# EFFICIENT IRRIGATION STRATEGIES AND WATER USE REDUCTION IN THE HIGH QUALITY PRODUCTION REGIONS OF PRIORAT AND MONTSANT (SPAIN)

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**Abstract:**
**Context and purpose of the study –** Priorat and Montsant Appellations of Origin are located in the south of Catalonia (North-East Spain), under severe Mediterranean climatic conditions, in terms of rainfall and water availability. Taking both appellations together, they account for close to 4000 ha cultivated by more than 1300 vine growers. Due to water stress during the growing season, irrigation is considered a suitable tool to ensure grape quality at harvest in order to maintain the high-quality standard of these regions' wines. However, optimal irrigation strategies based on plant water stress evaluation are not often undertaken, which may lead to inefficient water management. The objective of this study is to develop a regional irrigation strategy based on specific water potential measurements and meteorological data from different region sub-areas, in order to achieve an overall 10% reduction of water consumption in the region.
**Material and methods –** During two growing seasons (2017 and 2018), a total of 53 vineyard plots were monitored, which represented the main grape varieties planted in the region (*Grenache*, *Carignan*, *CabernetSauvignon* and *Syrah*) and were classified in eight sub-areas inside the region. From pea-size to harvest (phenological stages), measurements of phenology, water potential and meteorological data were collected. Irrigation recommendations were then given to growers, to avoid water potential below -1.4 MPa. Generic agronomic characteristics and production of the studied plots were also evaluated. Data on water use in the monitored vineyard network were compared to historical data of water use in the region. In addition, a specific field experiment was conducted to assess water consumption reduction using three different irrigation strategies.
**Results –** The monitoring of 53 vineyard plots per year was carried out during 2017 and 2018, with different meteorological conditions, accounting for a more water deficient season in 2017. Overall, more than 50 irrigation recommendations were emitted to growers. The water consumption with the optimized irrigation strategy ranged from 10 to 83 liters per ha, for the whole of 53 vineyards evaluated. Compared to the generic consumption reference of 80 l $ha^{-1}$, the recommended dose saved up to 87 % of the irrigation water per year. Moreover, two irrigation strategies also reduced water consumption compared to local grower strategy in the field trial comparing three strategies. The results of this study will help to develop an irrigation strategy, specific by region's sub-zones, in order to optimize water consumption while maintaining a high quality of the produced wines of this region.

**Keywords**: *Vitis vinifera*, Irrigation, Water use, water stress, regional strategy

## 1. Introduction

The Priorat region is located in the south of Catalonia, North-East Spain, and grapevines have been cultivated there since middle age, when Carthusian monks brought vines from Provence in the 12th. Currently, it includes one of the only two only Qualified Appellations of Origin in Spain, DOQ Priorat, and another high-quality Appellation of Origin, DO Montsant. This region is characterized by the diversity in qualitative soils for viticulture, from lime to schist, and particular meteorological Mediterranean conditions, with remarkable thermal changes between day and night. Annual rainfall ranges from 400 mm to 600 mm, which represent a constraint for grapevine growth, particularly during draught periods and dry growing seasons.

In these conditions, irrigation is an important tool to maintain grape and wine quality, since moderate water stress is usually considered as beneficial for wine quality, in particular for red wines (Matthews and Ishii, 1990; Keller et al. 2005).
However, access to irrigation resources Is scarce in the Priorat region, where there are only two small reservoirs, which have supply restrictions, usually at the end of the season. In addition, global warming may affect particularly to viticulture in Mediterranean regions (Malheiro et al. 2010) such as Priorat, where average annual rainfall has decreased from 532,2 mm in the 1950-1990 period to 476,3 mm in the 1990-2017 period (www.meteo.cat). Therefore, the prevision is to have higher irrigation demand and lower irrigation resources for viticulture in the following years.
Irrigation strategies in the region rely on the vineyard manager or grower's considerations about plant water stress, but without performing any objective measurement. Moreover, growers have not often specific training on grapevine hydric requirements and there is not a are not technical advice from private or public entities.
In the context of the European Union-funded project LIFE Priorat+Montsant, a wide package of environmental measures is implemented at a regional scale in the Priorat region. These measures include a regional strategy for irrigation, by offering recommendations to growers, based on water stress measurements during the season, in order to achieve a rational use of water resources and reduce irrigation water consumption in at least a 10 % compared to traditional practices. These recommendations are also related to weather conditions during the season and to the main grapevine cultivars grown in the region, since vine response to water supply might vary among winegrape varieties (Bellvert et al, 2016; Bota et al., 2001).
This study presents the results of two years of water stress monitoring and rational irrigation recommendations, achieving significant water consumption reductions and maintaining high standards of wine production in the whole Priorat growing region.

