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From precision irrigation to conservation irrigation

How to ensure vineyard sustainability with minimal water?

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With climate change, most agricultural regions are experiencing periods of water constraints, or even water stress, associated with an overall increase in temperatures, heat stress and evapotranspiration. Some vineyards may even face low water availability in the soil from the start of the growing season and throughout their development cycle right up to harvest. This affects crop yield, wine quality and vineyard sustainability and profitability.

A

B

Figure 1: Winter rainfall deficit, Roussillon, France: a rainfed block of Grenache Noir on May 20, 2022 (A) and June 9, 2023 (B). Photos Marty P. & Hérent N.

The wine region of Roussillon in the southwest of France experienced semi-arid conditions in 2022 and 2023 (figure 1). This article presents the key results of a trial done on conservation irrigation during these two years and aims to determine which soil-climate variables need to be taken into account when planning conservation irrigation in a semi-arid climate, to guarantee regular vine yields and an acceptable wine flavor profile to meet market demand. This study was carried out within the framework of the research project on new agroecological models in the wine regions of the Mediterranean area, created and funded by the Domaine Lafage, Roussillon, France.

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A B

Figure 2: Severe water stress at berries pea size in 2023 (Grenache noir/110R, BBCH 75): irrigated (A) and rainfed (B) treatments. Conservation irrigation ensures a satisfactory development of the vine and fruit when the weather conditions become extreme (photos: Hérent N. & Marty P.).

As the local water availability in the area is extremely limited, a strategy beyond what is called "precision irrigation, PI" is required. PI involves the precise and accurate spatial and temporal management of irrigation needed to satisfy the water demand and promote crop production, sustainability and profitability. In our case, conservation irrigation (figure 2) means using a maximum of 500m^3 of water/hectare of vineyard per year. Thus, water inputs during the vine growth cycle were rationed to avoid surpassing physiological limits such as leaf embolism and loss, berry shriveling and potential inhibition of the maturation process (for example berry sugar loading; inhibition of anthocyanins synthesis in berry skin), while reaching the predefined yield and wine quality targets. Appropriate management of transpiring leaf area to fruit ratio was adjusted to avoid over ripe wine styles whilst preserving fresh and mature wine aromatic profiles. ▸

The study was carried out on a plot of Grenache Noir (*Vitis vinifera* L.) grafted on 110R rootstock, planted in 2009 at a density of 4,000 vines per hectare and located between the emblematic wine-growing regions of Rivesaltes, Maury and Tautavel, in the south of France. This area has a Mediterranean climate, but reached semi-arid conditions in 2022 and 2023, with annual rainfall of 305 mm and 245 mm respectively. During the period from October to March (i.e. from leaf fall to budburst), total rainfall was close to average in 2022 (355 mm, +28 mm) but was reduced to 127 mm (-200 mm) in 2023. From April to August (i.e. during the growing season), total rainfall was 68 mm and 97 mm in

