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AN ATTEMPT TO QUANTIFY GRAPEVINE WATER STRESS IN A MEDITERRANEAN ENVIRONMENT

ESSAI DE QUANTIFICATION DU STRESS HYDRIQUE DE LA VIGNE DANS DES CONDITIONS MEDITERRANEENNES

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Abstract
Aiming to quantify the effects of the intensity and duration of grapevine water stress, physiological and agronomical data from an irrigation experiment conducted during 1999 at Alentejo, south of Portugal, with the red variety Aragonez (syn. Tempranillo) were correlated with an water stress index (S_ψ). This index was calculated by the integral of predawn leaf water potential below –0.2 MPa between bloom and harvest. Significant relationships were found between the S_ψ, yield components and berry composition. The multiple regression analysis shows that the S_ψ in the period bloom-veraison has a higher contribution to explain the variation in berry weight, anthocyanins and phenolics concentration than the S_ψ in the period veraison-harvest. The knowledge of those relationships, together with the relationship between available soil water content and predawn leaf water potential, may allow the adequate management of soil water availability to optimise the yield/quality ratio for each ecological situation.

Key words:
predawn leaf water potential, water stress index, Tempranillo

Résumé
Avec l'objectif de quantifier les effets de l'intensité et durée du stress hydrique de la vigne, on a corrélé un indice de stress hydrique(S_ψ) avec des données agronomiques, obtenues en 1999 dans un essai d'arrosage du cépage Aragonez (syn. Tempranillo) a la région d'Alentejo, au Portugal. Cet indice a été calculé d'après l'intégral du potentiel hydrique de base au-dessous de –0.2 MPa au cours de la période floraison-récolte. On a trouvé des corrélations significatives entre le S_ψ, les composants du rendement et la composition du raisin. La régression multiple montre que le S_ψ, dans la période floraison-véraison, a une contribution plus importante pour expliquer la variabilité du poids des baies et de la concentration en anthocyanes et phénols des pellicules que le S_ψ dans la période véraison-récolte. La connaissance de ces relations, combiné avec la relation entre la disponibilité en eau du sol et le potentiel hydrique de base, peut permettre une meilleure gestion de l'eau de façon à optimiser la relation rendement/qualité pour chaque terroir.

Mots clés:
potentiel hydrique foliaire de base**,** indice de stress, Tempranillo.

1. INTRODUCTION

It is well known that grapevine mild water stress improve fruit composition and wine quality (Carbonneau, 1980, Smart & Coombe, 1983; Williams & Mattews, 1990). All methods and strategies for scheduling irrigation of grapevines for quality wines foccus the importance of reducing the irrigation intensity on specific periods of the growing season in order to enable a mild water deficit for reducing vegetative growth and enhance berry composition (Prichard, 1992; McCarthy, *et al.* 1992). However, in general, the degree of water deficit experienced by the plant is not very well quantified.

There are several methods to measure water availability, plant-based methods providing the most reliable estimates of plant water status (Turner, 1986). Among them, predawn leaf water potential was shown to be a very strong indicator of vine water status as it measures the integrated effect of soil and plant on water availability within the plant itself (Chaves & Rodrigues, 1987;Van Zyl, 1987; Rodrigues *et al*.,1993; Lopes *et al*, 1999). Nevertheless, for studies about the effects of soil water regimes on crop plants we must well quantify plant water status throughout the growing season. This will enable to know the intensity and duration of water stress periods endured by the plants.

Ginestar *et al* (1998a,b) utilized the water stress integral proposed by Myers (1988) to express the intensity by duration of the water stress above a minimum value. They found significant relationships between this water stress integral and growth, yield and grape composition of Shiraz grapevines grown in South Australia.

The aim of this study was to examine the relationships between the integral of predawn leaf water potential below –0.2 MPa and growth parameters, yield components and berry composition in order to quantify their relative dependence of the intensity and duration of grapevine water stress in a field-grown Tempranillo grapevine at Alentejo, Southern of Portugal.

2. **MATERIALS AND METHODS**

The field trial was carried out in 1999 at a commercial vineyard located at Évora, Southern of Portugal. The fourteen-year-old grapevines of the red variety ‘Aragonez’ syn. ‘Tempranillo’, grafted on 1103P rootstock, were spaced 2.5 m between and 1.1 m along rows and trained on a vertical trellis. The soil is an Antrossoil with an ApCR profile derived from granite with 75% of sand and high percentage of gross elements.

