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WATER STATUS OF A CHARDONNAY VINEYARD AND ITS RELATION TO THE YIELD AND GRAPE QUALITY[1]

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ABSTRACT

The water availability is one of the most important environmental resources for yield and quality of the grapes. Although water is an abundant resource especially in Pinto Bandeira region whose rain annual depth is high, due to soil characteristics as shallow depth with waterproof horizons near the surface, the water may not be available sometimes among the year (short droughts), which often coincide with the sensible phenological periods of greatest grape water requirement. This study aimed to achieve accurate information regarding Chardonnay vineyard water requirement in Pinto Bandeira, RS, soil water potential through studies of soil water storage capacity and its relationships to yield and quality of the vines. The characteristics of soil water storage capacity and water loss of vineyard, especially by evapotranspiration, should be analyzed together for an adequate definition of the vineyard's water status and its relation to the grape yield and quality. Another important point is that there is considerable variability of water requirement in the same vineyard and this variability increases with topographic irregularity.

KEYWORDS: *Vitis vinifera* L., irrigation management, Denomination of Origin (DO)

STATUS HÍDRICO DE UM VINHEDO CHARDONNAY E SUA RELAÇÃO COM OS ASPECTOS PRODUTIVOS E DE QUALIDADE DA UVA

RESUMO

A disponibilidade hídrica é um dos fatores ambientais mais importantes para a definição do rendimento e da qualidade da uva. A água, ainda que seja um recurso abundante, especialmente na região de Pinto Bandeira, RS, cujos índices pluviométricos são elevados, devido às características de solos (pouco profundos, com horizontes impermeáveis próximo à superfície) encontrados na região, pode não estar disponível em determinadas épocas do ano (estiagens),

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as quais, frequentemente coincidem com os períodos fenológicos de maior necessidade hídrica. O presente estudo visou a obtenção de informações precisas sobre a demanda de água de um vinhedo Chardonnay em Pinto Bandeira-RS, o potencial hídrico do solo por meio de estudos de capacidade de armazenamento de água no solo e suas relações na produção e qualidade de videiras. As características de capacidade de armazenamento de água no solo e a perda de água do vinhedo especialmente por evapotranspiração devem ser analisadas em conjunto para uma definição adequada do status hídrico do vinhedo e sua relação na produtividade e qualidade das uvas. Outro aspecto é que existe uma variabilidade considerável de demanda hídrica num mesmo vinhedo e que deve ser considerada.

PALAVRAS-CHAVE: *Vitis vinifera* L., manejo da irrigação, denominação de origem

INTRODUCTION

The water availability is one of the most important environmental resources for yield and quality of the grapes (Ojeda, 2007). Although water is an abundant resource especially in Pinto Bandeira region whose rain annual depth is high, due to soil characteristics as shallow depth with waterproof horizons near the surface, the water may not be available sometimes among the year (short droughts), which often coincide with the sensible phenological periods of greatest grape water requirement. Terroir effect is a result of environmental stress and depends more on soil depth than on soil type (Coipel et al., 2006)

It is acknowledged that a range of environmental constraints may restrict vigour and yield and thereby enhance the winemaking potential of the grape (Coipel et al.,2006; Van Leeuwen et al.,2007). Of all these constraints, it is the restriction of water supply that plays the most significant role in vine behaviour and berry composition. A limitation in vine water uptake reduces shoot growth, berry weight and yield and increases berry anthocyanin and tannin content (Hardie and Considine, 1976; Matthews and Anderson, 1988; Matthews and Anderson, 1989; van Leeuwen and Seguin, 1994; Koundouras et al., 2006). The effect of water deficit stress on berry sugar content is yield-dependent; for low yields, vine water deficit enhances berry sugar content and for high yields, it depresses berry sugar content (Tregoatet al.,2002). In temperate climates, water deficit conditions are necessary to produce high quality red wine (Seguin, 1986). However, excessive water deficit stress may lead to yield and quality losses (Ojeda et al., 2002). Vine water status is dependent on soil and climate characteristics (van Leeuwen et al., 2004). Soil influences vine water status through its water-holding capacity. Climate acts on vine water status through rainfall and Reference Crop Evapotranspiration (ETo). Vines can be dry farmed or irrigated. Full irrigation increases yield but is detrimental for quality. Deficit irrigation strategies have been developed to produce high quality wines while limiting yield losses through severe water stress (Dry et al.,2001). Deficit irrigation also allows increasing water use efficiency compared to full irrigation. In rainfall regions as in "Serra Gaucha" in Southern Brazil, irrigation is applied to supplement rainfall depths in an atypicals years by short scarcity rainfall periods among the year.

