The Rate of Water Loss in Relation to Internodes Position and Wood Maturity in Canes of the Grapevine

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Abstract

The purpose of study was to assess the rate of water loss from the canes of the grapevine of vines in relation to internodes position on vine chords and degree of wood maturity. The biological material was represented by grape cultivar Burgund mare, to which were analyzed individually all internodes distributed on the chord length (internodes number IN_{2-19}). The rate of water loss and associated parameters (maximum rate of water loss - RWL_{Max} , total drying time - T , time to achieve RWL_{Max} - $t_{RWL_{Max}}$) were determined from the Burgund mare vine cultivar, in controlled condition. Parameters studied were associated with dry matter content (refractometric method), degree of maturity of the wood, and internodes positions on chord. RWL_{Max} had higher values in the basal internodes (IN_2 ; $RWL_{Max} = 0.252 \pm 0.005$ g/min) and lower in the apical internodes (IN_{17-19} ; $RWL_{Max} = 0.202 \pm 0.011$ g/min). RWL_{Max} distributions values, according to the position of internodes on cane was described by a third degree polynomial function, statistical safety ($R^2 = 0.949$, $p < 0.01$). Dry substance content in internodes (sugar) was correlated with the total time of water loss (T ; $R^2 = 0.945$), the time to reach the maximum rate of water loss ($t_{RWL_{Max}}$; $R^2 = 0.855$), and maximum rate of water loss (RWL_{Max} ; $R^2 = 0.984$).

Keywords: cane, rate of water loss, sugars, vine, wood maturation

INTRODUCTION

Water regimes in vines have been studied in relation to various biological, technological, and environmental factors. The specificity of vines cultivars in relation to water use (isohydric and anisohydric cultivars) determines different efficiency of water use, photosynthetic rates and variable tolerance to water stress (Rogiers *et al.*, 2011; Hugalde and Vila, 2014). Aspects of hydration level and water loss from leave and shoots or stem on vines were studied in relation to the moment of harvesting, the degree of vine defoliation and time (Nicoletti *et al.*, 2013).

Hochberg *et al.* (2013) based on their studies, found that isohidric vine cultivars presents higher

photosynthetic efficiency and respiration rate in water stress conditions compared to anisohidric cultivars. McCarthy *et al.* (2006) and Gerzon *et al.* (2015) have found that the “Shiraz” cultivar presented a more vigorous response to water deficit, which was manifested by a process of vegetative growth and defoliation slightly lower compared with “Grenache” cultivar. Analysis of anatomical architecture of the two vines cultivars, showed that “Grenache” have a larger diameter of conductive vessels (xylem), greater hydraulic conductivity and greater density of stomata than “Shiraz” (Schultz, 2003; Gerzon *et al.*, 2015). It was considered that isohidric and anisohidric strategies may not be the result of distinct mechanisms, but

rather a response, an adaptation of plants well defined in time. Soar *et al.* (2006) studying the two cultivars ("Shiraz" and "Grenache"), in terms of vapor pressure deficit (VPD), they found that the physiology of abscisic acid (ABA) is the key of contrasting responses between the two cultivars, being regarded as an genes expression in the leaves, but not in the roots.

Differentiated nutrition and water regime of the grapevine, on the constant background of soil and technological conditions, have led differentiated accumulation of dry matter and minerals in Burgund mare cultivar canes (Sala and Blidariu, 2012). Within some studies under irrigated conditions, Peacock (1998) found that low to moderate water stress level, achieved by controlled level of watering, had a positive effect for stopping the growth of shoots and maturation of wood on vines, and El-Gendy (2002) observed that excessive watering caused significant reduction in wood maturation in vine canes.

Developing methods for assessing the hydration status of plant and evapotranspiration level, it was considered to be necessary and useful for anticipating need for irrigation, in relationship to climatic conditions (Ferrari *et al.*, 2015). They considered that a large part of understanding the processes of gas exchange and water were realized on the basis of foliar level studies, and extrapolating the results to the whole plant being difficult and not always accurate. In order to overcome this limitation, and increasing the safety of studies, they proposed and used a study chamber to measure the gas exchange in the whole plant under, high evapotranspiration conditions and extended period of time.