The experiment was set up in a randomized block design with four replicates per treatment. Four drip irrigation intensities were established acording to the crop evapotranspiration (ETc): (DIv - 50% ETc witheld after veraison, DIh - 50% ETc supplied until harvest, FIv - 100% ETc witheld after veraison and FIh - 100% ETc supplied until harvest) are tested against a non-irrigated control (NI). Irrigation began at the end of May (10 days after full bloom) when the available soil water was around 60% and was cuted-off at the end of July for the DIv and FIv treatments and one week before harvest (end of August) for DIh and FIh ones. In the deficit irrigation treatments a total of 144 and 216 mm was applied once a week in DIv and DIh respectively. In the full irrigation ones a total of 270 and 431 mm was applied twice a week in the FIv and FIh respectively. During the irrigation period total rainfall was 14 mm and the most important event was 12 mm at 10 of August (mid-ripening).

Predawn leaf water potential (Ψ_{pd}) was measured periodicaly at the two central blocks in four fully mature and well-exposed leaves (total of 8 leaves per treatment), on the day before irrigation, using a pressure chamber (PMS Instrument Co, USA). Predawn leaf water potential was used to calculate a modified water stress integral (Myers, 1988) which expresses the intensity by duration of the stress:

$S_{\psi} = | [\Sigma (\Psi_{i,\, i+1} - c)\, n] |$ (MPa . day)

where $\Psi_{i,\, i+1}$ = mean of the predawn leaf water potential in an interval i, i+1; c = maximum value of the leaf water potential measured during the study and n = number of days of the interval. In our case for c value we had utilised -0.2 MPa which was the averaged value for full irrigation vines during all season (see Fig. 1).

For correlation analysis it was used the data from the two blocks where the predawn leaf water potential measurements were made.

3. **RESULTS**

3.1 Predawn leaf water potential

In NI vines predawn leaf water potential (Ψ_{pd}) show a decreasing pattern during the summer period attaining –0.6 MPa two weeks before veraison, *ca* -0.9 MPa at veraison (July 20[th]) and very low values during all the ripening period (< -1.0 MPa). In the full irrigation treatment plants Ψ_{pd} presented high values ($\Psi_{pd} \cong$ -0.2 MPa) during the whole season. In the DIh treatment the Ψ_{pd} presented a decreasing trend until veraison but thereafter it showed an unexpected increase during the midle of August and then a decrease after the irrigation cutoff just before harvest. Veraison irrigation cutoff resulted in a steep decrease of the Ψ_{pd} in both irrigation intensities (Fig. 1).

