the soil water content in G20 treatment overcame the water content of V20 treatment in 2.5 mm, becoming both content values similar in the middle of August. The differences observed between treatments were not statistically significant.

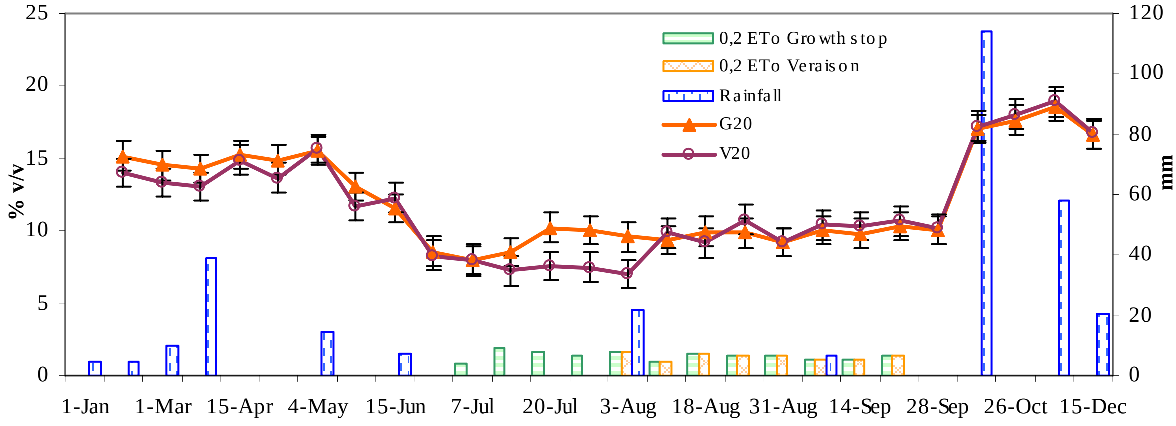

Figure 1. Soil water content (% v/v), irrigation (mm) and rainfall (mm), of the treatments G20 and V20, in 2005.

In 2006, the differences in soil water content provoked by the irrigation treatments were slightly more intense than in the previous year, although these differences were not statistically significant anyway (figure 2). The rainfall from January until the beginning of the vegetative cycle made the soil water content, in both treatments, to be between 20% and 15% (v/v). Nevertheless, between June and September this percentage decreased in G20 to 10% and in V20 to under 10%, except in the middle of August, when the rainfall helped V20 treatment to have the same water content level than G20.

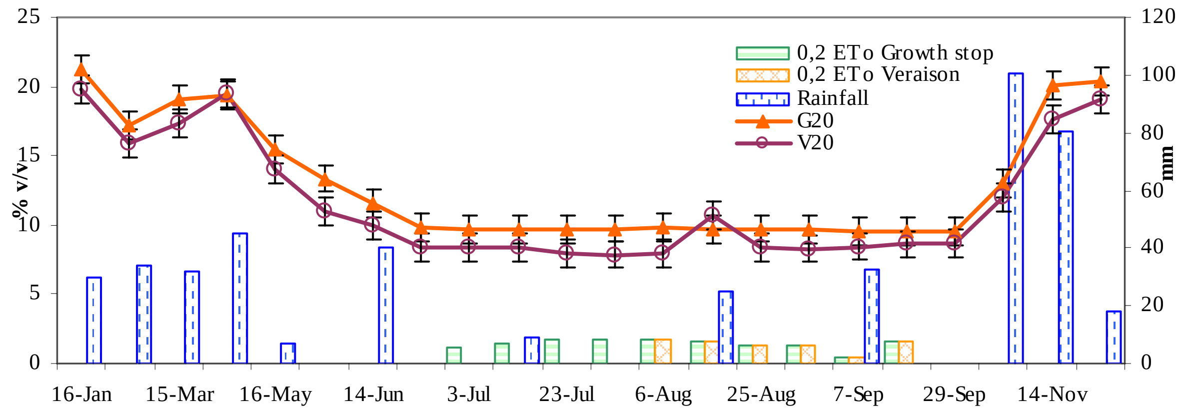

Figure 2. Soil water content (% v/v), irrigation (mm) and rainfall (mm), of the treatments G20 and V20, in 2006.

