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Water stress versus yield components and quality must (*Vitis vinifera* L.) cv. Negra Criolla

Estrés hídrico versus componentes del rendimiento y calidad de mosto (V*itis vinifera* L.) cv. Negra Criolla

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Abstract
The main objective of the current work was to evaluate the effect of irrigation water quantity (IWQ) on yield components and grape must quality of cv. Negra Criolla at Caraveli Valley, Arequipa. Results showed significant differences on grape bunch number (T3 = 57; T2 = 36), berry number per bunch (T0 = 147; T1 = 66), equatorial diameters of berries B1, B2 and B3 (T3 = 13, 14 y 14; T0 = 14, 13 y 13 mm), berry bunch weights (T3 = 10.58; T2 = 7.87 kg.cepa^{-1}) and grape must quality such as density (T2 - T3 = 1.104; T2 = 1.097 g.L^{-1}), pH (T0 = 3.75; T1 = 3.59), and phenol compound content a Gallic acid (T0 = 1.75; T2 - T3 = 1.66 mg.L^{-1}). In conclusion, T3 treatment produced the higher differences, but declining pH, Brix degrees and Gallic acid values.

Keywords: cultivar Negra Criolla, water dosage, yield component, grape must quality.

1. Introduction

The vine cultivation began in the valley of Caravelí shortly after the conquest, one of the first to produce wine. Choque (2006) published the first ampelographic research identifying a varietal, prevailing mix of 'Moscatel' and 'Negra Criolla'. The plant features of Negra Criolla are green stem with purple red stripes, the adult leaf is wedge-shaped, medium, lobed, smooth, shiny and consistent dark green, hermaphrodite flower, with medium bunches large, elongated, loose and conical, berry spherical oblate, medium and reddish purple to black with yellow-green pigmentation around the junction of the stalk with berry, with colorless juice and soft pulp (Choque, 2006).

The performance of plant variables such as leaf area index (LAI), number and weight of bunches per plant, diameter, number and weight of berries are influenced by variations in moisture available to plants. Leaf area is related to crop evapotranspiration. A good estimate of leaf area is the relationship between the length, width and sheet product (Legorburo, 2005). Elsner and Jubb (1988) and Gutierrez and Lavin (2000) estimated leaf area, using simple linear regression, where the dependent variable is the area and independent is the product of maximum sheet width by the length of the midrib, also the product maximum length for maximum sheet width.

Some authors like Hernandez (2007), Reynolds Naylor (1994) and Parra *et al.*, (2003) agreed that the number of bunches per plant and the number of berries per cluster are not affected by the application

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of different water regimes 'Syrah', 'Cabernet Sauvignon', 'Pinot Noir' and 'Riesling' but in 'Chardonnay'. However, size reduction was much lower compared to the reduction obtained with an induced before veraison (Coombe and McCarthy 2000; Hardie and Martin, 2000) water deficit. According Gurovich and Vergara (2005) water deficit between bud break and paints, prevents dehydration of the berries.

Yield performance is limited by water stress different times before or after veraison. Myburgh (2005) and Perez (2004) found no significant differences in weight when water stress applied at different stages of phenology in cultivars Cabernet Sauvignon, Carmenere, Chardonnay, Sauvignon Blanc and Chenin Blanc. However, it was possible 30 to 40% better performance increases when irrigation increased from the normal dose (Mathews and Anderson, 1989).

The water consumption of the vine throughout the year is not uniform, about 2% occurs in the period of winter rest, 10% of budding fruit set, 43% of fruit set to veraison, and 45% veraison to fall leaf (Hidalgo, 2002). In the grapevine, a strain of medium vigor may lose 600 to 800 liters of water through transpiration during the growing season and dry conditions a plant can lose 5 liters of water a day, while in irrigated conditions and vigorous plants, you can lose up to 20 liters per strain per day (Martínez de Toda, 1991).

The berry weight increase during ripening is dependent accumulation of solutes, particularly sugars and water (Hera Orts *et al*., 2005). Under reducing conditions of water stress there was a higher yield, which was associated with increased berry size (Ferreyra *et al*., 2002; Intrigliolo and Castel, 2008; Matocp, 2004; Matthews and Anderson, 1987). Ferreyra *et al*. (2002) and Matthews and Anderson (1989) found no correlation of water deficit with the number of berries per cluster.

