PROGRAMMING DIFFERENT IRRIGATION STRATEGIES: EFFECTS ON GRAPE AND WINE QUALITY

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Abstract

A study was completed on Syrah vines planted in shallow soil. This study compared the impacts of different irrigation programs in 2006 set up according to the water balance and based upon root deficit irrigation (RDI) principals. Three strategies were compared: an empirical one based on the vineyard manager's experiences (TRAD), one aimed to increase yield (REND) and one aimed to give quality (QUAL).

The three different strategies gave variable yields hence fitting with the initial objectives. On the analytical level, little difference was observed in must composition at the harvest, for the less irrigated programs the overall lower sugar and anthocyanin accumulation is compensated for by a greater berry concentration. The differences observed are mainly in the acid and polyphenol composition of the grapes. In the wines, irrigation leads to an increase in pH, which continues to increase as the irrigation end date is later. Inversely there is a decrease in the DO280. The sensorial profile differences are more notable than the analytical differences and involve the aromatic profile and in-mouth balance. The control is judged as unbalanced due to a more aggressive taste (astringency and dryness), and the REND program wines are deemed slightly diluted.

Introduction

The vine water balance from budding up until harvest has an effect on grape berry development and maturation conditions. Hence, also on the yields and berry composition at harvest. Measuring leaf or stem water potential using a Scholander pressure chamber is considered as the reference method to determine vine water stress (Carbonneau 1998, Choné *et al* 2001, Ojeda *et* al 2001, Deloire et al 2004). This method also led to the creation of models showing water comfort and restriction levels of the vine during the different stages of the phenological cycle (Carbonneau 2004, Ojeda 2006).

The objective of this 2006 study on Syrah vines was to show that it is possible to use different irrigation strategies which can be adapted according to the style of wine desired (amyl fruity, ripe fruit, intense etc…). This all by following simple and easy decisions and rules, which can be applied in different production conditions.

MATERIALS AND METHODS

Determining Irrigation Needs According to Water Balance

The irrigation programs were established according to the water balance, which was used to identify the fraction of transpirable soil water (FTSW). Using a stress coefficient Ks, variable according to the final objective and the development stage, allows for the determination of a theoretical amount of water to provide. This method was used in Australia for RDI (root deficit irrigation) (Goodwin, 1995, Kriedemann et al 2001, Mc Carthy et al, 2002), and was adapted for European vineyards (Lissarrague, 2005).

The soil water stock can be determined using the water balance calculation, according to the following formula (Riou, Lebon, 2000):

$$W = Wo + Pe + I - Es - Ev$$

With

Ev = Vine evapotranspiration = Kc*ETP (potential evapotranspiration)
Kc = Crop coefficient
Es = Soil evaporation
W = Soil water stock on day, d (in mm)
Wo = Soil humidity at budding (in mm)
Pe = Effective daily rainfall (mm/d)
I = Irrigation supplied (in mm)

The crop coefficient varies according to the leaf surface development (Table 1)

The irrigation needs Irr (in mm/d) can be determined by this formula

$$Irr = (Es + Ev*ks – Wo – Pe)*Ef$$

With

Ks = stress factor, according to the desired allowance for the vines
Ef = irrigation system efficiency (% water effectively distributed)

Month Phenologic Stage	April Budding	May Pre-Bloom	June Flowering	July Bunch closure	August Veraison	September Harvest	November Leaf Fall
	Crop Coefficient Kc (according to Goodwin, 1995)						
Kc	0,2	0,3	0,4	0,4	0,5	0,5	0,25
	Stress factors used for trial						
REND	1	1	1	1	1	1	1
QUAL	1	0,83	0,75	0,63	0,6	0,6	1

Table 1: Evolution of crop coefficient and stress factors according to vine development

Irrigation Strategy Programming

Two irrigation strategies were defined according to the specific stress factors (Table 1):

- REND = irrigation program aiming to maximizing yield on that zone, without wasting water
- QUAL = irrigation program aiming to produce quality grapes suitable for the production of high end red wines. This by using a progressive allowance starting from the bunch closing without causing water stress.

These were compared to a non irrigated control (CONTROL), and to a vineyard manager's empiric strategy (TRAD). The TRAD strategy was established according to visual controls by the vineyard manager and stopped at veraison at latest (TRAD).

The data used for the water balance were the ETP, given by the CIRAME meteorological station, 6 km from the experimental trial zones and the rainfall measured on the vineyard.

