EFFECTS OF IRRIGATION ON THE VIGOUR, YIELD AND BERRY COMPOSITION OF THE RED VARIETY TOURIGA NACIONAL AT THE DÃO WINEGROWING REGION, PORTUGAL

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Summary

In a field trial installed at the Centro de Estudos Vitivinícolas do Dão, Nelas, Portugal, the effect of three irrigation treatments on the agronomic behaviour of *cv* Touriga Nacional (*Vitis vinifera* L.) were studied during three growing seasons (2006-2008). Three irrigation treatments (DI30 - irrigation with 30% of ETc; DI50 - irrigation with 50% ETc, FI - full irrigation – 100% Etc) were compared to a control non-irrigated treatment (NI). Compared to NI, the deficit irrigation treatments (DI30 & DI50) showed no significant differences on the yield and its components. The full irrigation treatment induced a significantly higher yield due to a higher bunch weight, as compared with the others treatments. Compared to the control, the deficit irrigation treatments presented similar berry composition during all the three seasons. The FI treatment presented, in all seasons, a significantly higher total acidity and a significantly lower Brix and total anthocyanins concentration as compared to the other treatments. The pruning weight and shoot weight increased with the amount of irrigation water applied, but significant differences were found only between the FI and the NI treatments, the last presenting the lowest values. Despite the fact that in the non-irrigated vineyards of the Dão winegrowing region it is very common to observe vine water stress symptoms, mainly during the ripening period, during the three studied seasons (2006-2008), the deficit irrigation treatments showed no advantages relatively to the control non-irrigated. Despite the higher yield produced in the full irrigation, this treatment had the disadvantages of the excessive vine vigour and lower must quality produced.

Keywords: irrigation, yield, vigour, berry composition, 'Touriga Nacional', Dão.

INTRODUCTION

The water regime of vineyards is one of the factors that most influence the vegetative growth, yield and wine composition (Matthews *et al.*, 1990; Van Leeuwen *et al.*, 2003; Intrigliolo & Castel, 2009), being a key factor for the vintage quality (Ferrer *et al.*, 2007). Grapevine has a great ability to adapt and respond to different water regimes. A strong water stress can cause low yields, affect the quality and influence vine longevity (Junquera *et al.*, 2007). A severe water stress may lead to considerable loss of leaf area with consequent increased exposure of bunches to sunlight and the risks of sunburn, affecting the must quality (Lopes *et al.*, 2001).

Since the water stress situation arises frequently in Mediterranean conditions during ripening, irrigation is one important tool to mitigate the problem (Sánches-de-Miguel *et al.*, 2007).

In the Dão winegrowing region the rainfall is high in winter and very low in summer and most part of the soils are granitic derived with low water retention capacity. Consequently, in dry years the vineyards are prone to water stress mainly in the beginning of the ripening period. 'Touriga Nacional' (TN), one of the most widely used native red varieties in Portugal, is a vigorous variety showing high leaf defoliation when subjected to water stress. Recognized by its high quality, the plantations of TN increased in recent years in all Portugal and abroad, however, to our knowledge, no studies have been done to understand how water availability influence TN vegetative growth, grape composition and wine quality. This work aims to assess the effects of different water regimes in vine vigour, yield and quality of the red variety 'Touriga Nacional' at the Dão "terroir".

MATERIAL AND METHODS

This work took place at the " Centro de Estudos Vitivinícolas do Dão", Quinta da Cale, Nelas (Latitude 40 ° 31 'N, longitude 7 ° 51'W, Elevation 440 m) in a vineyard planted in 2000 with the red grape variety 'Touriga Nacional' grafted to 110 R rootstock. The vines were spaced 1.1 m within and 2.0 m between rows, trained on a vertical shoot positioning with a pair of movable wires and spur-pruned on a bilateral Royat Cordon system. All vines were uniformly pruned to 11 nodes per vine.

The soil is porphyritic granite of coarse texture, acid pH, low organic matter content, high hydraulic conductivity and low water retention capacity.

