INFLUENCE OF VINE SPACING ON WATER STATUS, PRODUCTIVITY, YIELD AND MUST COMPOSITION IN TEMPRANILLO GRAPEVINE UNDER DUERO VALLEY ZONE CONDITIONS

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Abstract

The purpose of the study is to evaluate the influence of vine spacing on plant water status (leaf water potential), productivity (dry matter and yield), and fruit quality (berry size, ºBrix, pH, total acidity, polyphenolic composition) of Tempranillo grapevine in the Valley of Duero river, at the A.O. Cigales. Vine spacing treatments applied were: 2645 vines per ha (2.70 m x 1.40 m), Low density, and 3953 vines per ha (2.20 m x 1.15 m), High density.

The experimental trial was located in Valladolid (Castilla y Leon, Spain). The 12-year-old vines grafted onto 110 Richter rootstock were vertically trellis trained, through a bilateral cordon, and spur pruned. The experimental vineyard was irrigated by means of doses of 20% ETo from July to September.

The increase of the number of plants per hectare has provoked a reduction of dry matter production and yield, in spite of the fact that predawn leaf water potential has not always shown the different water status of vines. The reduction of vine spacing corresponding to the higher plant density has provoked a significant reduction of berry size and the increase of the values of ºBrix, pH (related to higher K accumulation), titratable acidity and phenolic concentration. The increase of the number of plants per hectare has affected the production and the quality of Tempranillo grapevine in the conditions of the zone (Valley of the Duero river) and the soil of the experimental trial with a moderate doses of irrigation. The main effect of the increase has been the partial improvement of the fruit quality, related to sugar and phenolic concentrations, with the inconvenient of the yield reduction.

Résumé

L’objectif de cette étude est analyser l’influence de la densité de plantation sur l’état hydrique (potentiel hydrique), le comportement productif (matière sèche et rendement) et la expression qualitative (poids de baie, degrée Brix, pH, acidité totale, concentration polyphénolique) de la varieté Tempranillo dans la Vallée du Douro, à l’A.O. Cigales. Pour développer l’essai on a appliqué les suivantes densités de plantation: 2645 ceps/ha (2.70 m x 1.40 m), “basse densité”, et 3953 ceps/ha (2.20 m x 1.15 m), “haute densité”. L’essai experimental a été situé à Valladolid (Castilla et León, Espagne). Les ceps ont été plantés en 1993, sur porte-greffe 110R, et ont été conduites en espalier, menés en cordon Royat bilateral et taillés en coursons, ayant été cultivés avec une dose d’irrigation du 20% ETo depuis juillet jusqu’à septembre.

L’augmentation de la densité de plantation a permis d’apprécier une diminution de la production de matière sèche et du rendement, malgré que le potentiel hydrique foliaire de base n’a pas montré toujours que les ceps avaient un état physiologique plus mauvais. L’augmentation de la densité de plantation a provoqué une réduction significative du poids de la baie et un accroissement de la concentration de sucres, le pH (en relation avec une plus grande concentration de K), l’acidité totale et la concentration polyphénolique du moût. Dans les conditions de l’essai (zone de la Vallée du Douro) et avec une dose d’irrigation modérée (20% ETo), l’augmentation de la densité de plantation a provoqué une amélioration de la qualité du raisin de Tempranillo en ce qui concerne à maturation et concentration polyphénolique, bien que le vignoble a eu une réduction de la production du raisin.

INTRODUCTION

The choice of vine spacing is one of the most important decisions affecting vineyard design. Plant spacing has long-term effects on plant physiology, yield and grape quality (Hunter 1998 b) as well as on costs of plantation and cultivation (Winkler *et al*. 1974).

The 3 m x 1.5 m vine spacing has become the most common in Spain, and more concretely in the Valley of the Duero river, in the last decades (Pérez 2002). The election of this vine spacing is based on necessities of mechanization, not on vine response to different vine spacing.

It is difficult to extrapolate the results of vine spacing studies from one site to another, mainly when there are evident differences in the environment productive potential between sites (Archer 1991). Most of the available information comes from trials carried out in higher productive potential environment, especially due to a higher hydric availability. There are few studies carried out on low water-holding capacity soils and dry climates.