Canes maturation is an important aspect in the biological cycle of the vine, so for winter hardiness and canes quality for pruning fructifying for the maturation of buds or for the quality of the biological material for multiplying by cuttings (Rogiers *et al.*, 2000). Wood maturation in canes, and consequently resistance to wintering and frost, and the viability of buds, has been associated with the specificity of biological material, being well known, varieties and local populations with of woodcanes ripening and high frost resistance, compared to others more sensitive, in similar vegetation conditions (Dobrei *et al.*, 2015). Sugar content was the most frequently studied in grapes and other horticultural species, according

to carbohydrate metabolism in plants (Wu *et al.*, 2011), the relation of vine with soil, climate and technological factors (Jivan and Sala, 2014), production quality and wine processes (Dobrei *et al.*, 2010, 2016; Blidariu *et al.*, 2013), but equally important is the sugar content of the canes for the maturation of wood, winter hardiness, viability of buds and quality of chords for reproductive biological material (Rogiers *et al.*, 2010; Smith *et al.*, 2010).

In this study, evaluation of the loss of water was carried out under controlled conditions with a thermobalance in the infrared, in order to assess water loss parameters in correlation with the average content of dry substance (sugar) and the degree of maturation of the canes.

MATERIAL AND METHOD

The purpose of study was to assess the rate of water loss from the canes of vines in relation to internodes position on vine canes and degree of wood maturity.

The biological material was represented by Burgund mare vine cultivar. Samples were taken from the vine experimental plots of BUSAMV Timisoara. The canes were analyzed over the entire length (19 internodes; IN_{2-19}), from each internode being extracted samples, which have been subjected to drying under controlled conditions. The rate of water loss, and associated parameters, was made with a infrared thermobalance (AXIS, ATS 60 Model), with an accuracy of $\pm 0.001g$.

The rate of water loss and associated parameters (maximum rate of water loss - RWL_{Max} , total drying time - T , time to achieve RWL_{Max} - $t_{RWL_{Max}}$) were determined from the Burgund mare vine cultivar, in controlled condition. Parameters studied were associated with dry matter content (determined by refractometry method), degree of maturity of the wood, and internodes positions on canes.

The experimental results were analyzed by the ANOVA test for assessing overall statistical data, in terms of safety. To assess the interdependence of the studied parameters was used correlation and regression analysis (Excel package, Office 2007 Suite). Grouping of internodes in relation to the studied parameters, based on Euclidean distances and of the degree of similarity of the results generated, was performed by clusters analysis with PAST software (Hammer *et al.*, 2001).

Tab. 1. Values of dry matter, moisture, drying time and the rate of water loss from the vine canes by group of internodes in Burgund mare cultivar

Internodes grup	DM (%)	M (%)	T (s)	RWL _{med} (g/min)	RWL _{Max} (g/min)	t _{RWLMax} (s)
IN ₂	12.47±0.16	45.32±0.28	1060±19.03	0.07375±0.0071	0.252±0.005	90±0.55
IN ₃₋₄	12.35±0.13	46.43±0.08	1110±10.02	0.06979±0.0062	0.249±0.021	80±0.43
IN ₅₋₆	12.19±0.15	46.51±0.32	1065±5.04	0.06579±0.0013	0.249±0.009	70±0.47
IN ₇₋₁₆	11.91±0.09	47.88±0.19	977±12.83	0.06479±0.0015	0.233±0.006	60±0.38
IN ₁₇₋₁₉	10.37±0.11	49.38±0.31	857±20.27	0.05916±0.0028	0.202±0.011	50±0.26

DM – dry matter (carbohydrates); M – moisture; T – total drying time; RWL_{med} – the average water loss; RWL_{Max} – maximum rate of water loss; t_{RWLMax} – time to achieve RWL_{Max}; IN₂ ... IN₁₇₋₁₉ – internodes number on vine chord.