The quality of grapes and wine are the main factors affecting productivity in winemaking and depends on the interplay of climate and soil-plant and grower practices in cultivation Most wine organoleptic compounds are contained in the cuticle of the berries, which are released in the fermentation processes, (Gurovich and Vergara, 2005). Ferreyra *et al*. (2003) found no significant effect on the quality of wine when strains of 'Chardonnay' were subjected to water stress. Myburgh (2006) found differences in the composition of the wort between different doses of irrigation during ripening berry alone in a season. Overwatering during the ripening period influences negatively on the quality of the must and wine (Bravdo *et al*., 1984). Water stress was early with better quality wine (Acevedo *et al*., 2005; Hidalgo, 2003).

Concentrations of soluble solids obtained from different berries deficit irrigation treatments were different; where early water deficits had higher soluble solids concentration (Gurovich and Paez, 2004), similar results obtained Reynolds Naylor (1994) in the cultivar 'Pinot Noir', but 'Sauvignon Blanc', 'Tempranillo' and 'Shiraz' It was not affected by the different levels of water stress applied. However, 'Chenin Blanc' and 'Riesling' had lower brix with water stress early and irrigation after veraison (Buchanan, 2010; Ginestar *et al*, 1998; Hernandez, 2007; Myburgh, 2006; Reynolds Naylor, 1994). Lower concentrations were with severe water stress (Goodwin and Macrae 1990).

Increased water stress affects the pH of the wine and grape juice. The lowest levels of pH in wine were relations to water deficit, but intensive irrigation raised the pH of the must and wine, lowering the quality (Bravdo *et al*., 1985; Goodwin and Macrae, 1990; Hidalgo, 2003; Intrigliolo and Castel, 2008). Myburgh (2006) indicates that there must pH increase when there were risks in the maturation phase.

The content of anthocyanins and phenols is increased when irrigation decreased from paints maturation (Ferreyra *et al*., 2002; Gurovich and Vergara, 2005; Intrigliolo and Castel, 2008), however Acevedo *et al*. (2005) mentioned that this occurs after

fruit, others say that when the water deficit is before veraison increase (Gurovich and Paez, 2004; Hidalgo, 2003).
The growth of the surface of grapes for wine, pisco and table grapes is limited by the availability of water resources. In Peru, the different growing wine regions are in desert areas with limitations on soil quality and water availability. The water déficit or excess during a time of productive period or restriction of water quantity are to be known at each stage of growth and development of the berries.
Traditional irrigation in growing vine Caravelí Valley has been considered appropriate for producers for a long time, but there was a need to know if the volume of water allocated was sufficient to sustain current production. The information generated through experimentation can resolve the questions that serve to make adjustments to the amount of water required by vine plantations.
The aim of this study was to evaluate the effect of water stress on some components of yield and quality of wine grape cv. Negra Criolla in the valley of Caravelí, Arequipa.

2. Materials and methods

The field experiment was placed within the Valencia farm area, Sector Huarca in the valley of Caravelí, Arequipa Region, located at the geographic coordinates 15° 49' 11 "S, 73° 18'52" W and 1650 meters above sea level. The climate conditions correspond to a subtropical desertic area, with average monthly minimum temperature conditions of between 8.8 to 11.0 °C and maximum between 28.0 and 29.3 °C. Air relative humidity averaged 52% annually (55% maximum and 44% minimum). Evaporation measured in a A tank type was 5.8 to 7.2 mm. The sun hours varied between 8.8 and 10.3 hours (SENAMHI, 2011). The soil texture was a sandy loam, pH 7.5 and electrical conductivity of 6.2 dS / m, organic matter 1.24% and cation exchange capacity (CEC) of 9.6 meq-g. Irrigation water was 7.47 pH and electrical conductivity (EC) of 1.57 dS / m, with low value of exchangeable sodium (ONERN, 1975).
The experiment area had 24 rows and 4 strains per row within an area of 1.25 hectares of grapevine cv. Negra Criolla, plants were propagated by cuttings, aged seven years old, supporting on a simple T system, plants distance were in between 2x3 meters. Plantation management was running by short pruning, 22 chargers per plant, application of hydrogen cyanamide at a dose of 30 ml / l, for uniform sprouting; with modern irrigation by microtubules, 1 mm diameter, again, water reservoir. Irrigation was applied every three days, depending on the shift of water; since the beginning of the outbreak until a week before harvest.