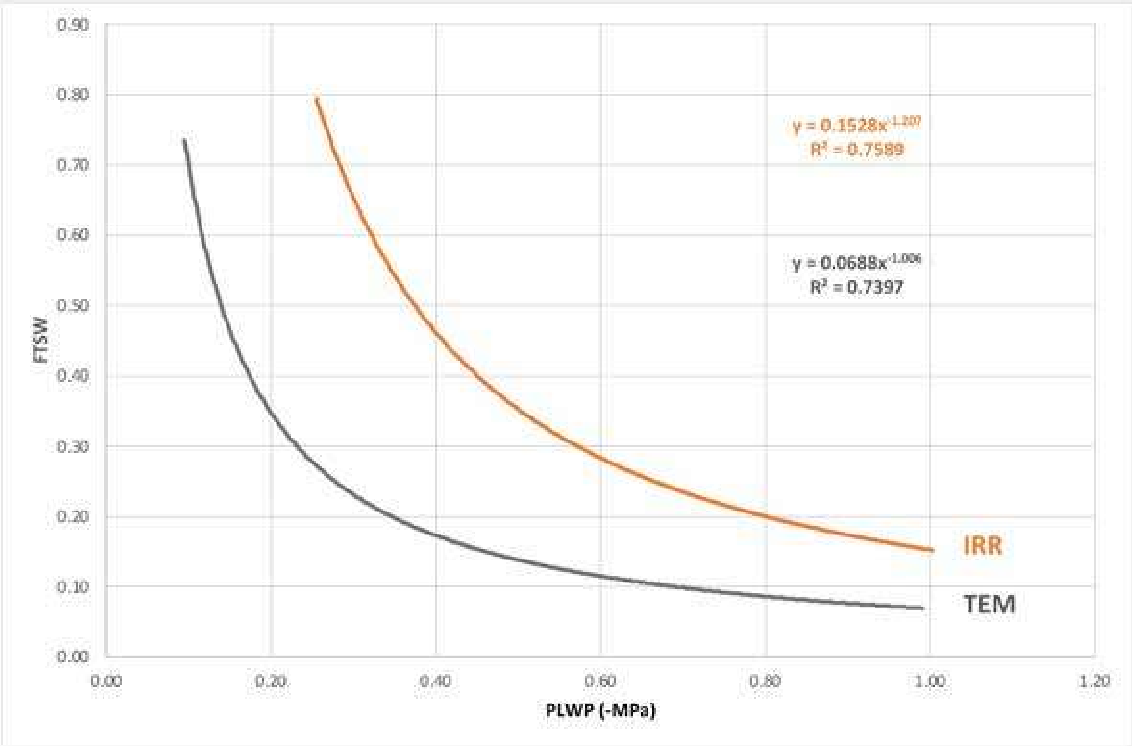

Figure 3: Evolution of the fraction of transpirable soil water (FTSW) with the predawn leaf water status (PLWP) for the rainfed and irrigated treatments, from May 1 to September 15 in 2022 and 2023.