Tab. 2. ANOVA test single factor

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	13235063	4	3308766	2491.781	3.46E-87	5.091526
Within Groups	112869.1	85	1327.872			
Total	13347932	89				

Alpha = 0.001

Tab. 3. Matrix table of correlations between parameters studied in the internodes of vine canes

	DM	M	Tt	RWL _{med}	t _{RWLMax}	RWL _{Max}
DM		6.53E-05	9.38E-06	0.016654	0.000183	0.002449
M	-0.801		2.76E-09	0.00816	1.75E-06	0.006675
Tt	0.847	-0.947		0.009432	2.90E-05	0.002805
RWL _{med}	0.556	-0.602	0.593		8.13E-03	6.29E-08
t _{RWLMax}	0.770	-0.877	0.822	0.603		0.010376
RWL _{Max}	0.668	-0.614	0.661	0.920	0.587	

RESULTS AND DISCUSSION

Parameters for water loss from the vine canes (rate of water loss - RWL, the time to reach maximum rate of water loss - t_{RWLMax}, and the total time of drying - T) had specific variations in relation to the position internodes on canes. The degree of accumulation of dry matter sugarcane internodes, and thus, the woodcanes in basal positions had a better ripening compared to the woodcanes in middle and end position, experimental results being presented in Tab. 1. ANOVA test indicated the existence of single factor variability in the experimental data, analyzed according to the internodes chord distribution (IN₂ - IN₁₉), Tab. 2. Correlative statistical analysis of experimental data showed the existence of negative correlation of the parameters of rate of

water loss with moisture and positive between them, with different level of significance, Tab. 3.

Time to achieve maximum rate of water loss (t_{RWLMax}) in relation to the internodes position on vine canes, had higher values in basal internodes and lower values for apical internodes, distribution of this parameter being described by a third-degree polynomial function (equation 1), safely statistics (R² = 0.949, p < 0.01). Less time to achieve RWL_{Max}, expresses a quicker loss of water from plant material of the vine internodes studied.

$$t_{RWLMax} = -0.0312x^3 + 1.0182x^2 - 11.154x + 100.75 \quad (1)$$

where: x – internodes number (IN = 2 to 19).

Multiparameter analysis, based on Euclidean distances, facilitated internodes grouping depen-

Fig. 1. Grouping clusters of vine internodes based on Euclidean distances, depending on the parameters RWL_{Max} and $t_{RWL_{Max}}$ (Burgund mare cultivar)

ding on the values of the parameters analyzed (RWL_{max} and $t_{RWL_{Max}}$) in two clusters with five subclusters, Fig. 1, safely statistics (Cophenetic index = 0.906).

For each group of internodes, of the five subclusters they were calculated functions that describe the rate of loss of water from the segments of the canes, depending on the time to achieve RWL_{Max} , equations (2) – (6).

For basal internodes, from the first two subclusters C_1 (IN_2) and C_2 (IN_3, IN_4), the rate of water loss according to the time until the RWL_{Max} has been described by polynomial functions of degree three in the statistical safe; C_1 : $R^2 = 0.997$, $p < 0.01$, equation (2); C_2 : $R^2 = 0.992$, $p < 0.001$, equation (3).

For internodes from subclusters C_3 (IN_5, IN_6), C_4 ($IN_7 - IN_{16}$) and C_5 ($IN_{17} - IN_{19}$), the rate of water loss in relation to time, until the RWL_{Max} , was described by polynomial functions of order four, also safely statistics; C_3 : $R^2 = 0.998$, $p < 0.01$, equation (4); C_4 : $R^2 = 0.998$, $p < 0.01$, equation (5); C_5 : $R^2 = 0.996$, $p < 0.01$, equation (6).

Graphic distributions of curves, that express momentary values of RWL , until the RWL_{Max} , are represented in Fig. 2.

$$y_{C1} = -0.0001x^3 - 0.0005x^2 + 0.0469x - 0.0196 \quad (2)$$

$$y_{C2} = -0.0003x^3 + 0.0008x^2 + 0.0455x - 0.0225 \quad (3)$$

$$y_{C3} = 0.0002x^4 - 0.0043x^3 + 0.0294x^2 - 0.0221x + 0.028 \quad (4)$$

$$y_{C4} = 0.0002x^4 - 0.0038x^3 + 0.0223x^2 + 0.0004x + 0.008 \quad (5)$$

$$y_{C5} = 0.0001x^4 - 0.0021x^3 + 0.0071x^2 + 0.0428x - 0.0187 \quad (6)$$

where: y – rate of water loss (RWL) until reaching RWL_{Max} ;
 x – time.

From analysis of the obtained functions, equations (2) – (6), and from graphically distribution (Fig. 2), was found a variable time to achieve RWL_{Max} and different values of the intensity of this parameter.