Treatments

In Table 1 there has been irrigation treatments that were characteristic and reducing the excess volume of water applied in relation to traditional irrigation (irrigation performed by the producer). Variables evaluated for performance.

Table 1
Percentage change in the amount of irrigation water (WIA) compared to control treatment (T0), duration period (months), WIA estimated volume per plant and irrigation as treatment

Treatments	Δ% of WIA relative to T0	Period duration (Months)	WIA/plant (liter x cepa^{-1})	Estimated volume of irrigation (m^3 x ha^{-1})
T0 (25L)	Traditional	September -March	25	42
T1 (20L)	20% less	September -March	20	33
T2 (15L)	40% less	September -March	15	25
T3 (30L)	20% more	September -March	30	50
T2-T3 (15-30L)	40% less 20% more	September - January January -March	15 30	25 50

The variables measured were leaf area 4 leaf samples selected by strain and experimental unit with the formula Af (leaf area, cm^2) = Lmax maximum length, cm) by Amax (maximum width, cm) after fruit set and in full marking paints randomly the third sheet (H3) and fourth sheet (H4), starting at the base of the bud. The number of clusters per plant was carried out in 4 composite samples average of three strains for experimental unit and then placed in plastic crates 72 harvesters. The number of berries per cluster was obtained from selected samples previously. The equatorial diameter of berries was measured with vernier every 7 days from painting to before harvest in clusters divided into upper thirds (Berry 1), medium (Berry 2) and lower (Berry 3) starting from the peduncle area insertion node of the plant. The weight of bunches weighing was carried bunches of each plant at harvest, using a scale platform.

Quality parameters must

The estimate must quality was performed with samples crushed in a pressing machine electro were analyzed in the laboratory of Biotechnology, Faculty of Food Industries UNALM. The density meter (g / cm^3) AllaFrace mark at 20 °C, recorded reading per sample. Brix was measured by a hand refractometer, Eclipse brand, model 47-02 per sample according treatment Check pH or potential hydrogen, Orion model 420 brand computer A. a reading each sample was scored with four samples per treatment. Determining anthocyanin and phenol it was carried out in 100 g samples of must by colorimetric means and optical density respectively. In the first, case due to fading suffering contact with chemicals such as sodium bisulfite (García, 1990).

Data analysis

The evaluation was performed in 16 strains for treatment and for each parameter evaluated four repetitions and four strains per experimental unit. The linear additive model was completely randomized design with 4 repetitions, level of significance of 5% and 5 degrees of freedom of experimental error. The results were analyzed with the R-project statistical program (Ri386 2.15.3) free access. Analysis of variance was performed for each characteristic evaluated, producing two sources of variation and error treatment. The averages were compared in the Tukey test.

3. Results and discussion

Yield components

The ANVA leaf area estimated at Criolla Negra cultivar produced no statistical differences in both the sheet H3 (p-value = 0.450) as well as H4 (p-value = 0.026). The control treatment T0 (25L) with the higher dose irrigation T3 (30L) always produced high estimates of leaf area compared to treatments lower water replacement in both assessments values (Table 2). However, despite the differences in the H4 they were low, but not significant, the results were insufficient to establish any relationship between the different levels of irrigation and leaf area. As for the method, Legorburo (2005) proposes to make adjustments to the linear estimate for a destructtive method; because sampling could be in more leaves along the outbreak. It should also be noted that the increase in leaf area would cause excessive shade inside the canopy, creating favorable conditions for pathogens such as powdery mildew, which cause large losses in production.

