PHYSIOLOGICAL RESPONSES OF CRIMSON SEEDLESS (*VITIS VINIFERA*) GRAPEVINES TO ALTERED MICRO CLIMATIC CONDITIONS AND DIFFERENT WATER TREATMENTS IN THE BREEDE RIVER VALLEY OF SOUTH AFRICA

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Abstract:

Context and purpose of the study - Challenging conditions created by limited water supply and changes in the climate require an understanding of the physiological status of table grapes along the whole value chain. This is critical to develop tools for regulatory management of growth balances and grape quality. This study aimed to determine the impact of different amounts of water and an altered micro-climate (complete covering of vineyards with plastic) on the physiological reaction of the grapevine during the growth season.

Material and Methods
Two trials, an open field (OF) trial and a trial underneath overhead plastic covering (OPC), were conducted in a Crimson Seedless / Ramsey vineyard in the Breede River Valley of South Africa. The plastic covering to alter micro climatic conditions was installed after budbreak. The sides of the vineyard remained open. Vines were trained onto a Pergola trellis system, micro-irrigated (32 L/h) and spaced 1.75 m x 3.0 m on a stony loam-sand soil. The trial layout design was a randomised complete block with water regime as main factor and grape ripeness level as split strip-plot factor. Four water treatments were applied from after budbreak until the end of harvest. The treatments included a control treatment (100% water application, calculated using evapotranspiration and crop factor), and respectively 80%, 70%, and 55% less than the control. The water treatments were replicated six times under OF conditions and four times under OPC conditions. Grapes were harvested at three dates. Physiological variables (photosynthetic activity, transpiration rate, stem water potential, and light intensity) were measured from berry set until the end of the harvest period (three harvest dates). Micro climatic variables were measured continuously in the vineyard.

Results –
For OF and OPC, stem water potential (SWP), and the photosynthetic and transpiration rates were decreased by 55% and 70% water compared to 100% water application. For all treatments, the light intensity underneath the OPC was decreased compared to the light conditions in OF conditions. For OF and OPC, light intensity tended to increase when only 70% and 55% water was applied. Relative humidity was increased by OPC and fell well within the optimal relative humidity range of 60 - 70% for photosynthesis.

Keywords - grapevine, physiology, micro-climate, overhead plastic covering

1. Introduction

Table grape production depends highly on irrigation (Chaves *et al*., 2010; Faci *et al*., 2014; Conesa *et al*., 2016). In addition to seasonal cultivation practices that are applied to improve growth balances (Dokoozlian & Hirschfelt, 1995), timing and amount of water application (Thomas *et al*., 2006; Chaves *et al*., 2010; Myburgh, 2012) is key for sustainable yields and acceptable grape quality. Water deficits, especially during the berry growth phase, would reduce yields because of smaller berries (Thomas *et al*., 2006). Water deficit led to reduced rates of photosynthesis (Bertamini *et al*., 2006), stem water potential, and transpiration (Choné *et al*., 2001). It has however also been shown that table grapes subjected to reduced water supply under arid conditions (Faci *et al*., 2014), semi-arid conditions (Myburgh, 2012), as well as Mediterranean conditions (Conesa *et al*., 2015), use less water with little or no impact on yield.

To ultimately recommend a growth balance and grape quality strategy that is focused on sustainable table grape growing, an understanding of grapevine physiological behaviour under different abiotic conditions, such as water supply and climatic changes, is required.

2. Material and methods

An open field (OF) trial and a trial underneath overhead plastic covering (OPC) were conducted in a commercial Crimson Seedless / Ramsey vineyard in the Breede River Valley of South Africa (Robertson, Longitude: 33°47'22.43"S, Latitude: 19°41'04.72"E). The OF trial was conducted for four seasons, from 2019/2020 until 2022/2023 and the OPC trial over two seasons (2021/2022 and 2022/2023). The results of 2021/2022 and 2022/2023 are presented. To alter the micro climatic conditions, vines in the OPC trial were covered after budbreak (in other words for what is generally known as protection), and the sides of the vineyard remained open. Vines were trained onto a Pergola trellis system, micro-irrigated (32 L/h) and spaced 1.75 m x 3.0 m on a stony loam-sand soil. The trial layout design was a randomised complete block with water regime as main factor and grape ripeness level as split strip-plot factor. Four regulated water treatments were applied from after budbreak until the end of harvest. The treatments included W100 (100% water application, calculated using evapotranspiration and crop factor) as a control treatment, W080 (80% less than the control); W070 (70% less than the control), and W055 (55% less than the control). The water treatments started after budbreak and were replicated six times in the OF trial and four times in the OPC trial. Physiological measurements took place bi-weekly from berry set until harvest. Commercial harvest took place at three dates. The harvest dates were selected according to ripeness level (R), as recommended by the Department of Agriculture, Forestry and Fisheries (DAFF, 1990), using total soluble solids (TSS) of 16°Brix as ripeness indicator, where R_1 (First harvest date) = 10% less than the recommended TSS, R_2 (second harvest date) = TSS recommended by DAFF and R_3 (Third harvest date)= 10% higher than the recommended TSS. Physiological variables were measured from berry set until harvest. The effects of the treatments and climatic conditions on photosynthetic activity (Pn), stem water potential (SWP), transpiration rate (T) and light intensity were measured. Micro climatic variables were measured continuously in the vineyard, starting before ripening, until the end of the harvest period. Photosynthetic activity was measured on leaves of the outer layer of the canopy just below the plastic. The light source of the photosynthesis apparatus was used for all measurements and was set at 2000 µmole/m^2/s.

