MANAGEMENT OF GRAPEVINE WATER STATUS WITH THE DSS Vintel® PROVIDES EVIDENCE OF SUSTAINABLE IRRIGATION STRATEGIES WHILE MAINTAINING WINE QUALITY OF PINOT GRIS IN FRIULI-VENEZIA GIULIA REGION, NE ITALY

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Abstract:

Context and purpose of the study - Deficit irrigation strategies can be valuable means to improve grape quality while saving important amounts of water. A simple way to use deficit irrigation can be based on irrigating a vineyard with a determined level of crop evapotranspiration. Using a precise physiological parameter indicating water status, irrigation could be managed to maintain a specific pre-dawn leaf water potential (Ψ_{PD}).

Material and methods - The DSS Vintel® (decision support system) by the French company ITK, was used during the seasons 2021 and 2022 to create three different irrigation regimes in a Pinot gris vineyard at experimental farm "A. Servadei" of the University of Udine. Three treatments were compared: WW, well-watered, where Ψ_{PD} was at -0.2 MPa throughout the season; MS, moderate deficit (flowering-harvest) where Ψ_{PD} was reduced to -0.35 MPa; and, SS, severe deficit, (flowering-harvest) where Ψ_{PD} was at -0.55 MPa. During both seasons, treatments were irrigated based on recommendations by Vintel®; Ψ_{PD} and Ψ_{stem} were measured June-August. From veraison to harvest, grape berry samples were collected in triplicate to observe ripening; at harvest yield parameters were assessed. Wine has been made in both seasons: varietal, fermentative aromas, thiols were analysed (GC-MS). Five months after, sensory characters of the wines were evaluated by an expert panel (only for 2021 wines).

Results - The trends of Ψ_{PD} and Ψ_{stem} were different between the two seasons, and in 2022 both parameters were more correlated than in 2021 with the imposed deficit irrigation strategies. Both MS and SS treatments resulted in a reduction of average cluster weight and yield. In addition, in 2022 cluster number per plant was reduced in SS, possibly indicating a carry-over effect from the previous season. The accumulation of berry soluble solids was reduced in MS and SS treatments, while no effect was recorded on titratable acidity and pH. The aroma profile (only 2021 wines) was slightly impacted by deficit irrigation. Alcohols and esters were increased in MS, but the most important effect was produced on 3SH concentration, which decreased in more challenging SS. The sensory analysis of 2021 wines did not highlight differences among treatments (to be confirmed in the second season). In summary, this trial yielded interesting results concerning the effect of deficit irrigation on yield, grape quality and wine aroma characteristics. MS resulted as the most sustainable strategy since it could maintain aroma characteristics of wines while reducing water use.

Keywords: Grapevine, irrigation, water deficit, Pinot gris, wine quality, sensory evaluation.

1. Introduction

The irrigation deficit strategies rely on results obtained on many different crops grown in mild water deficit, in which the yield of the crop was not affected by the deficit while the quality is improved (Chaves et al., 2010; Costa et al., 2007). The data on irrigation deficit strategies are well consolidated on grapevine, where it has been observed how supply a reduced level of evapotranspiration in summer is sufficient to maintain the yield adequate and improve the grape quality, while the waste of water resources is reduced (Cabral et al., 2022; Chaves et al., 2010; Permanhani et al., 2016). Mild water deficit during maturation stage promotes the synthesis of secondary metabolites utilized by the grapevine to alleviate: the excess of light, the overload of the electronic transport chain, and the decrease of water potential (Gambetta et al., 2020). With grape quality purpose, the compounds of main interest that have been observed to increase are: sugars (Canoura et al., 2018), flavonoids (Castellarin et al., 2007), antioxidant compounds (Salazar-Parra et al., 2012), and volatile aromatic compounds such as terpenoids(Savoi et al., 2016). The increase of these metabolites is associated with a higher concentration in the produced wines, and often with an increase in the final quality (Bonada et al., 2015).

To take advantages of an irrigation deficit strategies, the monitoring of the grapevine water status is crucial.

Soil water status can be monitored with soil moisture sensors, which are commonly used in agriculture (Hardie, 2020). However, soil moisture sensors require to be installed in a representative soil area which is often hard to be found in the field, require a precise knowledge of the roots depth and need to be calibrated to the soil type to offer a precise estimation of the soil moisture (Datta et al., 2018).