## 2. Material and methods

### *Zonification of the area of study and meteorological data collection*

The whole region of Priorat, including both DO Montsant and DOQ Priorat Appellations of origin, was separated into 14 sub-zones, according to geographical separation between valleys, height or other main climatic specificities. In each of the sub-zones, represent the climatic diversity of the region, a complete weather station (Decagon services Inc., Pullman, U.S.A) was installed. Hourly data of Temperature, Relative Humidity and rainfall were collected and uploaded into the web platform CESENS® (www.cesens.com). Data was shared with growers from the region, in order to provide reliable data to achieve a more precise interpretation of the growing season.

### *Vineyard network*

Due to lack of enough irrigated vineyards in every sub-zone, only nine out of the 14 subzones where included in the monitoring network. In each of the studied sub-zones, we selected six vineyard plots of the main grape varieties cultivated, which were representative of the subzone in terms of soil and location. Plots were relatively closely located among them and to the weather station. The grape varieties studied were: Grenache, Carignan, Cabernet Sauvignon, Merlot and Syrah as red varieties, and Macabeu and Grenache blanc, although not every variety was represented in every sub-zone.

### *Physiological measurements and irrigation recommendations*

From "berries pea-sized" phenological stage to harvest, vineyards were monitored each 7-14 days to assess water potential. In each vineyard, three leaves were taken from different vines, randomly selected. Water potential was measured using a Scholander-type chamber, by observing sap coming out from leave petiole. Values obtained from the three samples were used to calculate a mean water potential values for a certain grape variety, which were communicated to growers instantly. When average water potential values exceeded -1.4 MPa, a recommendation of irrigation with specific water volume to apply was emitted to the vineyard manager. The stress thresholds and recommended irrigation volume was calculated according to Hidalgo-Togores and Hidalgo (2011), then adjusting to variety and soil type, and targeting the specific production objective of the grower. In most of cases the recommendation targeted a moderate water stress, corresponding to a water potential between -1 and -1.2 MPa. Irrigation recommendations were only carried out during 2018 season.

***Irrigation strategies assay***

A specific assay was conducted in a Syrah vineyards plot in Poboleda municipality (sub-zone 14), comparing three treatments: 1) No irrigation, 2) Lower irrigation volume, maintaining water potential over -1.4 MPa and 3) Higher irrigation volume, to maintain water potential over –1.2 MPa. Water potential was assessed in the three blocks as previously described, and irrigation recommendations emitted when needed.

## 3. Results and discussion

**3.1.** *A complete network of 54 reference vineyard plots in 9 sub-zones and 14 weather stations has been settled in the Priorat region*

During 2017, we established a vineyard network including 53 plots in 2017 and 54 plots in 2018. These vineyards were property of 16 different wineries and 3 independent growers. The vineyards were distributed in the number of vineyards per sub-zone is described in Table 1.