Physiological variables were subjected to analysis of variance (Anova) according to the experimental design, for each trial separately, using GLM (General Linear Models) Procedure of SAS software (Version 9.4; SAS Institute Inc, Cary, USA). The Shapiro-Wilk test was performed to test for deviation from normality (Shapiro, 1965). Fisher's least significant difference (LSD) was calculated at the 5% level to compare means for significant effects (Ott, 1998).

3. Results and discussion

The water treatments affected the photosynthetic (Pn) and transpiration (T) rates of vines in the OF and OPC trials in both seasons. Compared to the OF trial, less pronounced differences were found underneath the OPC. In the OF trial, W080, W070 and W055 tended to decrease Pn (Fig. 1A) and T (Fig. 1C) compared to W100 throughout the growth and ripening season. In the OPC trial, W055 tended to decrease Pn (Fig. 1B) and T (Fig.

1D) mostly during ripening. In general, Pn and T rates were higher underneath OPC compared to OF conditions. The Pn:T ratio tended to be decreased by the W055 treatment in the OF trial and in the OPC trial by W070, compared to W100 (Figs 1E & 1F). Under OF conditions, the Pn:T ratio was higher compared to that underneath OPC.

Stem water potential (SWP) in both trials was decreased by W055, W070 and WW080, compared to W100 (Figs 1G & 1H). Stem water potential seemed to be a good indicator of water deficits experienced by vines that received only 55% or 70% water under OF and OPC conditions. Generally, SWP was higher underneath OPC than under OF conditions. Reduced water application resulted in reduced photosynthetic rates (Bertamini *et al*., 2006), stem water potential, and transpiration rates (Choné *et al*., 2001). The higher transpiration rates underneath OPC may be due to a higher availability of soil water (Choné *et al*., 2001) compared to the OF. The Pn:T ratios showed that the water use efficiency (WUE) was better under OF conditions compared to OPC conditions.

Light intensity for the different treatments in both trials mostly tended to increase with reduced water application (Figs 2A & 2B). In-canopy climatic variables recorded in 20212022 (Table 1) showed how conditions inside the vineyard differed from regional climatic conditions and the conditions on the farm. Temperatures underneath OPC were mostly lower compared to the temperatures for the different treatments in OF conditions; relative humidity was higher compared to OF conditions. The higher humidity, which was consistently between 60% and 70%, was optimal for photosynthesis (Hunter & Bonnardot, 2011) and thus would not have negatively affected photosynthesis. Likewise, although better light conditions would generally affect photosynthetic activity positively, the lower light intensity underneath OPC may not have been detrimental to photosynthesis *per se*, because it was mostly above the compensation point of 15 – 30 µmole/m^2/s (Kriedemann, 1968).

4. Conclusions

The value of stem water potential as indicator of plant water status was confirmed in this study. Reduced water supply resulted in a lower plant water status, regardless of the climatic conditions. In general, vines grown underneath plastic had a higher rate of photosynthesis, water status and transpiration compared to vines grown under OF conditions. Yet, vines grown under OF conditions used water more efficiently. The level of plant reaction to abiotic conditions (water deficit) was increased under overhead plastic cover compared to open field conditions.