Vine water uptake conditions can be assessed through (i) soil water monitoring by soil water moisture sensors (Nadal and Arola, 1995; Hanson et al., 2000; Seguin, 1986; Koundouras et al., 1999, (ii) water balance modelling (Lebon et al., 2003; Pellegrino et al., 2006) and (iii) the use of physiological indicators (van Leeuwen et al., 2001; Jones, 2004; Cifre et al.,2005). The vine water requirement can be assessed through (i) measured by the mass transfer or the energy balance method (Allen et., 1998), (ii) derived from studies of the soil water balance determined from cropped fields or from lysimeters (Allen et., 1998) and (iii) derived from meteorological and crop data by means of the Penman-Monteith equation (Allen et al., 1998).

In this article, precise data are presented about the impact of water status on vine development, yield parameters and grape quality. Methods for assessing vine water status and possible applications for water management in vineyards also are discussed.

MATERIAL AND METHODS

1. Experimental plot

The experimental plot selected was *Vitis vinifera* cv. Chardonnay chosen among existing dry-farmed blocks in a 7 year-commercial vineyard in the Geisse Winery, “Serra Gaúcha” region (29°09'01”S; 51°25'38”W) and 740m above sea level. Soil texture of the 1.6 ha-selected-vineyard was silty clay loam (Table 1) with a 0.5 m maximum depth, medium water infiltration rate and water table within the reach of the roots. Soil water-holding capacity were taken according Richards (1965) among 6 points into the vineyard.

Table 1. Soil physical-analysis of the experimental vineyard: field capacity (FC), permanent wilting point (PWP), availability of water (AW), bulk density (BD), density of solids (PD), total porosity (TP), % sandy, % silt, % clay and soil textural classification. Bento Gonçalves, RS, Brazil.

Soil Deph	FC[1]	PWP[2]	AW	BD	PD	PT	Frações granulométricas			Texture
							Sandy	Silt	Clay	
(m)	($cm^3\ cm^{-3}$)		mm	($g\ cm^{-3}$)		(%)	(%)			
0 – 0.20	0.350	0.280*	14.52	0.98	2,53	61	8	63	29	Silt clay loam
0.20 – 0.40	0.410	0.320	14.49	1.04	2,51	58	8	60	32	

[1] FC- Humidity corresponding to the matric potential (φ_m = 10 kPa); [2] PWP – humidity corresponding to φ_m = 1500 kPa;

Grape Vertical Positioning System Vines were Guyot pruned about July/August and trained with a vertical shoot positioned trellis, with two fixed and two movable wires. Vine density was 4545 vines/ha with 2,2 m row spacing x 1,0 m between plants. Usually phenological phases dates are: budding at the end of August; flowering on middle of October; maturation start in December late or beginning of January and leaf fall on April. This study covers 2016/2017 phenological cycle.

2. Meteorological data

An automatic micrometeorological station was installed on September, 2014 closed to experimental vineyard to take half-hourly air temperature (Celsius), air relative humidity (%), wind speed ($m\ s^{-1}$), solar radiation, Rs ($W\ m^{-2}$) and rainfall (mm). It was used FAO56 approach to net radiation (Rn) and soil heat flux (G) calculations and then reference crop evapotranspiration (ETo) calculation by Penman-Monteith equation (Allen et al., 1998) and actual evapotranspiration (ETc) calculated by multiplying the ETo by a crop coefficient (Kc):

$$ET_c = ET_o\ K_c \qquad (01)$$

where:

ETc crop evapotranspiration [$mm\ d^{-1}$];

ETo reference crop evapotranspiration [$mm\ d^{-1}$];

Kc crop coefficient [dimensionless].