A good indicator of the soil water availability is the pre-dawn leaf water potential (Ψ_{PD}) (Savi et al., 2019). Ψ_{PD} is measured during the night, when the lack of transpiration equilibrates the leaf potential with the root/soil potential, giving indications on the soil water availability. Therefore, Ψ_{PD} can be a good parameter to manage irrigation (Taylor et al., 2012), but the evaluation of such parameter with Scholander pressure chamber is time consuming and cannot be performed with hgh frequency. Recently, many attempts were carried out to predict Ψ_{PD} in order to manage the irrigation (Fares et al., 2021; Tosin et al., 2020). In recent years, a decision support system (DSS)named Vintel® (www.itk.fr/en/solutions/vintel) is available for commercial vineyards. The DSS involve several sub-models to calculate water balance and the available soil moisture (ASM) for transpiration. The ration between ASM and the total available water in the soil represent the fraction of transpirable soil water (FTSW), a parameter correlated with Ψ_{PD} (Lebon et al. 2003). Vintel® predicts Ψ_{PD} and so irrigation can be applied in order to maintain a certain condition of plant water status decided base on production or enological goals. In this work, we evaluate the goodness of a Ψ_{PD} prediction model to produce deficits of irrigation, and the effects on the grape quality of these treatments.

2. Material and methods

Experimental conditions

The trial was carried out in the experimental farm of the University of Udine "A. Servadei" in the seasons 2021 and 2022. Three grapevines rows of cultivar Pinot gris (*Vitis vinifera* L.) clone R6 grafted on S.O.4 were selected, and 3 different levels of irrigation between flowering and maturation imposed based on different thresholds of Ψ_{PD} decided before the start of the experiment. Along each row, three plots were selected randomly. The treatments in comparison were: WW, well watered (Ψ_{PD} = -0.2 MPa all along the season); MS, mild water deficit (Ψ_{PD} = -0.2 MPa until flowering, -0.35 MPa from flowering to harvest); and SS, severe water deficit (Ψ_{PD} = -0.2 MPa until flowering, -0.55 MPa from flowering to harvest). During both seasons, the prediction of Vintel® allowed different irrigations from flowering to harvest in order to match the target values of Ψ_{PD}.

Plant and grape measurements, microvinification procedure, GC-MS analysis of aroma compounds and sensory evaluation of wines.

During both seasons, Ψ_{PD} was also measured in the field between 4:30 and 5:30 a.m.; in short, fully expanded (mature) leaves were bagged in cling film, the petiole cut with a razor blade, and the measurement performed with a Scholander–type pressure chamber (©Soil Moisture Co., Santa Barbara, USA). The data of field Ψ_{PD} were used to assess the goodness of the Vintel® model. At maturation, yield parameters were collected on 10 vines per plot and average cluster weight calculated by rating yield and number of clusters. Moreover, berry samples have been detached and basic maturation parameters (total soluble solids, pH and titratable acidity) assessed. The grapes collected from each plot were pressed using a vertical A20 pneumatic press (Grifo Marchetti, Piadena, Italy) and the must was transferred into 10 liter glass carboys. The must was added with 30 g/hL of $K_2S_2O_5$, and immediately after *Saccharomyces bayanus* commercial yeast strain Mycoferm IT07 (Ever, Pramaggiore, Italy) was inoculated to start the fermentation. At the end of fermentation, the wines were racked, and the carboys were tranferred at 4 °C to allow tartaric stabilisation. In december, wines were bottled and stored for chemical and sensory analysis.

The profile of varietal and fermentative aroma compounds was analysed following LLE-GC-MS and SPE-GC-MS mothods, as reported in Voce et al. (2019). A panel of experts, made of enologists, researchers and students, was trained using a mixture of all wines to standardise the evaluation of the different descriptors, and as follows the 9 wines were subdue to the panel in three groups with the three treatments in every group but in a randomised order.

Statistical analysis

Data were processed using one-way ANOVA (p indicated), and when the test was significant the averages were separated using Student Newman Keuls test ($p<0,05$). The model's predictive performanceswas ascertained by evaluating the linear model between the actual *vs* the predicted values of Ψ_{PD}, separately by year and treatment. Principal Component Analysis (PCA) was also performed combining aroma profiles and sensory evaluation, in order to ascertain the overall effect of the treatments applied on the quality of obtained wines.