5. Acknowledgments

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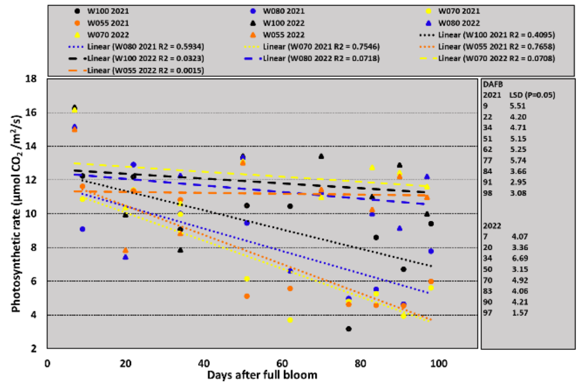
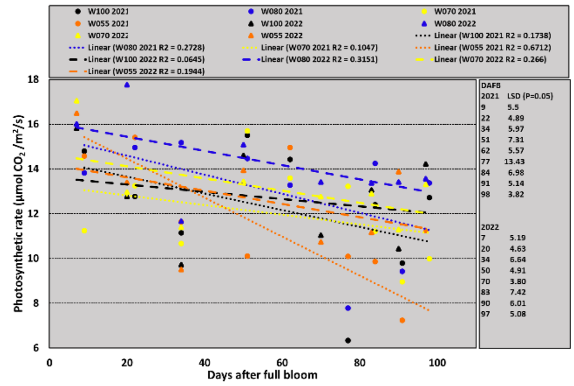


1A



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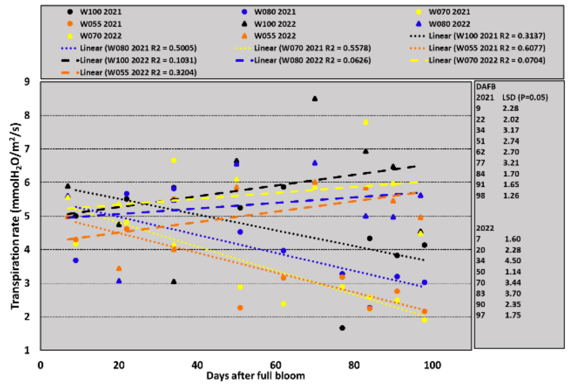

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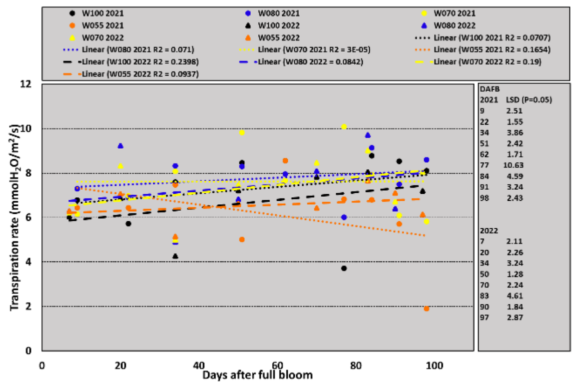

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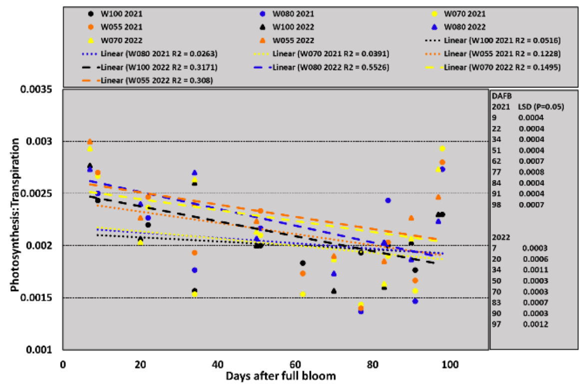

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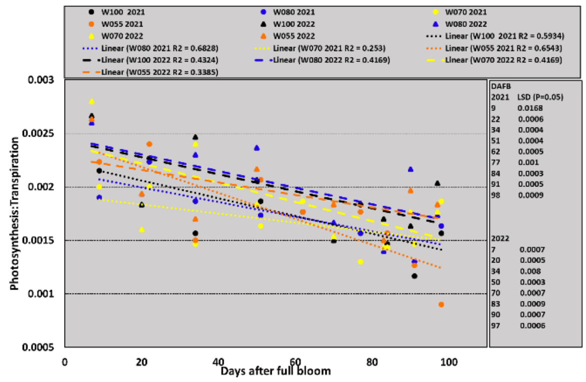
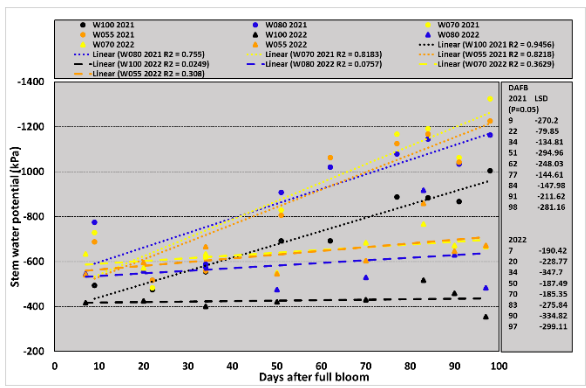
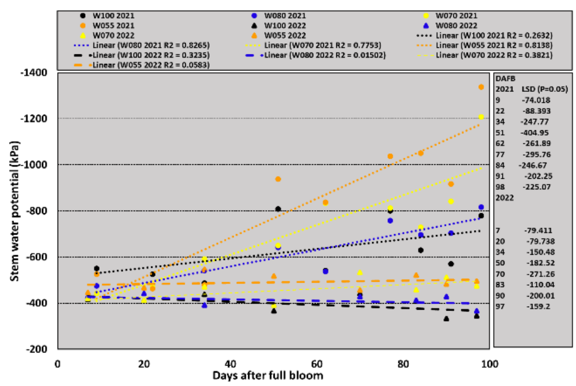