The largest time to reach RWL_{Max} was recorded at basal internode IN_2 (90 seconds), afterwards

Fig. 2. Graphic distributions of RWL and RWL_{Max} in relation with time

Fig. 3. 3D distribution of time to achieve RWL_{Max} , depending on the humidity and RWL_{Max} values in vine canes, Burgund mare cultivar

at the internodes $IN_3 - IN_4$ (80 seconds), and internodes $IN_5 - IN_6$ (70 seconds).

At the internodes with the middle position on cane chord, $IN_7 - IN_{16}$, $t_{RWL_{Max}}$ parameter had 60-70 seconds, and the shortest time to reach RWL_{Max} (50 seconds) was recorded at terminals internodes ($IN_{17} - IN_{19}$). 3D distribution of $t_{RWL_{Max}}$ parameter values is shown in Fig. 3.

Differentiated values for the total time of water loss (T), the time to reach the maximum rate of water loss ($t_{RWL_{Max}}$), and the maximum rate of water loss (RWL_{Max}), were correlated with the average content of dry matter (sugars) content from internodes, grouped into the five clusters.

Carbohydrate content had average values of: 12.47% in the second internode (IN_2); 12.35% in

internodes 3 and 4 (IN_{3-4}); 12.19% by internodes 5 and 6 (IN_{5-6}); 11.91% by internodes 7 to 16 (IN_{7-16}) and 10.37% in the internodes 17 to 19 (IN_{17-19}).

Among the studied parameters (DM , M , T , RWL_{Max} , RWL_{med} , and t_{RWLMax}) were found interdependencies. High correlations were found between dry matter and moisture ($r = -0.801$), dry matter and total drying time, respectively ($r = 0.847$). Average correlations were found between dry matter and t_{RWLMax} ($r = 0.770$), and RWL_{Max} respectively ($r = 0.668$). Low correlations were found between dry matter and RWL_{med} ($r = 0.556$). The specific parameters of weight loss rates were correlated with moisture, and based on direct and indirect relations of interdependence, the dry matter influenced water regime in vine canes.

The variation of carbohydrates in plants (leaves) in relation to water regime in plants, especially as an adaptation to water and temperature stress conditions, was also highlighted in other studies (David *et al.*, 1998).

This indicates indirectly the maturation of wood and maturity and vigor of basal buds in relation to the apical, on the canes length. This has practical importance for frost resistance, cane pruning and crop regulation (Dobrei *et al.*, 2015).

Another important aspect is related to the use of canes for vine propagation by classical techniques (by cuttings), by hydroponic or aeroponic techniques systems (Maroya *et al.*, 2014) and by grafting. Basal internodes and buds have a higher vigor, followed by ones with middle placement on the canes length, the terminal buds having a weaker vigor.

Viability of the buds (from perspective of fruition cutting, and for reproductive material of vine), is also in relation with sugarcane content, content of minerals elements from chord, the degree of cane maturation, and indirect with the canes water content, elements influenced by variety, technology of crop and climatic conditions (Ciobanu *et al.*, 2010; Smith *et al.*, 2010; Sala and Blidariu, 2012; Dobrei *et al.*, 2009, 2015).

The maturation of vine canes is an important aspect in the biological cycle of the vine, for winter resistance, and for quality of canes pruning, and for the quality of the biological material for propagation by cuttings (Rogiers *et al.*, 2000).

This study showed the variation of parameters for weight loss in internodes of vine, Burgund mare cultivar, in relation to placing them on the

chord length, values which were correlated with sugar content and degree of maturity of the wood in the canes.

CONCLUSIONS

The parameters, which expressing the water regime in vine cane (RWL_{med} , RWL_{Max} , T and t_{RWLMax}) showed differentiated values in relation to internodes positioning on cane length.

Sugarcane content varied downwards from the base toward termination of chord, correlated by the regime of water loss parameters, and the degree of wood maturation.

Complex analysis of experimental data (multi-parameter analysis based on Euclidean distances) facilitated grouping internodes function of the parameters analyzed (RWL_{Max} and t_{RWLMax}), in two clusters with five subclusters, safely statistics (Cophenetic index = 0.906), basal internodes showing quality indices in relation to the life cycle of the vine, and practical interest for the vine propagation and maintenance of the plantation.

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