In the first half of 2007, the soil water content in both treatments remained between 17 and 20%, passing the soil water content of the two previous years. Nevertheless, the water requirement of vines increased from June, since from this time a remarkable decrease of the water percentage in the first 60 cm of soil profile was observed, being the water content around 10% v/v from June to September, and higher in G20 than in V20 (figure 3). It is remarkable that the biggest differences (approximately 3%

in favour of G20) between G20 and V20 were produced between the end of June and the end of August, although not being statistically significant.

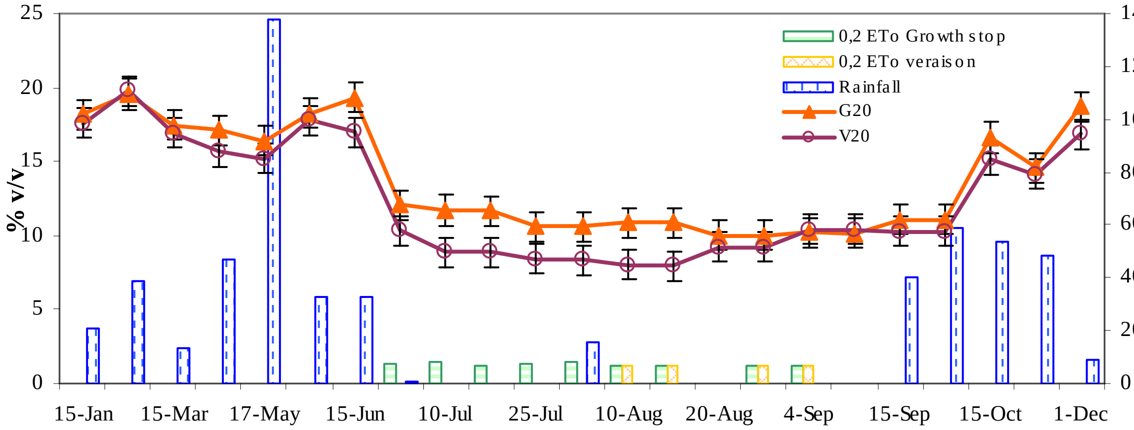

Figure 3. Soil water content (% v/v), irrigation (mm) and rainfall (mm), of the treatments G20 and V20, in 2007.

Leaf water potential

Leaf water potential, measured at the maximum vine physiologic activity day time, has shown a tendency during the summer very similar in the 3 years, showing G20 less negative values than V20, in general, which shows a less intense water stress of vines irrigated since the vegetative growth stop than vines irrigated since the veraison stage. In 2005, the differences were statistically significant in the July measurement. In this year, it was observed at the end of the cycle a slight recovery of V20 treatment vines, which reached leaf water potential values less negative than G20 treatment vines (figure 3).

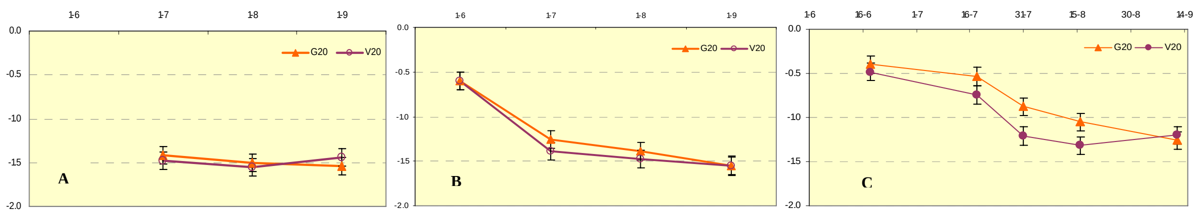

Figure 4. Leaf water potential (MPa) at 9:00 solar time of treatments G20 and V20, in 2005 (A), 2006 (B) and 2007 (C).