Thereby, a vine spacing trial has been developed in these conditions that are frequent in the Valley of the Duero river. The purpose of this study was to know the vine spacing implications on total productivity, yield and quality of Tempranillo grapevine, the most important red variety in this region as well as in Spain.

MATERIALS AND METHODS

Location. The trial was carried out in Valladolid, central-northern Spain, along 2002 and 2003. The experimental vineyard of Tempranillo variety grafted onto 110 Richter was planted in 1993. Vines were vertical trellis trained, 2-bud spur pruned in a bilateral Royat cordon. The row orientation was north-south (+ 25º). ET daily average during irrigation period was 3.89 mm in 2002 and 3.58 mm in 2003. Annual rainfall was 176 mm and 483 mm in 2002 and 2003, respectively.

The soil is highly stony (70% of thick elements along the first 100-cm depth), without physical or chemical limitations which allows a good drainage, high infiltration speed and low water storage capacity (70 mm . m^{-1}). Most part of the grapevine root system is located along the first 60-cm depth of soil.

Experimental design. The experimental design for vine spacing consisted of randomized blocks with 4 replications and elemental plot of 9 or 11 control vines depending on plant density. The number of shoots per unit of soil surface was 39600/ha on both vine spacing treatments. The treatments applied were: low density (2.20 m x 1.15 m) and high density (2.70 m x 1.40 m). The total amount of water applied (0.2 ETo) was 71 mm and 51.5 mm in 2002 and 2003 respectively, weekly distributed from June till September. The irrigation started in June 24th in 2002 and in July 7th in 2003.

Control of yield along both years was made in order to reach the balance between yield and leaf area focused on getting correct ripening. According to the behavior of the vineyard observed the previous years, in 2002 the relation SA/yield was limited to 1.8 m^2/kg in treatment L (low density) and 2.45 m^2/kg in treatment H (high density). In 2003, taking into account the previous results, this relation was reduced until 1.1 m^2/kg in treatment L, whereas it was maintained in 2.45 for treatment H. Yield prediction was based on the number of clusters counted, estimation of number of berries per cluster and estimation of berry weight, according to the weight observed the previous years.

Experimental determinations. Plant water status was evaluated through leaf water potential measured before dawn by means of pressure chamber technique. All measurements were made from June until harvest. Dry matter of renewable parts of the vine (shoots + leaves + clusters + second crop) has been evaluated from twelve representative shoots of each experimental treatment at the end of each vegetative cycle. Grape yield and number of clusters were measured on each control vine. Just before harvest time a sample of 200 berries per treatment and replication was picked, weighted and crushed. Total acidity (expressed in g/l of tartaric acid), pH and total soluble solids (^{o}Brix) were measured over an aliquot part of the must. In the left part of the must, concentration of polyphenolic substances (total polyphenols index, total and extractable anthocyanins) were measured through method of Glories (2001).

RESULTS AND DISCUSSION

Leaf water potential. The evolution of predawn leaf water potential has shown the same tendency in both treatments and years of study. In general, treatment H reached values more negative than treatment L, with statistically significant differences between them observed in some moments of the cycle (table 1).

Pérez (2002) found a similar behavior studying the same alternatives of vine spacing under similar conditions, with significant differences only in some concret periods. Archer & Strauss (1990) observed an increase of vine water stress along the season with the increase of plant density under dry farmed conditions. The differences observed in dry matter production and yield between treatments could indicate the differences in water status, however, the predawn leaf water potential has not detected the magnitude of these differences.

Global vine productivity. The treatment L, with higher vine spacing, showed a higher dry matter production per unit of soil surface in both years of study (table 2), although there were significant differences only in 2003. These results do not agree with those of Archer (1991), Hunter (1998a) and Pérez (2002), who found that the increase of number of plants per hectare showed a higher dry matter production due to a higher active leaf surface per unit of soil surface.