Table 2

Leaf area per plant as treatment in the cultivar Negra Criolla

Treatment	Leaf area (cm^2)		Variation perceptual relative to T0	
	H3	H4	H3	H4
T0 (25L)	247.6	309.7	0.00	0.00
T1 (20L)	229.6	259.2	-7.23	-16.30
T2 (15L)	239.2	254.9	-3.39	-17.69
T3 (30L)	276.1	323.9	+11.51	+4.58
T2-T3 (15-30L)	237.1	240.4	-4.24	-22.38

Number of bunch

In the ANVA the number of bunch showed significant differences between treatments (p-value = 0.048). However the result of multiple comparisons of Tukey there were no significant differences (Table 3). The results have similarities and differences with other particular cases where the number of bunches per plant was not affected by different levels of water stress in cultivars such as 'Cabernet Sauvignon', 'Syrah', 'Pinot Noir' and 'Riesling'. However, in other experiments the results were different in some cultivars, having been found effects on the number of bunches per plant in 'Cabernet Sauvignon' and 'Chardonnay' (Hernandez, 2007; Parra *et al*, 2003; Reynolds and Naylor, 1994).

Number of berries per bunch

The analysis of variance yielded significant results (p-value = 0.015). As it can be seen in Table 3 that there was greater number of berries per bunch in the treatment T3, which showed significant differences compared with the level of water stress undergone throughout the season (T2). There are investigations with similar results in different weather conditions and growing, but there are also reports where the effects were not significant in this parameter (Hernandez, 2007; Parra *et al*, 2003; Reynolds and Naylor, 1994). Tukey multiple comparisons identified the control as significant treatment T0 (25L) vs. T1 (20L) (p-value = 0.036).

Diameter of berries per bunch

Table 4 shows the mean diameter of berry bunch thirds for each treatment in each of the five evaluations. In all 5 evaluations, except measurements made B3 first and fourth berry evaluation and B1 of the latter, there were significant differences. One notable aspect is that the larger diameter in berries always corresponded to those produced in the T3 (30L) treatment and smaller diameters were measured in berries T2 (15L).

The diameter of the bunch results clearly show that the measurements in the T3 treatment, which received the largest amount of water during the campaign, recorded the largest diameter compared to other treatments evaluated.

This larger diameter represented signify-cant differences compared to the other treatments. This showed that water stress would directly affect the diameter of the berry and in the final stages of maturation differences in diameter would be lower under increased water stress.

Table 3

Number of bunch per plant (B x P), number of berries per bunch (b x B) and percentage change relative to T0 treatment according treatment

Treatment	Number B x P	% B x P relationship to treatment T0	Number b x B	% b x B relationship to treatment T0
T0 (25L)	44	0.00	147 a	0.00
T1 (20L)	48	+9.09	66b	-55.10
T2 (15L)	36	-18.18	104ab	-29.25
T3 (30L)	57	+29.54	108ab	-26.53
T2-T3 (15-30L)	36	-18.18	128ab	-12.92

Table 4

Mean diameter (mm) berry B-1, B-2 and B-3 since paints to maturity from the first (1^aE) to fifth (5^aE) treatment evaluation in cv. Negra Criolla

Treatment	1^a.E			2^a E			3^a E			4^a E			5^a E		
	B-1	B-2	B-3	B-1	B-2	B-3	B-1	B-2	B-3	B-1	B-2	B-3	B-1	B-2	B-3
T0 (25L)	11ab	12a	12	12ab	13a	13ab	13a	14a	14a	14	14a	14	14a	13	13ab
T1 (20L)	11ab	12a	11	13a	13a	13a	13a	13ab	13ab	13	14a	13	13ab	13	13b
T2 (15L)	11ab	11ab	11	11b	11ab	11ab	11b	12bc	12ab	13	13a	13	13ab	13	13b
T3 (30L)	12a	12a	12	13a	13a	13a	13a	14ab	14a	14	14a	14	13a	14	14a
T2-T3 (15-30L)	10b	11ab	11	12ab	12ab	12ab	12ab	13ab	13ba	13	13ab	13	13ab	12	13b

These results agree with those obtained by Ferreyra *et al*. (2003); Gurovich and Paez (2004); Hardie and Considine (1976); Hernandez (2007); Mathews and Anderson (1989); Ojeda *et al*. (2002) who found that the water deficit produced significant reductions in the diameter of the berries.