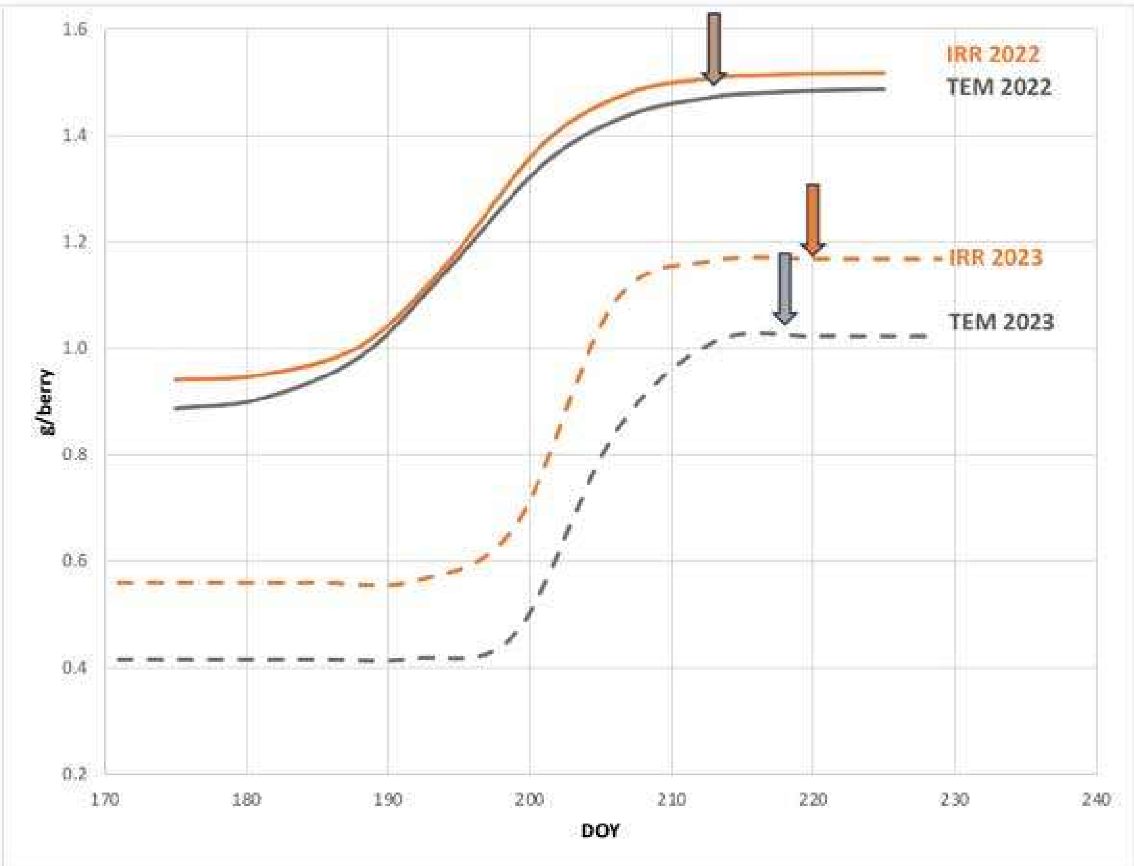

Figure 4: Berry fresh mass evolution for IRR and TEM treatments in 2022 and 2023. The arrows indicate 10 % alcohol potential (17.5 g:1 %).

2022 and 2023 respectively. The soil is a colluvium soil derived from quaternary terrace (Würm). The vine roots reach a depth of one meter. The soil water holding capacity, calculated over this one-meter depth, ranged between 91 mm and 97 mm over the block.

This affects crop yield, wine quality and vineyard sustainability and profitability.

An irrigated treatment (IRR) and a rainfed treatment (TEM) were compared. The soil and plant water status were monitored. Figure 3 shows the fraction of transpirable soil water (FTSW), measured with capacitive probes, as a function of pre-dawn water potential (PLWP) for both treatments. PLWP correlates well with FTSW as reported in the literature. However, the relationship differs between the two treatments IRR and TEM. For a given FTSW, PLWP is lower for irrigated plants than for rainfed plants.

Figure 4 shows the evolution of berry fresh mass for both treatments in 2022 and 2023. In 2022, the kinetics were similar for TEM and IRR. Thus, supplemental irrigation over the ripening period did not increase the volume of the berries. In contrast, treatments differed in 2023, with a positive effect of irrigation on berry weight. At maximum berry weight (i.e. 10 % alcohol potentials) the rainfed treatment displayed a 31 % increase in 2022 compared to 2023, which was consistent with the higher PLWP from flowering to veraison in 2022. Irrigation in 2023 did not permit to achieve the berry fresh mass obtained in 2022.

The ripening kinetics (sugar loading and malic acid degradation, in mg/berry) were also studied and were identical between the two treatments in 2022 and 2023. The yield in 2023 for TEM and IRR reached respectively 44 % and 67 % of the values obtained in 2022 (2.70 kg/vine for TEM and 3.08 kg/vine for IRR). Finally, both treatments displayed an appropriate leaf-to-fruit ratio (ELA/Yield) in 2022 and 2023, around 1 m^2/kg.

In 2022, IRR was irrigated three times between veraison and harvest, receiving a total volume of water per vine of 48 L (equivalent to 190 m^3/ha). In 2023, due to drier spring conditions, IRR was irrigated seven times between bud break and harvest, corresponding to a total volume of 107 L per vine (equivalent to 430 m^3/ha). Note that based on observations of the wet bulb dimension in relation to the duration of irrigation and the root system (especially the fine roots), each irrigation event was programmed for 10 hours (c. 16 L/vine). Conservation irrigation with such low inputs nevertheless enabled the vineyard's productivity to be maintained above sustainability threshold.

In conclusion, our study confirmed the relevance of a soil-plant-atmosphere approach to practice irrigation with limited water availability. The results suggested that

i) the basis for irrigation or vine water supply should be considered on a per-vine basis;

ii) the quantity of water in liters per vine must align with the vine's needs to primarily avoid inhibiting the photosynthesis activity, and the development and evolution of berries ripening (i.e., the biosynthesis of berry compounds).

iii) total water per vine must be matched to variety, climate including rainfall, irrigation delivery and soil water holding capacity within the vine root zone.

iv) competition for water from vineyard floor plants and between vine rows must be considered in the total water budget for the vineyard.

It is thus essential to understand the vine's water needs in terms of specific thresholds. Finally, our study suggests and proposes to calibrate the capacitive probe based on the specific situation (variety × soil × climate) using the PLWP (other vine water status indicators could be used). The rate and duration of irrigation must therefore be carefully reasoned to optimise the shape and size of the wetted bulb at the root system level, depending on soil type and moisture and root architecture. Depending on the quantity of irrigated blocks, a platform to easily process the data in a timely manner (e.g. Swan Systems) may be required. GW