In 2006, the G20 leaf water potential values were maintained above V20 values, from July until September, although in this month the values of both treatments were very close but maintaining the same tendency that they had the rest of the summer. The differences were statistically significant for July 20th measurement. In 2007, G20 treatment vines showed leaf water potential values clearly higher than V20 vines, although G20 and V20 values became similar (-1.26 and -1.20 MPa respectively) in September under warmer temperatures and less limiting conditions for the development of vineyard physiologic activity.

Photosynthesis and stomatal conductance

Net photosynthesis and stomatal conductance have been lightly influenced by the timing irrigation period, with higher values, in general, in G20 than in V20 in the 3 years (table 3), although the differences observed between treatments were not statistically significant in neither measurement date. Vines with low available water adjust their stomatal opening during the day in order to adapt the gas interchange rates per leaf surface unit to this limitation (Yuste 1995). In 2006, the differences observed in favour of V20 treatment in June (table 3) were due to the fact that the vines developed their physiologic activity by means of the water soil reserves derived from the rainfall, taking into account that the established treatments had not been applied yet, since they started on the first days of July.

Year	Treatment	June		July		August		September	
		Photo.	**Cond.**	**Photo.**	**Cond.**	**Photo.**	**Cond.**	**Photo.**	**Cond.**
2005	**G20**			9.2	90	11.6	142	9.4	105
	V20			5.4	52	9.3	103	9.5	140
	S.L.			-	-	-	-	-	-
2006	**G20**	18.3	155	14.9	206	7.8	70	11.4	152
	V20	22.5	354	10.1	113	7.4	70	11.2	145
	S.L.	-	-	-	-	-	-	-	-
2007	**G20**	14.5	270	15.8	400	13.6	280	12.0	210
	V20	13.0	240	16.3	350	12.5	190	13.4	270
	S.L.	-	-	-	-	-	-	-	-

Table 3 Net photosynthesis (mol CO2.m-2.s-1) and stomatal conductance (mmol H2O.m-2.s-1) at 9:00 (solar time) of treatments: 20% ETo irrigation from Growth stop (G20) and from Veraison (V20), in 2005, 2006 and 2007. Statistical signification level (S.L.): - =

Yield

Irrigation treatments have provoked higher differences in yield in 2005 and 2007 than in 2006 (table 4). Particularly, in 2005 the yield reached by G20 was 3.5 tones/ha higher than V20 yield. In 2006, yield of both treatments was close to 10 t/ha, whereas in 2007 it decreased noticeably (5.2 t/ha in G20 and 3.2 t/ha in V20) due to the extraordinary pathologic problems occurred through the vegetative cycle (downy mildew, botrytis, etc.). Definitively, the yield increase of G20 with respect to V20 has been 34.8%, 7.1% and 38.9% in 2005, 2006 and 2007 respectively, being these differences statistically significant in 2005 and 2007. The increase of G20 with respect to V20 was due to the number of clusters as well as to the cluster weight (except in 2006), although the differences were not statistically significant non of the years. Cluster weight was superior in G20 than in V20, in 2005 and 2007, but smaller in 2006, being the differences highly significant in 2005 and 2007.
The berry weight has shown the same tendency than the yield, so, the biggest berry was that of G20 treatment all 3 years, although the differences were statistically significant only in 2005. The berry size has been partially reduced due to the water stress started before the veraison stage.