Experimental Plan

Vineyard Characteristics

The study was completed on a vineyard of Syrah vines grafted on Ru140, planted in 1987, 2,25m by 1,3m, trained in Cordon Royat with 5 to 6 spurs having 2 buds, per vine, and trellised to give 3,2m^2 of potential exposed leaf surface per meter of cordon.

The vineyard is irrigated through a superficially buried drip by drip irrigation system on every other row, on a weekly basis.

The soil is a superficial brown calcareous soil where the available water capacity is measured at 36mm.

The rainfall measured during the vine growth cycle was 170mm, of which 109mm between budding and veraison.

Design

The experimental design consisted of 4 blocks having 3 rows of 140 vines each. The homogeneity of the experimental vineyard was verified by measuring the diameter of the stocks.

Measurements Taken

Vines:

- Leaf water potential at flowering, bunch closure and veraison.
- Weekly follow-up of the apex state and berry weight starting from flowering

Grapes: weekly analyses starting from 10 days after veraison (sugars, total acidity, malic acid, tartaric acid, pH, total anthocyanins, total polyphenols).

Experimental winemaking trials were completed following a standard protocol at the ICV experimental winery. A quantified descriptive sensorial analysis was completed after bottling by an expert jury of 7 people, all educated and trained about the descriptor scoring method used for odour and taste.

RESULTS AND DISCUSSION

Water Use

For the TRAD strategy water was supplied early in notable amounts (20mm/week) and was stopped on the 4th of July, just after bunch closure. A total of 110mm were supplied.

The QUAL strategy was started two weeks later. After notable amounts during flowering (15 to 20mm/week), the supply was significantly reduced (5 to 10mm) and was completed stopped after veraison. In total, only 90mm were supplied, in other words 18% less than the TRAD strategy.

The REND strategy started 1 week before the QUAL strategy, with notable water supplied (15 to 20mm/week) up until veraison, consequently reduced after veraison until the beginning of September, for a total of 210mm (91% more in comparison to the TRAD strategy).

The soil humidity monitoring showed that the soil was completely dry starting mid-June for the control, starting from mid-July for the TRAD strategy and the 20th August for the QUAL strategy. As for the REND strategy, a satisfactory humidity level remained for the duration of the trial.

Vine Water Potential Evolution

The control plot had a more significant water restriction after bunch closure, having moderate water restriction at this stage, which increased further at veraison (Table 2).
Whereas the REND strategy remains in the water comfort zone, without excessive water supply.

The QUAL strategy induces light water restriction, at levels near the lower limit of the water comfort zone without causing water stress.

The TRAD strategy has values between the QUAL and REND strategies.

Stage	*Date*	TRAD	QUAL	REND	CONTROL
Flowering	07-giu	-0,21 ab	-0,26 b	-0,17 a	-0,26 b
Closure	28-juin	-0,28 ab	-0,38 b	-0,30 a	-0,50 c
Veraison	26-lug	-0,39 ab	-0,49 a	-0,31 a	-0,71 c

The differences are significant at a significance level of α = 0,05 (Student and Fischer Tests)

Table 1 : Comparison of leaf water potential at flowering, bunch closure and veraison.

Grape Berry Development

The grape berry growth of the CONTROL is clearly slower after bunch closure (Figure 1) and abruptly stops 15 days after veraison. During the maturation, the grape berries follow the same tendency and slightly decrease in weight.

For the TRAD strategy the berry growth slows at the beginning of July right after irrigation interruption.