1F



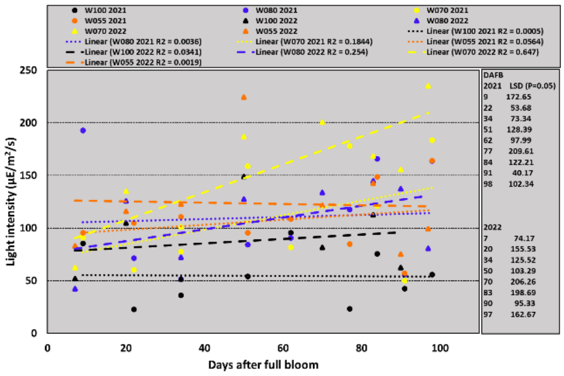
1G

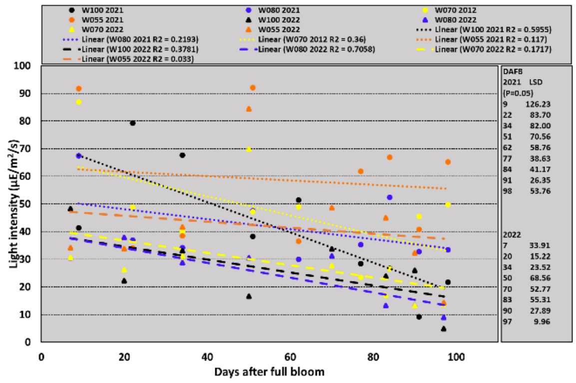


1H

Figure 1. The effect of water treatments on physiological variables of Crimson Seedless vines grown under open field (OF) conditions (left) as well as overhead plastic covering (OPC) (right): Photosynthetic rate OF (1A),

Photosynthetic rate OPC (1B), Transpiration rate OF (1C), Transpiration rate OPC (1D), Photosynthesis (Pn):Transpiration (T) ratio OF (1E), Pn:T OPC (1F), Stem water potential OF (1G) and Stem water potential OPC (1H). W100 = 100% water; W080 = 80% water; W070 = 70% water and W055 = 55% water. Combined data for 20212022 and 20222023 seasons





2A **2B**

Figure 2. The effect of water treatments on light intensity in the bunch zone of Crimson Seedless vines grown under open field (OF) conditions (2A) as well as overhead plastic covering (OPC) (2B) 20212022. W100 = 100% water; W080 = 80% water; W070 = 70% water and W055 = 55% water. Combined data for 20212022 and 20222023 seasons

Table 1. Climatic variables in a Crimson Seedless vineyard grown in open field (OF) and underneath overhead plastic covering (OPC) for the 20212022 season. Macro-climate = climatic conditions in the region, Meso-climate = climatic conditions around the vineyard / on the farm, Micro-climate = climatic conditions in the grapevine canopy and bunch zone. W100 = 100% water; W080 = 80% water; W070 = 70% water and W055 = 55% water.

Date	**Jan 2022**					**Feb 2022**				
Climatic variables	**Macro**	**Meso**	**Water Trt**	**Micro OF**	**Micro OPC**	**Macro**	**Meso**	**Water Trt**	**Micro OF**	**Micro OPC**
T_Ave	25.92	25.71	**W100**	24.57	24.44	25.24	24.95	**W100**	23.84	24.1
			W080	24.37	22.93			**W080**	23.66	22.8
			W070	24.48	23.08			**W070**	23.74	22.94
			W055	24.72	23.2			**W055**	23.93	22.96
RH_Ave	56.16	63.19	**W100**	57.59	60.78	56.03	62.93	**W100**	58.52	62.99
			W080	62.64	65.92			**W080**	63.39	67.49
			W070	55.82	66.02			**W070**	57.02	67.14
			W055	60	61.84			**W055**	61.07	64.3