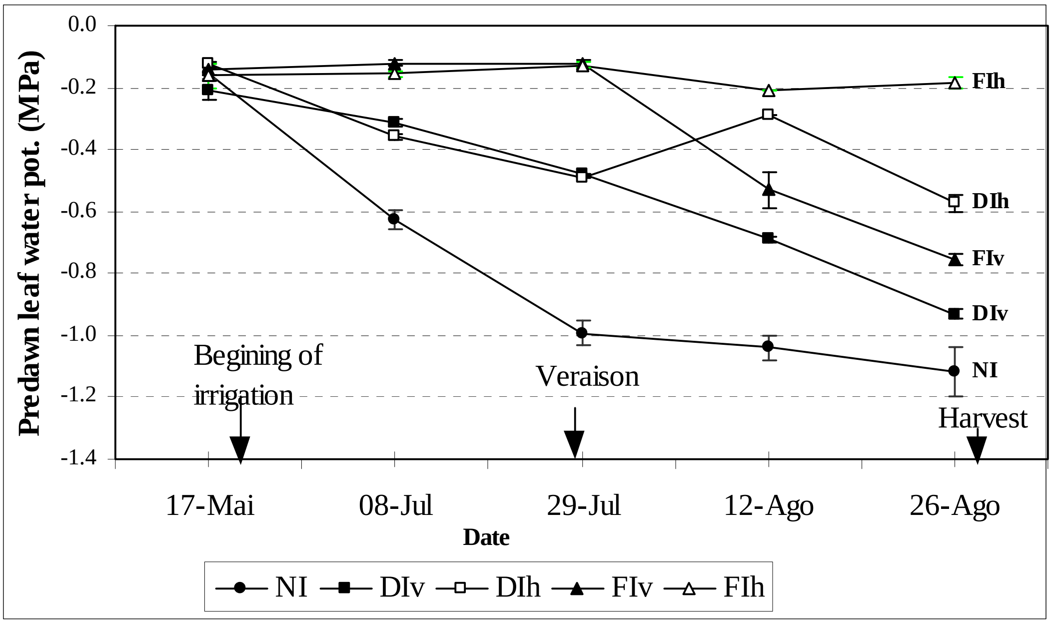

Figure 1

Predawn leaf water potential of Tempranillo grapevines measured during 1999 growing season. NI- non-irrigated; DIv - 50% ETc witheld after veraison, DIh - 50% ETc supplied until harvest, FIv - 100% ETc witheld after veraison and FIh - 100% ETc supplied until harvest. Average ± standard error of 8 adult exposed leaves.

Figure 1

Évolution saisonnière du potentiel hydrique de base, mesuré en 1999 sur le cépage Tempranillo. NI- non-irrigué; DIv - 50% ETc arrêté à la véraison, DIh - 50% ETc irrigué jusqu'a la récolte, FIv - 100% ETc arrêté à la véraison et FIh - 100% ETc irrigué jusqu'a la récolte. Moyen ± écart type de 8 feuilles adultes exposées.

3.2. **Leaf senescence**

In NI vines leaf senescence began prematurely (3 weeks before veraison) and, at veraison, 60% of main leaf area had already been lost. At harvest date (end of August) while the most irrigated plants showed only 23% of defoliation, NI vines presented 82.5%. Irrigation cutoff at veraison induced also a fast increase in leaf senescence which was more evident in the deficit irrigated plants.

3.3- **Yield and must quality**

In NI vines the severe water stress delayed full veraison by two weeks relatively to irrigated ones. Due to a significantly higher berry and cluster weight, irrigated plants presented a significantly higher yield than NI ones. At harvest, when compared to irrigated vines, the NI ones showed a significantly lower sugar content and titratable acidity, higher pH and higher total anthocyans and phenols.

3.4- **Water stress integral**

The water stress integral (S_ψ) of the whole measurement period was significantly higher in NI plants being the lowest values experienced by the full irrigated plants (table 1). During the period between bloom and veraison, while the full irrigated treaments presented a null S_ψ, the NI plants have already experienced 30% of the total season S_ψ and the deficit irrigated ones showed a low S_ψ. During the ripening period the DIv experienced the second most important S_ψ after NI while the DIh and FIv presented similar values but significantly higher than the FIh.

Table 1

Integral of predawn leaf water potential below –0.2 MPa (S_ψ) for different phenological periods of the 1999 growing season of tempranillo grapevines.. NI- non-irrigated; DIv - 50% ETc witheld after veraison, DIh - 50% ETc supplied until harvest, FIv - 100% ETc witheld after veraison and FIh - 100% ETc supplied until harvest.

Tableau 1

Intégral du potentiel hydrique de base, au-dessous de – 0.2 MPa au cours de différents périodes phenológiques mesuré en 1999 sur le cépage Tempranillo. NI- non-irrigué; DIv - 50% ETc arrêté à la véraison, DIh - 50% ETc irrigué jusqu'a la récolte, FIv - 100% ETc arrêté à la véraison et FIh - 100% ETc irrigué jusqu'a la récolte.

Treatment	S_ψ bloom-veraison (MPa . day)	S_ψ veraison-harvest (MPa . day)	S_ψ bloom-harvest (MPa . day)
NI	12.7 a	28.9 a	41.6 a
DIv	3.9 b	15.6 b	19.4 b
DIh	3.0 b	7.6 c	10.6 c
FIv	0.0 c	8.0 c	8.0 cd
FIh	0.0 c	0.1 d	0.1d
Significance	**	**	***

Values having the same letter are not significantly different at $p < 0.05$.

3.5. Relationship between water stress integral and yield components, berry composition and vine growth

Significant correlations were found between the S_ψ, yield components and berry composition (table 2). Berry weight and yield presented higly significant correlations with S_ψ independently of the period considered. Juice sugar content and titratable acidity showed a negative correlation with the S_ψ but the correlation coeficients were not significatives. Juice pH presented a significantly positive correlation with the intensity of S_ψ experienced during the ripening period.