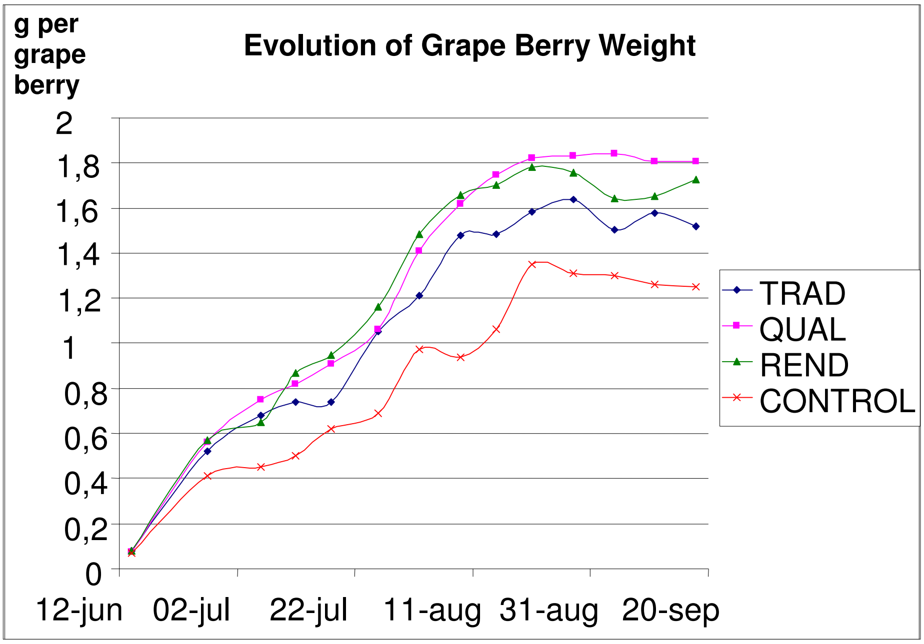

Figure 1: Evolution of average grape berry weight according to the strategy employed.

The QUAL and REND strategies have practically identical grape berry growth up until veraison, with more uniform kinetics seen for the QUAL strategy. There is a weight loss tendency during the maturation in the REND strategy, which is however compensated for by rainfall in mid-september.

For all the strategies, the grape berry growth stops very soon after veraison, even when irrigation is continued. To ensure a continued grape berry growth, it would have been necessary to distribute the water supply more frequently by following a daily irrigation strategy and not weekly.

Yield

All of the irrigated strategies gave a significant increase in yield when compared to the control: +69% and +76% respectively for the TRAD and QUAL strategies and +107% for the REND strategy (Table 5).

The increased yielded is justified by a greater number of grape berries per bunch (+28 to +36%) and by an increase in grape berry weight (+22% for TRAD, +44% for QUAL and +38% for REND). The differences between the irrigation strategies are foremost in grape berry weight, which are notably lower for the TRAD strategy than for the REND and QUAL strategies.

Strategy	TRAD	QUAL	REND	CONTROL
# bunches/vine stock	17,1	15,2	17,6	16
Average weight of bunches (kg)	0,172	0,201	0,205	0,109
Average weight of a grape berry (g)	1,52	1,81	1,73	1,25
# of grape berries/bunch at harvest	108	106	113	83
Yield at harvest (kg/vine stock)	2,94	3,05	3,6	1,74
Exposed leaf area m²/vine stock	3,4	3,9	3,9	2,2
Exposed leaf area/weight m²/kg	1,14	1,26	1,07	1,29

Table 2 : Yield components at harvest according to strategy employed

Leaf Area

The leaf canopy height is the same for all 4 strategies (1,30m), however with a less thick canopy for the control (40cm versus 50cm). The main differences are in canopy porosity, evaluated as 50% for the control, 5% for the QUAL and REND strategies and 20% for the TRAD.

The QUAL strategy has an exposed leaf area/weight comparable to that of the control, but with 76% greater yield, which is close to the level considered suitable for high end wines of the Rhone Valley. The REND strategy has a lower exposed leaf area/weight, slightly higher than 1m²/kg, the ratio required for the maturation of grapes for middle end wines. The TRAD strategy is between the two.

Grape Maturation

Grape composition at Maturity:

The must sugar concentrations are very similar across the strategies, just a little greater for the TRAD strategy and the control. The main differences are observed for malic acid, which decreases across the strategies in the following order REND, QUAL, TRAD and control, and for tartaric acid and total polyphenols which increase. At the end of the maturation, the sugar/acidity ratio progression remains constant for the QUAL and RENDS strategies, whereas it suddenly accelerates in the control and TRAD strategy.

Maturation Kinetics:

The amount of sugar per grape berry is much lower for the control, with an early stop the 4/9 (Figure 2). It is the QUAL and REND strategies which have the greatest quantity of sugar per grape berry, but with different kinetics: consistent and steady for the QUAL strategy up until a stop on the 11/9 and slower but without stops up to harvest for the REND strategy.

The amount of sugar for the TRAD strategy is intermediate, with levels lower than the QUAL and REND strategies, and accumulation kinetics which slow around the 28/8 and stop the 11/9.

The QUAL strategy is clearly differentiated from the others by having a greater amount of anthocyanins (+40% in comparison to TRAD and +15% in comparison to REND and TRAD).