Berry results in B2, under treatment T3 produced the largest diameter reached during all evaluations, and presented significant differences when compared with other treatments. For these reasons, the water deficit would be causing negative effects on the diameter of the berry in this part of the bunch. These results are consistent with those obtained by Ferreyra *et al*. (2003); Gurovich and Paez (2004); Hardie and Considine (1976); Hernandez (2007); Matthews and Anderson (1989); Ojeda *et al*. (2002), who showed the effect of water stress on the diameter of the berry.

The diameter of berries in water-stressed plants early with replenishment of water from veraison had no significant differences compared to water stress maintainned throughout the season. The water deficit in the early stages of development would affect the growth of the berry and then not be recoverable because the sensitivity of berry growth would be higher in the early stages of fruit growth. In different studies the effects on the expansion of berry deficits were higher with water before painting (Hernandez, 2007; Hardie and Considine, 1976; Matthews and Anderson, 1989; Ojeda *et al*., 2001).

Weight of bunches per grapevine

Table 5 contains the average weight of bunches per grapevine each treatment and the percentage change in relation to the treatment T0 in cv. Negra Criolla. In the ANOVA, there were significant differences between treatments (p-value = 0.0014). In the multiple comparisons of Tukey, the weight of bunch of plants in the T3 treatment, which had the highest water replacement throughout the campaign had significant differences compared to that resulting weight in T0 (25L), T1 treatments (20L), T2 (15L) and T2-T3 (15-30L). It also produced a higher value; yes this is expressed as the percentage change in relation to treatment and lower weights T0 with T2 (30L), T2-T3 (15-30L) and T1 (20L).

Table 5

Mean weight of bunch and percentage of change based on treatment T0 cv. Negra Criolla

Treatment	Mean weight (kg.cepa^{-1})	Percentage change T0
T0 (25L)	9.90 b	0.00
T1 (20L)	8.86 b	-10.50
T2 (15L)	7.87 b	-20.50
T3 (30L)	10.58 ab	+6.87
T2-T3 (15-30L)	8.49 b	-14.24

In comparison, treatment T3 produced the greatest weight of bunches other treatments. There were no significant differences in the weight of clusters at the level of irrigation suffered water stress in the early stages of development to paints and increasing irrigation to maturity (T2-T3) compared with traditional irrigation (T0) and lower doses (T2). These results indicate that higher yields can be obtained more fluid replacement. The same trend has been found in investigations, which relate irrigation and fruit weight (Esteban *et al*., 2001; Ferreyra *et al*., 2002, Ferreyra *et al*., 2003; Hernandez, 2007; Intrigliolo and Castel, 2008; Matocp, 2004; Matthews and Anderson, 1987; Matthews and Anderson, 1989; Reynolds and Naylor, 1994). However, Gurovich and Paez (2004); Myburgh (2005); Perez (2004) found no significant differences in weight when compared various levels of irrigation, carried out in different cultivars and areas of the world.

Water deficits before painting would cause reduction in the weight of bunche and replenishing water from veraison would not increase the weight of the fruit. In several studies, researchers have found lower yield with water deficits before painting (Ferreyra *et al*., 2003; Matthews and Anderson, 1989; Matthews and

Anderson, 1987). This decrease in weight with early water deficits could be explained by the loss of fruitfulness (Hardie and Considine, 1976). However, there was better performance with early water stress in vineyards of Cabernet Sauvignon and Tempranillo cultivars (Buchanan, 2010; Esteban *et al*, 2001).

Estimated yield and water use efficiency

Table 6 shows the estimated yield of each treatment depending on the volume of irrigation water, the water use efficiency (EUW), weight per volume of water used in the cv. Negra Criolla. The results show that traditional irrigation (T0) and T3 (30L) that had increases in the amount of irrigation water, accounted for the highest yields; otherwise it happened in lower irrigation water replacement. Table 7 contains the rate of water use efficiency (EUW) in each treatment, expressed in kilograms of grapes produced per cubic meter of irrigation water. Treatment T2 (15L) yielded the highest rate in weight per volume of water used (WVWA), but the lowest volume of water applied (VWA). The greater weight of bunches per vine (PRC) and yield (R) was produced with the T3, but with the lower value of VWA.