The skin concentration of anthocyanins and phenolics presented a significantly positive dependence from the S_ψ in all the periods, being the higher correlation coeficients observed at the period bloom-veraison.

The vegetative growth parameters showed also significant correlations with the intensity of S_ψ experienced during all periods. The higher correlation coefficients were presented by the main leaf area at veraison (negative correlation) and the percentage of leaf senescence at veraison (positive correlation).

In order to quantify the relative importance of water stress in the different periods a multiple regression analysis was conducted with three independent variables: S_ψ bloom-veraison, S_ψ veraison-harvest and S_ψ bloom-harvest. The results show that the S_ψ in the period bloom-veraison has a higher contribution to explain the variation in berry weight, anthocyanins and phenolics concentration than the S_ψ in the period veraison-harvest (Fig. 2).

Table 2

Correlation coefficients between the integral of predawn leaf water potential (S_ψ, MPa. day), and yield components, berry composition and vegetative growth, measured in Tempranillo grapevines. (n =10)

Tableau 2

Coefficients de corrélation entre l'intégral du potentiel hydrique de base et les composants du rendement, la composition du raisin et les paramètres de croissance végétative mesurés en 1999 sur le cépage Tempranillo.

VARIABLE	S_ψ bloom-veraison	S_ψ veraison-harvest	S_ψ bloom-harvest
berry weight	-0.87***	-0.84**	-0.86***
yield	-0.86**	-0.84**	-0.86***
juice sugar content	-0.28 ns	-0.46 ns	-0.41 ns
titratable acidity	-0.49 ns	-0.52 ns	-0.51ns
juice pH	0.57 ns	0.68*	0.65*
skin anthocyanins	0.75*	0.68*	0.71*
skin total phenolics	0.86***	0.83**	0.85**
main leaf area (veraison)	-0.80**	-0.79**	-0.80**
senescent leaf area (% at veraison)	0.95***	0.86***	0.90***
senescent leaf area (% at harvest)	0.54 ns	0.76*	0.70*
secondary leaf area (harvest)	-0.47 ns	-0.50 ns	-0.50 ns
pruning weight	-0.64*	-0.67*	-0.67*

ns, *, **, *** - non-significant and significant at 5%, 1% and 0.1% levels, respectively.

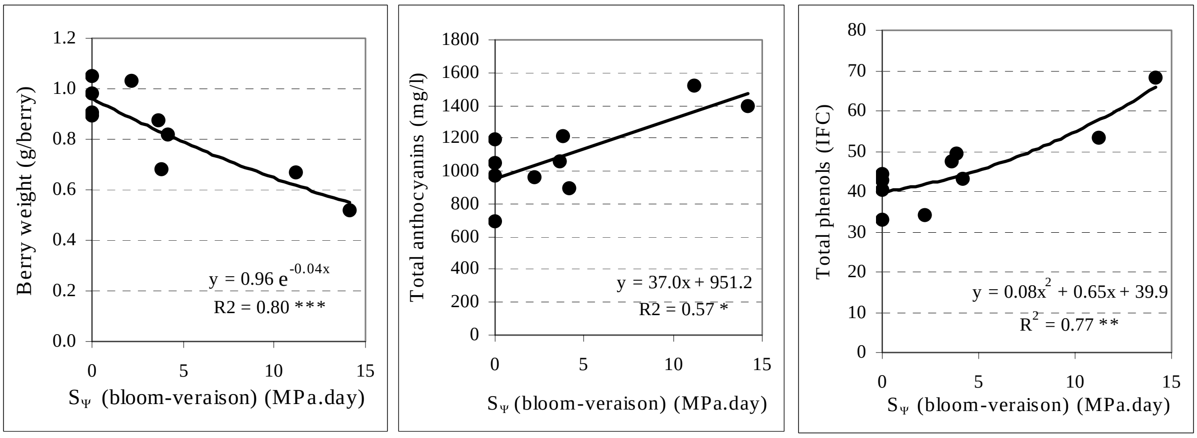

Figure 2

Regression analysis between the integral of predawn leaf water potential (S_ψ), in the period bloom-veraison and berry weight, anthocyanins and phenols concentration of the berry skin, measured on Tempranillo grapevines.