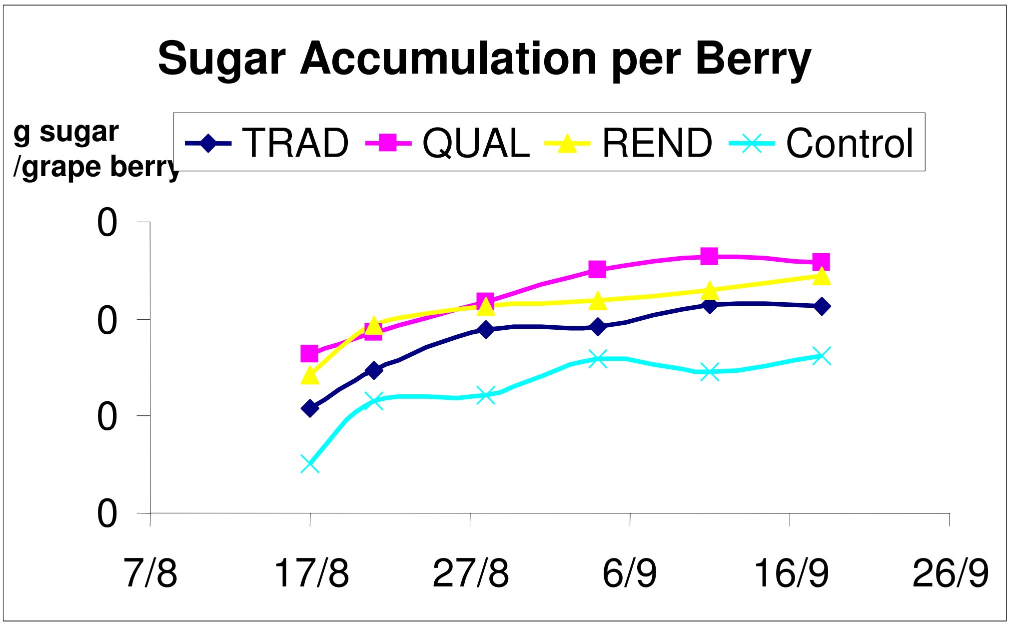

Figure 2 : Evolution of the amount of sugars per grape berry according to the strategy employed

Wine Quality

Analytical Profiles

There are not great differences in the potential alcohol degree nor in the total acidity (Table 4) however there are significant differences in pH, which are greater in the QUAL and REND strategies, lower for the TRAD strategies and intermediate for the control. The control also has a greater colour intensity (CI) and also a lot more total polyphenols (DO280).

Strategy	Sugar (g/L)	Degree (% vol.)	Total Acidity (g H2SO4/L)	Volatile Acidity (g H2SO4/L)	pH	CI	DO280	Tartaric Acid (g/L)
TRAD	3	14,46	3,41	0,38	3,67	17,59	63	1,9
QUAL	3,2	14,62	3,24	0,43	3,85	16,71	70	1,72
REND	3	14,51	3,3	0,4	3,82	18,86	68	1,75
CONTROL	3,3	14,75	3,39	0,34	3,77	23,73	87	1,57

Table 3 : Comparison of wine analytical profiles

Wine Sensorial Profiles

The control is characterized by a low intensity odour profile, having notes of fruits preserved in spirits that are slightly herbaceous. The initial volume sensation felt in mouth is medium, and does not manage to support the strong tannic structure, which gives a final dryness that leans towards a burning character.

The REND strategy is judged as having a very fruity nose, and a slightly diluted taste. The TRAD strategy has an odour profile of jam and spice, with a very notable structure in mouth that is supple. The QUAL strategy gives wines with a very intense jam smell, a high volume sensation in mouth, and a less astringent and drying tannin structure. The TRAD and QUAL strategies lead to wine profiles that are deemed suitable for a high end wine positioning, given their tannin structure.
The tannins are more apparent in the TRAD strategy wines, therefore making them suitable for traditional markets and are more supple in the QUAL strategy and therefore better suited to the international market (Figure 3).

