

INFLUENCE OF ELEVATION AND SLOPE EXPOSURE UPON PRODUCTIVITY AND MUST QUALITY OF « TOURIGA NACIONAL » (SUB-REGION OF DOURO SUPERIOR)

Ana Alexandra OLIVEIRA* and Maria José CORREIA

Universidade de Trás-os-Montes e Alto Douro, Apartado 1013, 5001-801 Vila Real, Portugal

Abstract

Aims: This work presents the results of a 3 year study on the influence of elevation and slope exposure upon the productivity and quality of the Touriga Nacional variety.

Methods and results: Touriga Nacional variety standing on 18 plots dispersed along the sub-region of Douro Superior (laid out in a randomized complete block design). We determinate productivity, alcohol, volume, mass, total acidity, chromatic characteristics, anthocyanins, polyphenol index, maturation index, vegetative mass, vigour estimation and ravaz index.

Conclusion: The results revealed a decrease in most parameters related to productivity and quality as the elevation increases and, simultaneously, the concentration of phenolic compounds increased proportionally in relation to elevation. In relation to the plots set either on northern or southern exposures, the SW and NW exposures surpass the N, S, NE, and SE exposures in terms of the concentrations phenolic compounds, but all other parameters, either productivity or quality related, had lower values.

Significance and impact of study: The results confirm the importance of elevation and slope exposure of sub-region Douro Superior, in productivity and must quality of Touriga Nacional.

Key words: « Touriga Nacional », Douro (sub-region of Douro Superior), slope orientation, elevation, quality, productivity

Résumé

Objectif : Ce travail présente les résultats de trois années d'étude sur l'influence de l'altitude et de l'exposition sur la production et la qualité du cépage Touriga Nacional.

Méthodes et résultats : L'étude a été conduite sur le cépage Touriga Nacional dans 18 parcelles de la région du Douro Supérieur (modèle expérimental en blocs aléatoires). Nous avons déterminé la productivité, l'alcool, le volume, le poids, l'acidité totale, les caractéristiques chromatiques, les anthocyanes, les composés phénoliques, l'indice de maturation, l'expression végétative, le calcul de la vigueur et l'indice de Ravaz.

Conclusion : Les résultats ont montré des diminutions de la plupart des paramètres productifs et qualitatifs avec l'augmentation de l'altitude, et simultanément la concentration des composés phénoliques a augmenté proportionnellement à l'altitude. Pour les pentes des parcelles exposées nord et sud, l'exposition SW et NW ont dépassé les expositions N, S, NE, SE, en termes de concentration des composés phénoliques, mais tous les autres paramètres productifs et qualitatifs ont révélé des valeurs plus basses.

Signification et impact de l'étude : Les résultats confirment l'importance de l'altitude et de l'exposition de la région Douro supérieur sur la productivité et la qualité du Touriga Nacional.

Mots clés : « Touriga Nacional », Douro (région Douro Supérieur), orientation, altitude, qualité, productivité

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INTRODUCTION

The wine region of Douro has many microclimates: it is « made of deep valleys, steep slopes, a profusion of slope exposures, as well as a richness of microclimates raised from this disturbing orography » (Magalhães, 1998a). The climatic diversity in association with the soil water availability to the vine plants creates 3 sub-regions in the Douro - Baixo Corgo (BC), Cima Corgo (CC) and Douro Superior (DS), with different mesoclimates in a mosaic of slope formations standing on metamorphic schist of different geological origin. The sub-region of Douro Superior shows the highest summer temperature and an annual rainfall of 400 mm, in contrast to 900 mm in Baixo Corgo and 650 mm in Cima Corgo (Magalhães, 1998b).

The « Touriga Nacional » variety has a long vegetative cycle and is one of the last varieties to ripen in the Douro Region. It needs a favorable exposure to attain the desired quality. The most favorable is the southern exposure at elevations below 300 meters (Oliveira *et al.*, 2000).

Magalhães (1989) defines the « Touriga Nacional » as a variety with high potential to achieve a good quality, but its production varies widely inside its population, which is corroborated by other authors e.g. Toscano (1996) and Martins *et al.* (2001). Presently, thanks to clonal selection, this variety has a productivity average per plant of about 1.5 kg in the Demarcated region of Douro (DRD) (Toscano, 1996; Oliveira *et al.*, 2001; Martins *et al.*, 2001; Queirós, 2002; Oliveira, 2003).

Riou (1994) and Jacquet and Morlat (1997) say that there is a positive influence of the summation of the active temperatures (X) computed for particular periods of the vegetative cycle (especially the period from maturation to the harvest) upon the concentration of sugars in the must. Calo *et al.* (1992) say that the insolation during the same period is very important for the concentration of sugars.