Figure 2

Analyse de régression entre l'intégral du potentiel hydrique de base (S_ψ) au cours de la période floraison-véraison et le poids de la baie et la concentration en anthocyanes et phénols mesurés sur le cépage Tempranillo.

4- DISCUSSION

The significant correlations found in our study clearly demonstrate the strong influence of the degree of water stress on growth, yield and berry composition. Similar results were obtained by Ginestar *et al* (1998 a,b) for cultivar Shiraz at South Australia.

The negative dependence of berry weight and yield from S_ψ during the period bloom/veraison shows the importance of the early water deficits on berry growth (Matthews & Anderson, 1989). Nevertheless, this effect, when not to severe, could be beneficial for red wine quality as a consequence of the increase on the skin/pulp ratio as berry weight decreases.

The positive relationship between S_ψ and the anthocyanins and phenolics concentrations appears to be a consequence of the indirect effects of the water stress on cluster exposure, by leaf senescence, and in the skin/pulp ratio, by berry growth. Furthermore, the higher contribution of the S_ψ in the period bloom-veraison to explain the variation in anthocyanins and phenolics concentration indicates that the degree of water stress experienced before veraison has an important role on the development of berry colour.

Vegetative growth, which is much more sensitive to water stress than the reproductive growth (Williams & Matthews, 1990), showed also significant dependence from the S_ψ, being the positive correlation with leaf senescence at veraison, one of the most important responses of the grapevine to water stress that influences the source size and the cluster microclimate for the ripening period.

Predawn leaf water potential values, when integrated along the season, seem to be a valuable tool for quantifing the degree of water stress experienced by the vines. The relationships presented, together with the relationship between available soil water content and predawn leaf water potential (Lopes *et al*, 1999), may allow the adequate management of soil water availability and irrigation schedule to optimise the yield/quality ratio for each ecological situation.

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LITERATURE CITED

CHAVES; M.M. & RODRIGUES, M.L. 1987. Photosynthesis and water relations in grapevines-response to environmental factors. In: *Plant response to stress-Functional analysis in mediterranean Ecosystems.* J. D. Tenhunen, F.M. Catarino, O.L. Lange &W.C.Oechel,eds. Springer -Verlag. Berlim,pp. 379-390.

GINESTAR, C.; EASTHAM, J.; GRAY, S.; ILAND, P., 1998b. Use of sap-flow sensors to schedule vineyard irrigation. II Effects of pos-veraison water deficits on composition of Shiraz grapes. *Am. J. Enol. Vitic.* 49(4), 421-428.

GINESTAR, C.; EASTHAM, J.; ILAND, P., 1998a. Use of sap-flow sensors to schedule vineyard irrigation. I Effects of pos-veraison water deficits on water relations, vine growth and yield of Shiraz grapevines. *Am. J. Enol. Vitic.* 49(4), 413-420.

LOPES, C.; VICENTE-PAULO, J.; PACHECO, C.; TAVARES, S.; BARROSO, J.; RODRIGUES, M. L.; CHAVES, M.M., 1999. Relationships between leaf water potential and photosynthetic activity of field grapevines grown under different soil water regimes. *11^th Meeting GESCO*, Univ. Degli Studi di Palermo, Palermo, Italy, 211-217.

MATTEWS, M.A. & ANDERSON, M.M., 1989. Reproductive development in grape (*Vitis vinifera* L.): responses to seasonal water deficits. *Am. J. Enol. Vitic.*, **40**: 52-60.

MYERS, B.J. (1988). Water stress integral - a link between short-term stress and long-term growth. Tree Physiology: 4:315-323.

RODRIGUES, M.L., CHAVES, M.M., WENDLER,R., DAVID,M.M.,QUICK, P., LEEGOOD, R., STITT, M. & PEREIRA, J.S., 1993. Osmotic adjustment in water stressed grapevine leaves in relation to carbon assimilation. *Australian Journal of Plant Physiology*, **20**, 309-321.

TURNER, N.C., 1986. Crop water deficits: a decade of progress. *Adv. Agron.* 39, 1-51.

WILLIAMS, L.E. & MATTEWS, M.A., 1990. Grapevine. **In** *Irrigation of Agricultural Crops*. Nº 30 in the Series of Agronomy, Madison, Wisconsin USA. 1019-1055.