It was used Kc values according to Conceição and Mandelli (2007) who recommend $Kc_{initial}$, Kc_{medium} and Kc_{final} values, respectively, at 0.30; 0.70 and 0.45 for grape vertical positioning system which are according to reported by FAO56 (Allen et al., 1998). Based on 10 years-phenology studies of the Chardonnay variety (Mandelli et al., 2003, it was adopted Kc values mentioned above at the appropriate phenological stages (dates).

3. Soil water moisture measurements and water balance modelling

Soil moisture content was taken periodically to the crop water balance approach (Rolim et al., 1998). The measurements were taken from 0.10m, 0.20m, 0.30m and 0.40m soil depth by PR2/4 Profile Probe used within access tubes inserted into augered holes in the soil to produce optimal contact between the soil and the wall of the access tube.

4. Vine water status

Vine water status was assessed with the pressure chamber technique (Scholander et al., 1965). Stem water potential (Choné et al., 2001) was measured with a pressure chamber in one of the water requirement critical phenological phase. The measurements were taken on exposed and shaded leaves covered with an opaque plastic bag one hour prior to measurement. Each measurement was replicated 6 times, on 6 individual vines.

5. Grape yield and quality

Grape load was determined on 20 vines in the experimental Chardonnay vineyard so as to obtain the average yield per vine. The yield from1.6 ha experimental vineyard was obtained at grape harvest.

As grape quality parameters were analyzed: (i) total soluble solid grape using a digital temperature-compensated refractometer; (ii) total acidity by neutralization of the titratable acids to pH 8.2 with 0.1N sodium hydroxide solution and phenolphthalein as indicator; (iii) pH according to Brasil, 1986; (iv) reducing sugars were quantified by the Lane-Eynon method as described in the Analytical Standards of the Adolfo Lutz Institute (1985) and Official Methods of Analysis of the Association of Official Analytical Chemists (1995); (v) ammoniacal inorganic nitrogen was measured according to Richter, 2008; (vi) readily assailable nitrogen as recommended by Zoecklein, 2001; (vii) proline was read by spectrophotometry (Amerine & Ough, 1980; Zoecklein, 2001).

RESULTS AND DISCUSSION

1. Climate Conditions

Climatic conditions varied considerably during the two seasons analyzed (Table 1). The 2016/2017 season was slightly warmer and slightly drier than 2015/2016 season and compare to 1961-1990 climatological average. This 2016/2017 climatic condition influenced to higher reference evapotranspiration (ET_o) rates compare to 2015/2016 season.

Table 1. Meteorological conditions on 2015/2016 (1) and 2016/2017 (2) Chardonnay phenological stages. Rs – solar radiation; Ta – air mean temperature; RH – air relative humidity; u -wind speed, and ET_o – reference evapotranspiration. Bento Gonçalves, RS, Brazil.

Phenological stage[1]	**Rs ($W\ m^{-2}$)**		**Ta (°C)**		**RH (%)**		**u ($m\ s^{-1}$)**		**ET_o (mm)**	
	1	2	1	2	1	2	1	2	1	2
Pruning (P) to budding (B) – 27 days	115	176	17.1	16.8	76.1	79.9	1.3	1.8	2.01	1.88
B to Full Flowering (FF) – 67 days	199	227	15.3	16.2	87.4	80.2	2.9	1.6	3.15	4.60
FF to beginning of Maturation (BM) – 51 days	246	536	18.8	19.6	87.7	80.3	2.6	2.8	3.30	6.80
BM- Harvest – 26 days	276	370	21.7	22.6	84.5	88.8	2.3	2.2	3.77	5.90
Average /Sum	209	327	18.2	18.8	84	82	2.3	2.1	3.05	4.70

1 - Chardonnay phenological stages: pruning (P) to budding (B) (between Aug 01 to Aug 27); B to full flowering (FF) (between Aug 28 to Nov 02); FF to beginning of maturation (BM) (between Nov 02 to Dec 23) and BM to harvest (H) (Dec 24 to Jan 18).