Riou (1994), Riou *et al.* (2001) and Van Leeuwen *et al.* (2007) consider that besides insolation, temperature is a very important factor in berry growth and development. Tukey (1958) and Riou (1994) conclude that high temperatures have a depressing effect upon the berry size when water stress is high.

Kliwer (1970), Merioux and Panine (1988), Riou (1994) and Zufferey and Murisier (2007) found a positive influence of the summation of active temperatures upon sugar concentration, in particular during the maturation period.

According to Dumas *et al.* (1997) and Guyot (1997), temperature decreases with elevation by a gradient of -

0.65 °C per 100 m, and this decrease is closely related with wind speed, slope, slope exposure and elevation. The same authors also found that the slope and its exposure influence the interception of solar radiation.

The decrease of temperature at higher elevations is followed by a larger thermal amplitude (larger variation between diurnal and nocturnal temperatures) relative to lower elevations when other factors remain equal (Guyot, 1997), and there is a reduction of evaporation of 10 to 30 % at higher elevations as a function of wind speed and distance between plant rows (Reynolds *et al.*, 2007). According to Riou (1997), Kennedy (2006) and Harbertson and Spayd (2006), these factors associated with poor soils, might result in lower berry mass, increased concentrations of tartaric acid, and increased concentration of total anthocyanins and polyphenols as a consequence of water stress.

On sloping areas, Branas (1974), Nigond *et al.* (1986), and Kliwer and Dokoozlian (2005) mention that the interception of solar radiation is closely related with slope angle and slope exposure where the vineyard stands, and for a given slope, the received energy reaches higher values as the elevation increases.

Relative to slope exposure, Branas (1949) (Aguilar, 1988) says that the SE exposure is the most favorable to promote quality. Carbonneau (1980) and Oliveira (2003) said that SE, E, and S exposures are more favorable than N exposure for light interception.

The exposure is measured in the Demarcated Region of Douro using the grading method of Moreira da Fonseca (1948) that considers elevation and exposure as factors of utmost importance.

MATERIALS AND METHODS

This study took place on a set of 18 plots of « Touriga Nacional », standing along the sub-region of Douro Superior of the Demarcated Region of Douro (DRD). Each plot had five replicates (with 6 vines per replicate) per class of altitude and class of exposure, laid out in a randomized complete block design (each plot with 150 vines).

The criteria to choose the plots were:

- a) Grafting year between 1983 and 1992 (age of the grafting in 1998 of 6 to 15 years);
- b) Every plant in the plot was in a good sanitary condition, and was well trellised;
- c) All the plots had a similar soil type, rootstocks (R110), Cordon system (with 4 stump of vine after pruning), compasses (1 m x 2 m) and similar vegetation.

The measurements performed are summarised in figure 1.

Based on the viticulture parameters we measured, other indexes were derived:

- a) Maturation Index = brix degree / titrable acidity
- b) Vegetative mass (kg) = pruning mass
- c) Vigour estimation (g) = average mass of the shoots = pruning mass / number of shoots per plant
- d) Ravaz index = yield (kg/plant) / pruning mass (kg/plant)

Alcohol concentrations are given in table 3, but it appears these are Baume values derived from the grape juice. The figures in table 3 should be quoted as Baume if this is the case. Also, the maturation index should have units. No information is given on time of harvest, which is important in influencing total acidity and sugar concentration.

The statistical analysis was based on analysis of variance and a comparison of means for a 3 year period.

The interaction between year and variable was not significant.

RESULTS AND DISCUSSION

Tables 1 and 2 show that elevation influence was not significant effect on cluster mass, significant effect ($P < 0.01$) on yield and vigour, and was highly significant effect ($P < 0.001$) on all other parameters measured.

The influence of exposure on all parameters was highly significant effect ($P < 0.001$) but not significant effect on vigour estimation and on cluster mass per plant.

As the elevation increased (Table 1), we register a significant decrease in the yield, mass, and volume of the berries, and also in the number of berries per plant. The decrease of yield per plant with elevation was followed by smaller numbers of clusters per plant, and by a significantly lower mass and volume of the clusters. These facts might be the result of a lower soil fertility in sub-region Douro Superior, and water availability in the plots at higher elevation, which implies, on one hand, a smaller load at pruning time and, on other hand, a reduced volume of the berries due to a higher water stress.