3. Results and discussion

Simulated vs Measured water potentials differs between 2021 and 2022

The linear regressions between the measured and predicted Ψ_{PD} showed differences between the two seasons. The model better estimated the season 2022 compare to 2021 in terms of determination coefficient (R^2) and angular coefficient (Figure 1). In 2022 the Vintel model underestimates the Ψ_{PD} in the WW and SS treatments and overestimates in MS, however the angular coefficients were between 0.7 and 1.3, indicating a sufficient estimation of Ψ_{PD}. In 2021 the R^2 indicates a poor model estimation of Ψ_{PD}, furthermore, the angular coefficients showed a broader underestimation of Ψ_{PD}. Among the irrigation treatments, the estimates in the WW were in greater agreement between the two years (Figure 1). The angular coefficients in 2021 and 2022 were respectively 1.075 and 0.7435, while in MS and SS the 2021 coefficient was above 2.3. These differences can be due to the meteorological differences between the two seasons.

Although the summer of 2021 was one of the hottest seasons on record in Europe, the 2022 season was hotter and drier than 2021 (figure 2). The reduced winter rainfall in 2022 caused a long period of drought in northern Italy, consistently the lowest values of Ψ_{PD} were measured in 2022. The difference in terms of rainfall could have reduced the consistency of Ψ_{PD} between the two years for the Vintel®model. In the WW treatment, the meteorological differences were less influential, because the water conditions were kept the same. Several study evidences how some species shows a Ψ_{PD} disequilibrium, defined as the differences between the Ψ_{PD} and the soil water potential (Donovan et al., 2003; Kangur et al., 2017). The Ψ_{PD} disequilibrium has been associated with the soil water availability

(Donovan et al., 2001), thus the differences between the two seasons can explain how the model poorly predict Ψ_{PD}, and potentially a direction to further calibrations.

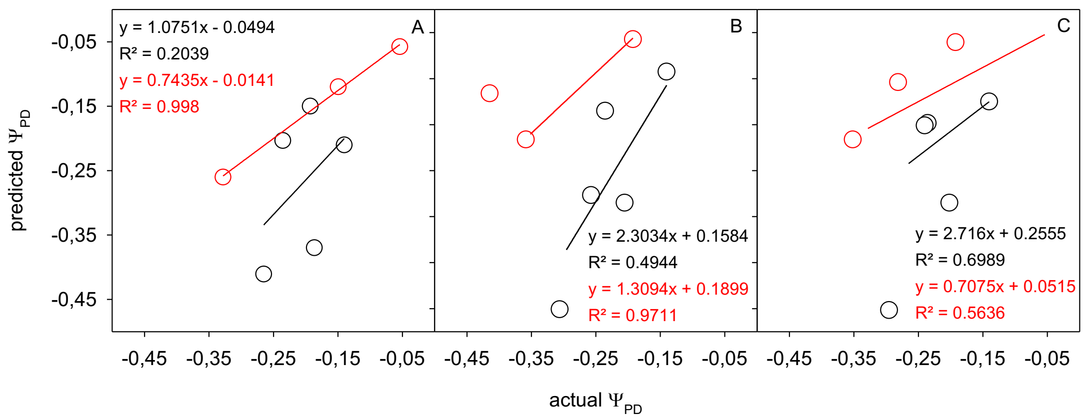

Figure 1. Regression lines of pre-dawn leaf water potential measured in field and predicted with the model for the season 2021 and 2022. The plots are separated for the three irrigation treatments: well watered (A), mild water deficit (B), and severe water deficit (C).

Yield parameters

The irrigation treatments did not significantly affect yield and average cluster weight (Table 1). Furthermore, pH and titratable acidity of the berry also did not differ between treatments in both the seasons. The quantification of TSS was significantly lower in SS treatments compared to WW in both the seasons (Table 1). In the season 2021 this reduction was shown even in case of MS as compared to WW.

Table 1. Measure of: number of cluster, yield, average cluster weight, total soluble solids (TSS), Titratable acidity, and pH, at the harvest time for the season 2021 and 2021. The differences in the treatments: well watered (WW), mild water stress (MS), and severe water stress (SS).were assessed with one way ANOVA followed by pairwise Tukey test with a significance level of $p<0.05$ (*p>0.05 = n.s., p<0.05 = *, p<0.01 = ***).