2. Actual evapotranspiration and crop water balance

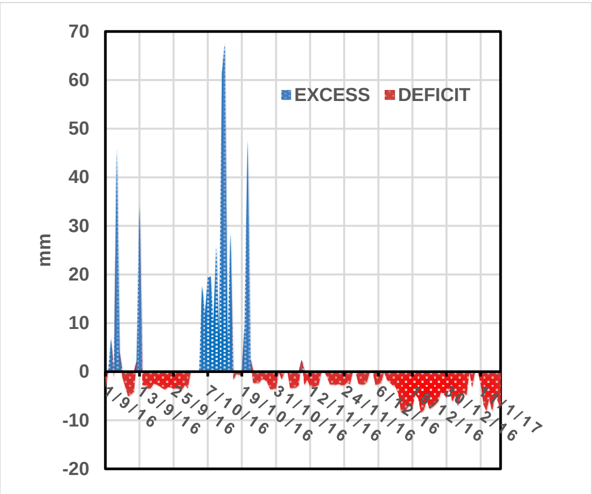
Annual crop evapotranspiration (ET_C) were about half of rainfall in both 2015/2016 and 2016/2017 seasons (Table 2). From beginning of maturation and harvest, ET_c was 52 and 64 mm higher than rainfall, respectively, in 2015/2016 and 2016/2017. ET_c from full flowering (FF) and beginning of maturation (BM) (2016/2017) was 66 mm higher than rainfall.

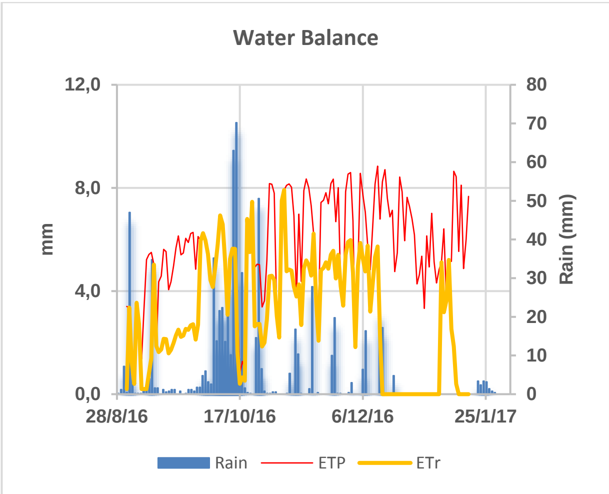
Table 2. Rainfall and Grape evapotranspiration using ET_0 Penman-Monteith method parameterized by FAO-56 and Chardonnay Kc for 2015/2016 and 2016/2017 phenological stages. ETc – crop evapotranspiration (mm dia^{-1}). Bento Gonçalves, RS, Brazil.

Phenological stage[1]	Accumulated ETc/Rain (mm)			
	Geisse Winery – Pinto Bandeira, RS			
	2015/2016		2016/2017	
	ET_c	Rain	ET_c	Rain
Pruning (P) to budding (B) – 27 days	18	70	35	60
B to Full Flowering (FF) – 67 days	158	608	140	588
FF to begining of Maturation (BM) – 51 days	217	314	223	157
BM- Harvest – 26 days	129	77	79	15
Sum	522	1069	477	820

1 - Chardonnay phenological stages: pruning (P) to budding (B) (between Aug 01 to Aug 27); B to full flowering (FF) (between Aug 28 to Nov 02); FF to beginning of maturation (BM) (between Nov 02 to Dec 23) and BM to harvest (H) (Dec 24 to Jan 18).

The occurrence of water deficit stress during those seasons had a profound effect on the yield. As reference 2014/2015 the yield was 21,829 kg in 1.6 ha experimental vineyard. Already in 2015/2016 it was only 2,717 kg due to the frost event on September 12th, 2015. In 2016/2017 yield was 9,827 kg at the same vineyard which was lower than expected due both frost event on last season but also because the water deficit stress more accentuated on two last grape phenological stages as shown on crop water balance modelling (FF to harvest) (Figure 1). In temperate climates, water deficit conditions are necessary to produce high quality red wine (Seguin, 1986). However, excessive water deficit stress may lead to yield and quality losses (Ojeda et al., 2002).