In both years of the study, the higher dry matter production reached by treatment L was based on a higher bunch dry weight while the dry weight of leaves and shoots was similar in both treatments. The cluster dry weight of low-density treatment was 54.1% and 48.9% of the renewable parts dry weight in 2002 and 2003 respectively, while this percentage was 31% in high-density treatment in both years.

Yield. The differences caused by the vine spacing treatments have shown the same tendency than those found in dry matter production. The treatment L showed higher yield in both years, although there were significant differences only in 2003. The increase of yield per unit of soil surface was related with higher berry and bunch weights in both years, in the same way as Pérez (2002) found. On the contrary, Hunter (1998a) and other authors observed that yield increased with plant density in higher water availability conditions.

Grape quality

Berry size. The increase of plant density has generated a significant decrease of berry weight in both years of study (table 2). Hunter (1998b) and Pérez (2002) also found a reduction of the berry size due to the increase of plant density, but Hedberg & Raison (1982) and Archer & Strauss (1991) did not found this relationship between plant density and berry weight. These different results could be related with the different water availability in the cited studies because berry weight is very sensible to water status, fundamentally before veraison (McCarthy 1997).

Soluble solids. In 2002 the final concentration of soluble solids was significantly higher in treatment H. The higher yield of treatment L, and the consequent worse relation between yield and external leaf surface, affected the sugar accumulation (Schneider 1989, Candolfi-Vasconcelos & Koblet (1990). In 2003 the soluble solids concentration was also higher in treatment H than in tretament L, but without significant differences (table 3), probably due to some unusual high temperatures in the ripening period.

Total acidity. The total acidity has been slightly higher in treatment H in both years of study, but the differences were significant only in 2002 (table 3). In warm climates as in this case, the total acidity depends largely on the tartaric acid accumulation, since the malic acid is degraded more intensely during ripening (Winkler *et al*. 1974, Mullins *et al*. 1998). Taking into account the metabolic stability of tartaric acid, the decrease of concentration of the tartaric acid could be attributed to a dilution effect due to the increase of berry volume (Mullins *et al*. 1998, Ollat *et al*. 2002).

pH. Must pH of high-density treatment was higher than low-density one in both years of study (table 3). The higher pH and the higher total acidity of the high-density treatment during both years of study must be related to a higher potassium accumulation in the berries since the potassium concentration is one of the factors that influence more in must pH (Boulton 1980, Esteban 1995, Ollat *et al*. 2002). Williams & Arnold (1999) found higher potassium concentration and pH in closer spaced vines (1 m x

1.8 m) than in wider spaced ones (1.5 m x 2.7 m). The utilization of soil is more effective in closer plant spacing (Archer 1991) and so it could have increased the absorption of potassium and the K level in berry (Mpelasoka *et al*. 2003).

Polyphenols. The closer spaced vines showed a higher poliphenolic content (higher total phenols index, extractable anthocyanins and total anthocyanins) in both years of study (table 3), with significant differences in 2003. The higher polyphenolic concentration was related to the lower berry size and the consequent increase of skin to pulp ratio (McCarthy 1997, Ojeda *et al*. 2002, Roby *et al*. 2004). Furthermore, the polyphenolic synthesis could have been increased in closer spaced vines by the higher water stress (Ojeda *et al*. 2002, Roby *et al*. 2004).

CONCLUSIONS

The increase of plant density has provoked a reduction of the vine physiologic activity, which has been shown through a lower global productivity and yield. Nevertheless, the pre-dawn leaf water potential, even being higher in the low plant density, have not always shown the differences of vine water status that have been expressed in productivity.

The increase of plant density has caused the improvement of grape quality related to lower berry size, higher concentration of soluble solids and higher concentration of phenolic compounds. On the other hand, the closer spacing vines have shown higher values of pH that could be related to a higher accumulation of potassium in berries.

The increase of plant density has represented a partial improvement of the quality grape with the inconvenient reduction of global productivity and yield.

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Tables

Table 1. Predawn leaf water potential (MPa) of treatments L and H in 2002 and 2003. Analysis of variance, signification levels: - (ns), * (p<0.05), ** (P<0.01).