The experimental design was a randomized block design with four replications of the following four treatments:
- NI - Non irrigated (rainfed, control);
- DI30 - deficit irrigation of 30% crop evapotranspiration (ETc);
- DI50 - deficit irrigation of 50% ETc;
- FI - full irrigation - 100% Etc.

Each elemental plot has twelve experimental vines. Drip irrigation line were positioned in the centre of the row and consisted of pressure compensating 2.3 L/h emitters at 1.0 m spacing positioned between two adjacent vines.

Watering was applied according with the available soil water fraction at 0.6 m depth. For each treatment, the amount of water supplied in each irrigation was determined by the percentage of the accumulated values of daily ETc

recorded since the previous irrigation and estimated from the reference evapotranspiration (ET_0), which was obtained in an automatic weather station located within the experimental vineyard, using the crop coefficients proposed by Allen *et al.*, (1998).

Soil water content was monitored along the growing season using a capacitance probe (Diviner 2000®; Sentek Environmental Technologies, King Town, Australia). In each experimental unit two access tubes were installed, one on the row next to the dripper, between two plants, and another one between rows. Readings were taken twice a week, from flowering to harvest at increments of 10 cm from the soil surface to a depth of 160 cm.

The yield was monitored by recording the number of clusters and their total weight from the 12 plants per elemental plot. At harvest quality control was done through the sampling of 100 berries per plot and it was determined the soluble solids, titratable acidity, pH, berry skin anthocyanins, total phenols and tannins. The soluble solids, acidity, pH and tannins were determined by the Founier Spectometry Transform Infrared (FTIR). The anthocyanin content was measured by the method of discolouration by sodium bisulfite and total phenols by Folin-Ciocalteau index (Ribéreau-Gayon *et al.*, 1972).

In winter, shoot number and fresh pruning weight per vine were also recorded.

ANOVAS were carried out in accordance with GLM procedures, from the SAS® program package (SAS Institute, Cary, NC, USA) and statistical differences between means were assessed by LSD test ($P < 0.05$).

RESULTS AND DISCUSSION

Vegetative Growth

The average winter pruning weight presents an increase from 2006 to 2008 (0.6, 0.9 and 1.2 Kg per vine for 2006, 2007 and 2008 respectively). The higher pruning weight observed in 2008 was a consequence of the low yield obtained in that season as a result of the poor setting caused by cold and wet weather conditions that occurred during the flowering period. Compared to NI the full irrigation treatment induced a significantly higher winter pruning weight while the deficit irrigation treatments returned intermediate values (Table 1). As for the pruning weight, the average shoot weight, one of the best indicators of vine vigour (Champagnol, 1984), shows an increase from 2006 to 2008 (46.5, 69.5 and 105.0 g per shoot in average respectively). This increase in vigour may be explained by the different weather conditions observed between seasons.

The effect of irrigation amount on shoot weight was similar to the effect reported for pruning weight (Table 1). This increase in vegetative growth and vigour in the FI treatment as compared to NI is a common result observed in irrigation trials (Santos *et al*., 2003; De la Fuente *et al.*, 2007) being explained by the positive effect of the higher soil water availability on vegetative growth (Williams and Matthews, 1990).

Shoot number presented similar values along the three seasons with no significant effect of the irrigation amount (Table 1).

Table 1. Effect of irrigation amount on vine vegetative growth and Ravaz index. Average of 2006-2008 seasons.

Treatment	Pruning weight (kg vine^{-1})	Shoot number vine^{-1}	Shoot weigth (g)	Ravaz Index
NI	0.8 b	12.1	68.7 b	4.2
DI30	0.9 ab	11.8	74.4 ab	4.1
DI50	0.9 ab	12.2	72.8 ab	4.1
FI	1.0 a	12.3	78.7 a	4.3
Sig.	*	ns	*	ns

In each column different letter suffixes indicate statistically significant differences at $P < 0.05$ by LSD test. * and ns indicate significance at $p < 0.05$, and not significant respectively.

The Ravaz Index (ratio yield/pruning weight) presented a decrease from 2006 to 2008 but irrigation amount showed no significant differences (Table 1).