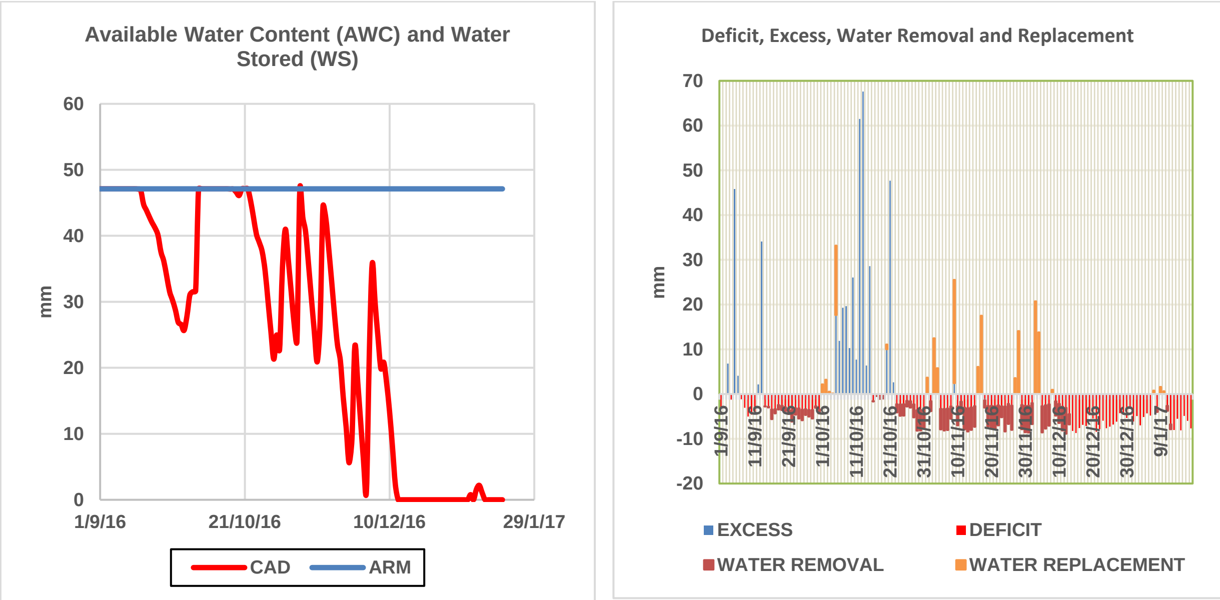


Figure 1. Crop water balance on 2016/2017 Chardonnay phenological stages. Bento Gonçalves, RS, Brazil.

3. Grape quality

The water deficit stress had a slight impact to grape quality (Table 3). The reducing sugars content indicated that the grape has an alcoholic potential of 9.5% mL% (v/v) and can be used for sparkling wines processing. Despite a low pH of 3.2 it favors physical stability, improving clarity and brightness for white wines (Vigara and Amores, 2010). Another quality parameters had shown within the literature range.

Table 3. Grape quality parameters of Chardonnay on 2016/2017 season. Bento Gonçalves, RS, Brazil.

Parameter	Value	Reference
Total soluble solids (°Brix)	17.9	15-17 Giovaninni&Manfroi (2009); 18-19 Meneguzzo (2011)
Reducing sugars content (mg L^{-1}) – alcoholic potential (% ml mL% v/v),	161.9 9.5	9.5-11.5% (v/v) Togores (2011)
pH (dimensionless)	3.2	3.5 – 4.5 Zambonelli (2003) 2.8 – 3.2 Togores (2011)
Total acidity (g L^{-1})	8.29	> 5.5 Togores (2011)
Readily assimilable nitrogen (mg L^{-1})	212.8	> 150 mg L^{-1} to 12% v/v Granés, (2006)
Proline content (mg L^{-1})	176.7	30, 120, 290 e 510 mg L^{-1} Ribereau-Gayon (2007)

CONCLUSIONS

Water deficit stress was detected on 2015/2016 and 2016/2017 seasons. This water deficit had a profound effect on the yield and slightly on grape quality parameters. The water requirements needs a good knowledge of sensible heat flux (H) / net radiation (Rn), soil heat flux (G) / Rn and latent heat flux (LE) / Rn rations which depends of tree vigor. Future improvements (2017/2018 season) will incorporate spatially distributed multispectral and thermal data into the accurate spatial (into the vineyard) and temporal (different grape phenological stages) ET data.

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