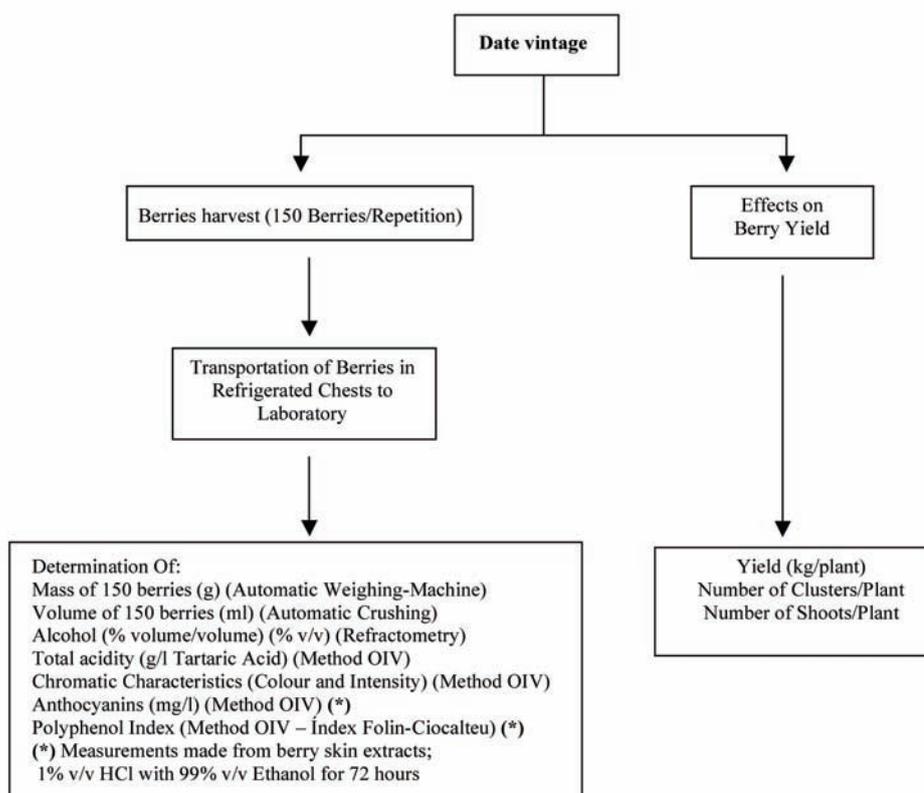


Fig. 1 - Schematic representation of the processing and measurements made for « Touriga Nacional » in sub-region of Douro Superior

Table 1 - Three years average for yield, mass and volume of the berries, cluster mass, and number of clusters/plant in the plots of Douro Superior in relation to elevation and slope exposure.

Parameter	Position	Yield (kg/Plant)	Mass Berry (g)	Volume Berry (ml)	Cluster Mass (g)	Number of Clusters/Plant
Elevation	> 300m	0,96 a	161,55 a	74 a	110 a	9 a
	200 - 300m	1,95 b	209,64 b	113 b	120 a	16 b
	100 - 200m	2,20 b	222,97 c	126 c	120 a	19 c
Exposure	N	2,02 bc	216,85 c	122 c	130 a	15 b
	NE	2,31 c	229,04 d	132 d	130 a	18 c
	NW	1,78 b	204,68 b	109 b	130 a	13 b
	S	1,78 b	199,02 b	104 b	110 a	17 b
	SE	2,26 bc	224,98 d	127 cd	110 a	20 c
	SW	1,30 a	172,98 a	81 a	110 a	12 a

Mean values followed by the same letter are not significantly different ($P \geq 0.05$)

Table 2 - Three years average for Ravaz Index and for mass of one shoot (vigor estimation), in the Douro Superior plots as function of elevation and slope exposure.

Parameter	Position	Ravaz Index	Vigor estimation (g)
Elevation	> 300m	0,53 a	97 a
	200 - 300m	1,60 b	112 b
	100 - 200m	1,90 c	115 b
Exposure	N	1,61 c	110 a
	NE	1,94 d	114 a
	NW	1,31 b	115 a
	S	1,53 c	110 a
	SE	2,01 d	113 a
	SW	0,84 a	108 a

Mean values followed by the same letter are not significantly different ($P \geq 0.05$)

The influence of the exposure upon the productive parameters showed a marked reduction of the yield per plant for SW exposure (Table 1) as seen in the smaller number of clusters/plant, which might have its origin in a lower load at Ravaz Index and vigour estimation (Table 2), and in smaller mass and volume of the berries. The largest productivities were found in SE and NE exposures where both the number of clusters/plant, and the volume and mass of the berries were higher, because they benefited from more favorable microclimates.

A similar pattern was observed on the Ravaz index (Table 2), either regarding the influence of elevation or slope exposure. The estimation of vigor (Table 2) also was reduced as elevation increased, but was not influenced by slope exposure, which is in agreement with Reynolds et al. (2007).