Year	**Treatment**	**cluster number**	**yield (kg/vine)**	**average cluster weight (g)**	**TSS (°Brix)**	**Titratable acidity (g L-1)**	**pH**
2021	WW	27,81	3,14	116,15	20,17 **a**	5,86	3,37
	MS	26,84	2,76	102,31	18,77 **b**	5,54	3,38
	SS	27,97	2,89	104,66	18,53 **b**	5,64	3,42
	Sign. F	*n.s.*	*n.s.*	*n.s.*	**	*n.s.*	*n.s.*
2022	WW	23,78	3,93	169,22	20,03 **a**	5,50	3,50
	MS	23,11	3,45	151,00	19,77 **a**	4,83	3,52
	SS	19,87	3,11	156,21	18,07 **b**	4,77	3,57
	Sign. F	*n.s.*	*n.s.*	*n.s.*	*	*n.s.*	*n.s.*

Many studies report how soluble solids are accumulated in the berry under water limitation (Canoura et al., 2018;

Marciniak et al., 2013). However, other authors observed a decrease of TSS related to drought condition (Calderan et al., 2021). The *cv.Pinot Gris* is considered to be an isohydric cultivar. The stomatal closure and the consequent reduction of the photosynthetic rate can lead to a reduction in the biosynthesis of sugars and their accumulation in the berries.

*Aromatic composition and sensory analysis*The wine quality was affected by the irrigation treatments in the season 2021. The PCA in figure 2 shows how the sensory analysis and the aromatic compounds separates the treatments. Most of the aromatic compounds quantification were associated with the treatments MS. However, many of the sensory indicators such as: fruit, persistence, bitter, and flowery were associated with the SS treatment, including the overall impression (Figure 2). The treatment WW was instead associated with the sensorial: acidity and herbaceous, and with few aromatic compounds. Water status is widely known to influence the wine quality. However, the influence on the composition of the aromas and on the sensory characteristics are closely linked to the cultivar and to the geographic area, in some cultivars the water scarcity limited the accumulation of aromatic compounds and the sensory characteristics of the wines (Marciniak et al., 2013; van Leeuwen, 2010), while other cultivars were enhanced by drought conditions (Bonada et al., 2015; Lakso & Pool, 2000). Under the water deficit conditions imposed in the present trial, our results suggests an improvement of the global characteristics of the final wines. Interestingly, we observed a disagreement with the aromatic composition and sensory analysis in the wines produced in MS and SS. This result can suggest a prevalence of some aromatic compounds in determining the overall wine quality.

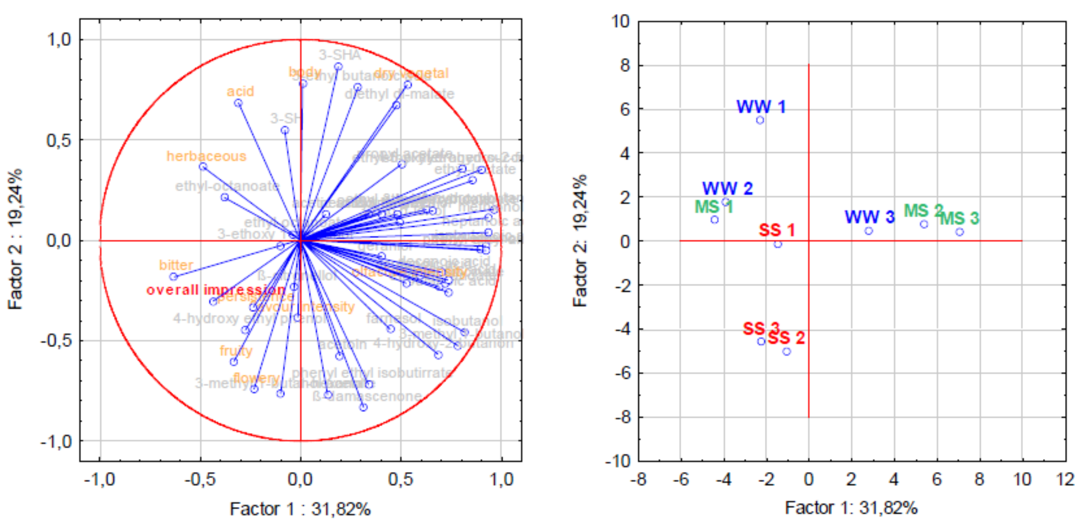

Figure 3. Principal component analysis (PCA) of the sensory analysis (in orange and red letters) and quantification of aromatic compounds (in gray letters) for the wines produced in the season 2021 . Wine replicates are shown in the PCA on the right and are marked for treatments: well watered (WW), mild water stress (MS), and severe water stress (SS).

4. Conclusions

The possibility to use the DSS Vintel allowed to manage the irrigation ceating three different situations of plant water status that partially impacted the yield and the maturation of the grapes. From the aromatic and sensoric point of view, although the results need to be confirmed with the dataset of the second year 2022, there was a clear difference in 2021 in case of SS, and partially also between WW and MS. Altogheter, the DSS Vintel represent an optimal tool to manage irrigation with the aim to target grape and wine quality.

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