Quality must

The ANVA of soluble solids (Brix) berry data showed no significant difference between treatments in the five evaluations (Table 8). The highest values were measured in the fifth assessment compared to the first evaluation. One aspect to note is that between the fourth and fifth assessment brix values tended to be quite similar. In addition, brix minor value changes occurred porcently to the fifth assessment in T0 (40.12%) and T3 (48.77%) treatment. Similarly, major changes occurred in the treatments T2-T3 (122.77%) and T2 (100.85%).

Table 6

Water volume of applied irrigation water use efficiency (EUW), weight per volume of water used and estimated average yield

Treatment (Doses of irrigation)	Volume of water irrigation (mm)	EUA (m3.kg)	Weight per volume of water used (kg.m^{-3})	Estimated yield (t.ha^{-1})
T0 (25L)	237.5	158	6.3	15.0
T1 (20L)	190.0	129	7.9	15.0
T2 (15L)	142.5	109	9.2	13.0
T3 (30L)	285.0	162	6.2	18.0
T2-T3 (15-30L)	180.0	127	7.9	14.0

Table 7

Percentage change of VWA, WVWA, WRC and R in relation to the control treatment (T0)

Treatment (Doses of irrigation)	VWA	WVWA	PRC	R
T0 (25L)	0.00	0.00	0.00	0.00
T1 (20L)	-20.00	+25.39	-10.50	0.00
T2 (15L)	-60.00	+46.03	-20.50	-13.33
T3 (30L)	+20.00	-1.58	+6.87	+20.00
T2-T3 (15-30L)	-24.21	+25.39	-14.24	-6.67

Table 8

Density, pH, brix, anthocyanin content (maldivina) and phenol (gallic acid) in the must of cv. Negra Criolla

Treatments	Density (g.L)	pH	Brix		Maldivina (mg.L^{-1})	Acid gallic (mg.L^{-1})
			1ªE	5ªE		
T0 (25L)	1.102 ab	3.75 a	16.15	22.67	256.04	1.75 a
T1 (20L)	1.100 b	3.59 d	13.48	23.47	213.22	1.68 b
T2 (15L)	1.097 c	3.61 cd	11.48	23.72	251.93	1.69 ab
T3 (30L)	1.101 b	3.68 bc	16.20	24.07	269.66	1.70 ab
T2-T3 (15-30L)	1.104 a	3.62 cd	10.09	22.45	285.23	1.66 b

This would indicate that the lower water replacement treatments had lower water consumption and was higher with increasing the amount of irrigation water.
In similar experiments, Hera-Orts *et al*. (2005); Ginestar *et al*., (1998); Hernandez (2007); and Myburgh (2006) also found no differences in degrees brix accumulation in different situations of water stress. The sampling results indicaded brix berry during the ripening process showed no effects at different irrigation strategies. However, it can be seen that the rate of increase of soluble solids was reduced as the maturation proceeds, while also occured uniformity in the rate of accumulation of soluble solids in advanced stage (Coombe and McCarthy, 2000). In one case, the rate of sugar accumulation was affected by water deficit, but on the other had no effect (Hera-Orts *et al*., 2005; Matthews and Anderson, 1988).

4. Conclusions

Grapevine performance in T3 was the best treatment but it did not surpassed T0 (traditional irrigation) relative to the bunche weight per amount of water used. T0 treatment produced higher levels of pH and phenol content in the cv. Negra Criolla vine must. Phenols content was lower in the skin of the must with early water stress strategies in relation to paints and onwards growth stages when there were increases of water amount. Similary response occurred with density and brix must in T2-T3 and T0 which it increased with early water stress into paints state and by increment the water amount to maturity. However there was more brix must in the treatment T3 compared to traditional irrigation (T0). At T2 was observed similary results to T0, suggesting it can lower water consumption without reducing the yield and quality of the must.

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