Year	Treatment	**Yield**	**N. clusters**	**Cluster weight**	**Berry weight**
2005	**G20**	10.16	21.2	177	1.51
	V20	6.62	18.8	133	1.29
	S.L.	**	-	**	**
2006	**G20**	10.65	21.4	187	1.90
	V20	9.89	18.3	206	1.80
	S.L.	-	-	-	-
2007	**G20**	5.18	14.7	132	2.13
	V20	3.16	14.1	82	1.98
	S.L.	*	-	**	-

Table 4 Yield (t/ha), number of clusters per vine, cluster weight (g) and berry weight (g) of treatments: 20% ETo irrigation from vegetative Growth stop (G20) and from Veraison (V20), in 2005, 2006 and 2007. Statistical signification level (S.L.): - = no signif

Summarizing, the variation of the beginning of irrigation has provoked an increase in yield and in its components for G20 (irrigation from vegetative growth stop) with respect to V20 (irrigation from veraison).

Grape quality

The watering application in different periods of the season has neither definitively nor evenly influenced on the grape quality non of the 3 years. In 2005, sugar concentration was higher in V20

than in G20, although the differences were not statistically significant. This result seems to be related with the lower yield of the treatment irrigated from the veraison (V20) in comparison with the treatment irrigated from the vegetative growth stop (G20), which also corresponds also to smaller berry weight of V20. Total acidity reached similar values in both treatments, as well as the pH. Total poliphenols index was higher in V20 than in G20 with statistically significant differences (table 5).
In 2006 there were not noticeable differences observed in sugar concentration between V20 and G20 treatments, although V20 was lightly higher than G20. Total acidity was little higher in G20, whereas the pH showed a higher value in V20 than in G20. Total poliphenols index of V20 treatment had a higher value than G20, although the differences were not statistically significant.

Year	Treatment	**Sugar conc.**	**Total acidity**	**pH**	**Poliphenols**	**LAI total**	**LAI princ.**	**LAI lateral**
2005	**G20**	22.4	4.58	3.42	51.2	2.04	1.26	0.78
	V20	23.4	4.69	3.49	59.9	2.31	1.20	1.11
	S.L.	-	-	-	**	-	-	-
2006	**G20**	22.9	5.02	3.76	43.5	2.12	1.06	1.06
	V20	23.2	4.87	3.86	46.1	1.64	0.79	0.85
	S.L.	-	-	*	-	-	-	-
2007	**G20**	22.9	5.65	3.37	51.7	3.30	1.47	1.83
	V20	23.2	5.43	3.45	57.4	2.72	1.16	1.56
	S.L.	-	-	-	-	-	-	-

Table 5 Sugar concentration (ºBrix), total acidity (g tartaric acid/l), pH, total poliphenols index, total leaf area index (LAI), and leaf area of principal shoot and of laterals (m2/m2), of treatments: 20% ETo irrigation from vegetative Growth stop (G20) and from Veraison (V20), in 2005, 2006 and 2007. Statistical signification level (S.L.): - = no significant; * = p< 5%; ** = p< 1%.

In 2007 sugar concentration showed the same tendency as in 2006, with higher values of V20, but not statistically significant differences. Total acidity was lightly higher in G20 than in V20, whereas the pH was very similar in V20 and G20, in such a way that the applied treatments did not provoke significant effects on these grape quality parameters. Total poliphenols index showed again that V20 values were higher than those of G20, although the differences between them were not statistically significant.

Conclusions

The application of moderate irrigation in different periods of the vegetative cycle has shown different effects on Tempranillo grapevine. Thus, pruning weight and shoot weight have been lightly higher in G20 than in V20. The developed leaf area has been, in general, higher in G20 than in V20, mainly for that coming from laterals. Soil water content has shown some differences provoked for the delay in the application of irrigation, which have not been statistically significant. Leaf water potential, measured at 9 hours solar time, has shown to be a reliable indicator that has detected the differences in water status of the treatments in most of the measurements done during the summer. Related to physiologic activity, the irrigation timing period has not definitively influenced net photosynthesis neither stomatal conductance per leaf area unit. The application of moderate irrigation doses in different periods of the vegetative cycle has provoked, in general, an increase of yield components in G20 with respect to V20. The quality of the grape has shown a tendency to increase sugar concentration, pH and total poliphenols index in V20 with respect to G20, although the differences have not been statistically significant for neither analyzed parameter.

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