***3.2.*** *Water stress assessment showed differences among grapevine varieties and studied sub-zones and the irrigation recommendations emitted represented a significant water use saving*

Water potential was monitored in the 54 vineyards during 2017 and 2018 seasons. Differences were detected among the studied subzones, and they were related to meteorological conditions, mostly due to rainfall variability among sub-zones (data not shown). Grapevine varieties also presented different water potential values, although no clear overall trends were observed, and differences were dependent on the studied sub-zone. With the recommendations emitted, growers decided to finally apply 10 to 83 l $m^{-2}$, depending on the subzone. These applied volumes represent a reduction from 55 to 87 %, compared to a generic value of 80 l $m^{-2}$. Only in the sub-zone 2, no reduction was achieved. However, the reference value correspond only to a part of the irrigation practices in the region and further research has to be carried out in order to obtain more specific historical data by sub-zone, and hence have more accurate reduction values.

*3.3. The optimized irrigation strategies saved water, controlled water stress levels and increased production maintaining grape quality*

Figure 1 shows the dynamic of water potential in Syrah vines when they were subjected to different irrigation regimes. The application of the two regimes reduced plant's water stress, achieving, approximately, the targeted water potential of -1.2 and -1.4 MPa. A rain event of 34 mm (17/08/2018) increased water potential for the three blocks compared, although differences among treatments were maintained. Further studies by Garcia (2019) showed an increased yield with similar quality parameters for must at harvest in both irrigated blocks, compared to the non-irrigated. These results indicate an improvement of vineyard management because of optimized irrigation.

## 4. Conclusions

The implementation of rational irrigation strategies program in the Priorat region for two years, in the framework of the LIFE Priorat+Montsant project, provided tools for growers in order to save water resources and achieve more rational vineyard management. These specific strategies for different sub-zones and grape varieties are extensible to more than 100 ha with irrigation resources in the region.

## 5. Acknowledgments

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**Table1**: Vineyard plots monitored and irrigation data

| Sub-zone | Appellation of origin | Municipality | Number of plots | Irrigated volume (l m$^{-2}$) | % reduction* |
|---|---|---|---|---|---|
| 1 | D.O. Montsant | Tivisa | 5 | 36 | 55 |
| 2 | D.O. Montsant | García | 14 | 83 | -3 |
| 3 | D.O. Montsant | Marça | 5 | 20 | 75 |
| 4 | D.O.Q. Priorat | Bellmunt | 6 | 30 | 62 |
| 5 | D.O.Q. Priorat | Porrera | 4 | 10 | 87 |
| 6 | D.O.Q. Priorat | El Molar | 9 | 33 | 58 |
| 7 | D.O.Q. Priorat | Gratallops | 4 | 25 | 68 |
| 8 | D.O. Montsant | Cornudella | 5 | 10 | 87 |
| 14 | D.O.Q. Priorat | Poboleda | 1 | 16 | 80 |

*Reduction values are referred to a generic value of 80 l m$^{-2}$

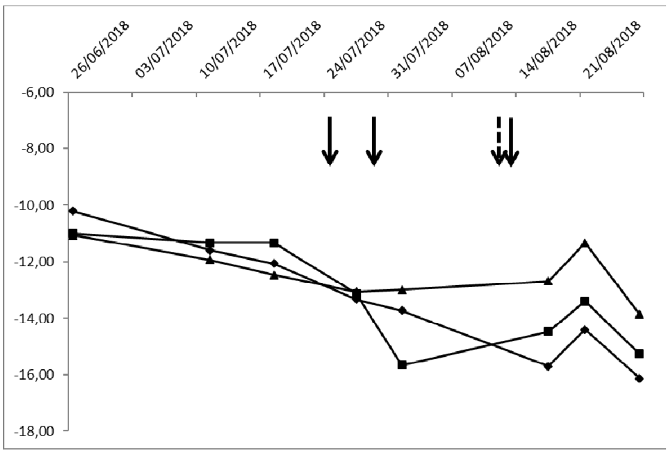


**Figure 1:** Water potential measurements in a Syrah vineyard with no irrigation (diamonds), lower irrigation volume (squares) and a higher irrigation volume (triangles). Each point is the average of 3 measurements. arrows represent irrigation events in the higher (solid) or lower (dotted) irrigation volume strategies. Irrigation events consisted of 16 l m$^{-2}$.