Regarding the values of alcohol content, maturation index, and chromatic characteristics (coloring and intensity), lower values were measured but with wider amplitude as elevation increased; these values were not independent of slope exposure (Table 3).

The slope exposure had a significant and positive influence upon those parameters (alcohol, maturation and

chromatic characteristics) (Table 3). The S, SE, and SW exposures had a higher influence than the N, NE, and NW exposures, probably due to better interception of the solar radiation for S, SE, and SW, that resulted in increased production of sugars (S, SE and SW with higher alcohol compared with N, NE and W).

The values for phenolic compounds (polyphenol index and anthocyanins) shown in table 4 show a departure from the productive parameters (yield, mass and volume of the berries, Ravaz index and vigor estimation), i.e., the values were significantly higher for higher elevations and for SW and NW exposures where we measured the lowest values for mass and volume of the berries.

The widespread reduction of the mass and volume of the berries and the rise of phenolic compounds as elevation increases are in agreement with Riou (1997) who states that poor soils together with water stress are responsible for these results. In this case, the soil type is the same all the plots, but the elevation increases given situations a 300 m the elevation are more prone to water stress than 100 m the elevation. Regardless of the inverse variation of all parameters of quality and productivity, except for phenolic compounds, with elevation, we did not observe

Table 3 - Three year average for alcohol, maturation index and chromatic characteristics (coloring and intensity) in the plots of Douro Superior in relation to elevation and slope exposure.

Parameter	Position	Alcohol (% v/v)	Maturation Index	Coloring	Intensity
Elevation	> 300m	12,1 a	6,75 a	1,36 a	4,07 a
	200 - 300m	12,3 b	7,15 b	1,49 b	4,64 b
	100 - 200m	12,7 c	7,73 c	1,64 c	4,92 c
Exposure	N	12,3 b	7,14 b	1,53 bc	4,54 ab
	NE	12,0 a	6,69 a	1,39 a	4,33 a
	NW	12,3 b	7,31 b	1,62 d	4,75 bc
	S	12,7 d	7,74 d	1,61 cd	4,99 c
	SE	12,6 c	7,49 c	1,53 bcd	4,69 b
	SW	12,7 d	7,58 d	1,49 b	4,66 b

Mean values followed by the same letter are not significantly different ($P \geq 0.05$)

Table 4 - Three year average for phenolic compounds (polyphenol index and anthocyanins) in the plots of Douro Superior in relation to elevation and slope exposure.

Parameter	Position	Polyphenol Index	Total Anthocyanins (mg/l)
Elevation	> 300m	186 c	811 c
	200 - 300m	162 b	618 b
	100 - 200m	157 a	594 a
Exposure	N	158 b	589 b
	NE	147 a	493 a
	NW	159 b	607 c
	S	171 c	702 d
	SE	158 b	610 c
	SW	175 d	730 e

Mean values followed by the same letter are not significantly different ($P \geq 0.05$)

any incompatibility between quality and productivity, an observation shared by the same author.

That most of the plots on a southern exposure showed higher values for the parameters of quality (alcohol and maturation index), while the ones on a northern exposure showed better productivity corroborates the statements of Carbonneau (1980), Champagnol (1984), Riou *et al.* (1989), Murisier (1993), Intrieri *et al.* (1998), Jackson (1998), Kennedy (2006) and Harbertson and Spayd (2006) who argued that the southern exposures are more prone to water stress, to scalding of the cluster, resulting in productivity losses but higher concentration of sugars.

CONCLUSIONS

This study with « Touriga Nacional » that took place for 3 years in the sub-region of Douro Superior shows a reduction in productivity and in volume of the berry for both higher elevations and SW slope exposure. Meanwhile, the musts yielded lower concentrations of phenolic compounds and of alcohol.

The plants standing on eastern slopes had higher productivity together with larger berries, probably because over-maturation was less prevalent. The plants standing on SW and SE slopes, vis-a-vis the ones on NW and NE slopes, rendered higher alcohol content and higher maturation index. The polyphenol index and total anthocyanins were noticeably higher in plants standing on SW slopes.

The highest elevations were more favorable for accumulation of phenolic compounds but the plants produced less than half the amount yield per plant than the ones standing lower and the alcohol content was reduced as well.

In the sub-region under study, the best relation production x quality for the « Touriga Nacional » variety is probably found at elevations between 100 and 200 meters and in southern exposures that rendered a good production, high contents of alcohol and phenols, and were more suitable for the vegetative cycle of the plants. The SW exposure produced plants with good quality parameters.

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