2002	14/06/2002	19/07/2002	20/08/2002	26/09/2002
L	-0.33	-0.44	-0.39	-0.54
H	-0.40	-0.51	-0.47	-0.60
	-	*	-	*

2003	05/06/2003	19/06/2003	04/07/2003	18/07/2003	29/07/2003	13/08/2003	26/08/2003	10/09/2003	23/09/2003
L	-0.09	-0.08	-0.31	-0.24	-0.27	-0.28	-0.48	-0.31	-0.465
H	-0.13	-0.06	-0.29	-0.33	-0.29	-0.30	-0.45	-0.27	-0.524
	**	-	-	**	*	*	-	-	*

Table 2. Dry matter production, grape yield, bunch number, bunch weight and berry size of treatments L and H in 2002 and 2003. Analysis of variance, signification levels: - (ns), * (p<0.05), ** (P<0.01).

2002	dry matter ($g·m^{-2}$)	yield ($kg·m^{-2}$)	bunch number ($bunch·m^{-2}$)	bunch weight (kg)	berry size (g)
L	377.64	0.460	2.8	0.165	1.69
H	352.83	0.384	3.2	0.120	1.48
	-	-	-	*	*

2003	dry matter ($g·m^{-2}$)	yield ($kg·m^{-2}$)	bunch number ($bunch·m^{-2}$)	bunch weight (kg)	berry size (g)
L	573.99	1.093	5.3	0.206	1.63
H	464.41	0.625	4.9	0.127	1.27
	*	**	-	**	**

Table 3. Soluble solids, total acidity, pH, T.P.I., extractable anthocyanins and total anthocyanins of treatments L and H in 2002 and 2003. Analysis of variance, signification levels: - (ns), * (p<0.05), ** (P<0.01).

2002	soluble solids (ºBrix)	total acidity TA (g/l)	pH	T.P.I	extractable anthocyanins (mg/l)	total anthocyanins (mg/l)
L	23.25	4.53	3.64	85.15	1232	1732
H	24.31	4.67	3.85	87.10	1363	1891
	**	*	**	-	-	-

2003	soluble solids (ºBrix)	total acidity TA (g/l)	pH	T.P.I	extractable anthocyanins (mg/l)	total anthocyanins (mg/l)
L	22.27	4.23	3.87	40.56	903	1711
H	22.40	4.42	4.01	44.48	1172	2040
	-	-	*	*	*	*

Figures

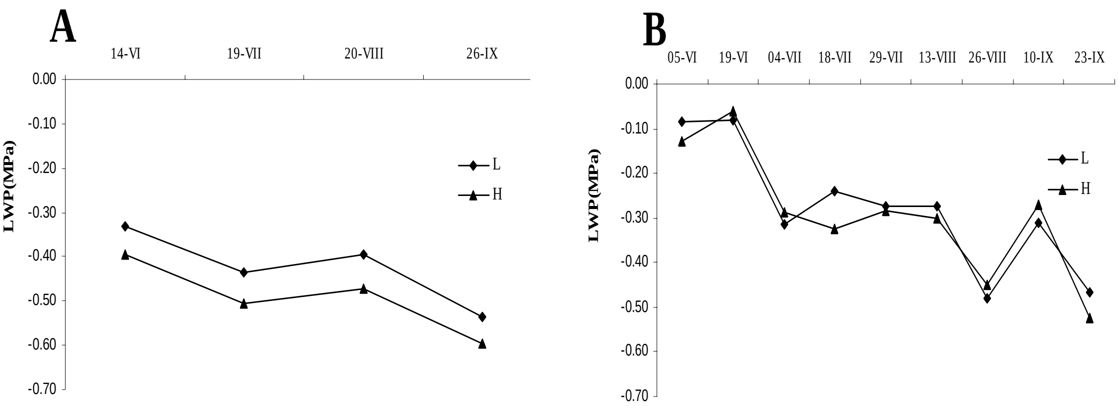

Figure 1. Seasonal evolution of predawn leaf water potential (MPa) of treatments L and H in 2002 (A) and 2003 (B).