Yield and yield components

Table 2 presents the 2006-2008 average data for yield and yield components. Cluster number presented similar values along the three seasons and was not significantly affected by irrigation amount. The average yield was similar in 2006 and 2007 (3.7 and 4.0 Kg/vine respectively) but was very low in 2008 (1.5 Kg/vine) as a consequence of a poor setting, as already reported. FI presented a significantly higher yield than the other treatments which returned statisticaly similar values.

While the cluster weight values presented in 2006 and 2007 (averaged 179.2 and 191.5 g/cluster, respectively) are normal values for 'Touriga Nacional', the very low values presented in all treatments in 2008 (ranging from 64 g in DI50 to 75 g/cluster in FI) show that the poor setting greatly affected the cluster weight and consequently the yield in 2008.

The effect of irrigation amount on cluster weight presented a similar pattern showed by yield with FI showing a significantly higher value than the other treatments which presented statisticaly similar values. Similar results were obtained by Santos *et al.*, (2003; 2005) with the red variety 'Castelão' in Portugal and Intrigliolo & Castel (2009) with the red variety 'Tempranillo' in the region of Valencia, Spain.

Table 2. Effect of irrigation amount on yield and yield components. Average of 2006-2008 seasons.

Treatment	Cluster number/ vine	Yield/vine	Cluster weight (g)
NI	20.4	2.9 b	139.7 b
DI30	20.8	3.0 b	148.7 b
DI50	20.4	2.8 b	139.5 b
FI	21.1	3.4 a	160.4 a
Sig	**ns**	*	*

In each column different letter suffixes indicate statistically significant differences at $P < 0.05$ by LSD test. * and ns indicate significance at $p < 0.05$, and not significant respectively.

Fruit composition at harvest

Although not significant every year (data not shown), the effect of irrigation on the three seasons average total soluble solids and titratable acidity was significant, FI showing a lower ºBrix and a higher acidity than the other treatments which presented similar results. These results are similar to those obtained by Santos *et al.* (2005) and Ojeda (2008). FI presented the lowest pH (Table 3).

While no significant differences were detected in total phenols, FI treatment presented a significantly lower berry skin anthocyanins than the other treatments which returned similar values (Table 3). This negative effect of full irrigation on anthocyanins content may have resulted from the positive effect of water supply either on berry size and consequent decrease of the skin to flesh ratio, and on the vegetative growth via the indirect effects of the increase in canopy density and cluster shading (Williams and Mathews 1990; Van Leeuwen and Seguin 1994; Lopes *et al.*, 2001; Santos *et al.*, 2005).

Table 3. Effect of irrigation amount on fruit composition at harvest. Average of 2006-2008 seasons.

Treatment	Total soluble solids (ºBrix)	Titratable acidity (g/L)	pH	Antocyanins (mg/L)	Total phenols (TPI)
NI	22.4 a	7.7 b	3.21 a	1089 a	57
DI30	22.2 a	7.7 b	3.20 ab	1116 a	59
DI50	22.0 a	7.7 b	3.22 a	1144 a	59
FI	21.5 b	8.2 a	3.18 b	972 b	54
Sig.	*	*	*	**	ns

In each column different letter suffixes indicate statistically significant differences at $P < 0.05$ by LSD test. *, ** and ns indicate significance at $p < 0.05$; 0.01 and not significant respectively.

Despite the fact that in the non-irrigated vineyards of the Dão winegrowing region it is very common to observe vine water stress symptoms, mainly at the ripening period, during the three studied seasons (2006-2008), the deficit irrigation treatments showed no advantages relatively to the control non-irrigated. Despite the higher yield produced in the full irrigation, this treatment had the disadvantages of the excessive vine vigour and lower must quality produced.

These results should be looked with care because the three year period of this experiment (2006-2008) was characterized by abnormal low atmospheric demand and absence of water stress (data not shown), which is atypical for this region of hot and dry summers. Further studies are needed mainly in dry years which frequency are expected to increase in the near future as a consequence of the climate change.

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