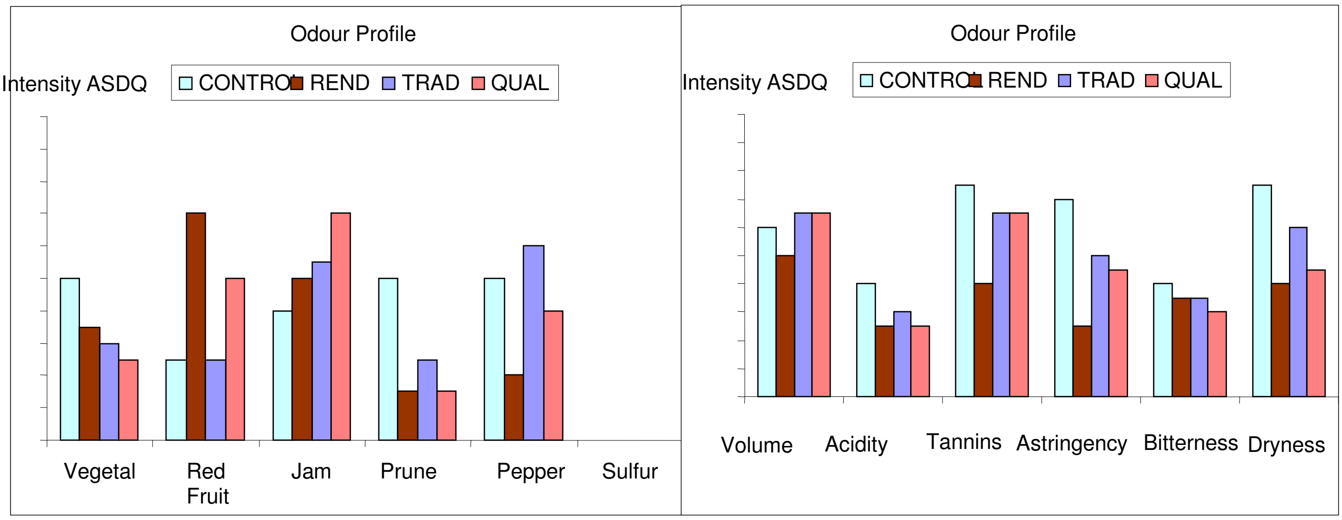

Figure 3: Sensorial profiles after bottling

COMMENTS

Effects of Irrigation on the Vine, Grapes and Wines

Irrigation gave an increase in yield due to an increased numbers of grape berries per bunch and bigger grape berries. At the same time, the exposed leaf area increased, whilst the vine did not undergo too intense water restriction. The absence of water restriction at bunch closure limits tannin and total polyphenol concentration without necessarily producing a diluted wine (as seen for QUAL or TRAD). As the irrigation interruption is delayed, the potassium and malic acid are higher, and the accumulation of sugars and anthocyanins is better.

The differences in grape berry size lead to concentration phenomena in the control, which justify the absence of large differences in must and wine composition.
Irrigation allowed for a comparable maturation which was even more balanced than the control, and notably for superior grape production.

Irrigation furthermore facilitated malolactic fermentation progression when compared to the control, this step is very important for the qualitative control of the wine aromatic profile, notably by avoiding the development of sulfurous odours.

Impact of the Different Irrigation Strategies

The different irrigation strategies applied prevented the water stress seen in the control and resulted in different wine styles: REND gives a fruity wine, at yields high enough to have a good profitability for that vineyard plot at a competitive sales price in a premium market. QUAL and TRAD give more structured wines, suitable for the production of high end wines for aging, TRAD being more suitable for local markets and QUAL for more international markets. The control resulted in the least appreciated wine, being concentrated, dry and burning, with low yields which would require a higher sales price in order to just reach the threshold of profitability.

Despite a doubled water supply, the yield of the REND strategy only increases by 18 to 22% in comparison to the QUAL and TRAD strategies. This limited difference could be due to inefficient water distribution: when there is high water supply, once the drip by drip bulb is saturated, the extra water supplied tends to percolate, therefore causing greater losses. Furthermore the mineral nutrition of the vine becomes the limiting factor when the water needs are met.

The Interest of Programming According to Water Balance

The model used allowed for the programming of irrigation strategies suited to the initial desired objectives.

In comparison to a vineyard manager's practices, it was possible to reach, using 18% less water, a comparable to superior qualitative level with slightly higher yields. The two strategies tested, QUAL and REND, allowed for the programming of the right time to start irrigation and for the determining of the weekly water supply adapted to the objectives.

The use of water balance information alone does not allow for the establishment of irrigation strategies: it is important to also follow the soil humidity and water state of the vine.

CONCLUSION

Irrigation allows for, in situations where there is limited water supply, the compensation of effects associated with water restriction which limit not only yields, but also canopy development. The impact on the sensorial aspects is notable, wines from the more irrigated strategies being judged as more fruity, more voluminous and less drying. All the irrigation strategies globally influence the wine profiles, in comparison to the control, and there are also notable organoleptic differences between these irrigation strategies.

By choosing a particular program and control methodology an irrigation strategy adapted to the production objectives can be established. This can take in account quantitative and qualitative objectives as well as economical aspects, by optimizing the water supply efficacy. The water balance is an interesting programming tool which consents the establishing of water supply amounts that are adapted to the production objectives. However, it is important to also carefully follow the soil humidity and the water state of the vine.

Key-words: Irrigation, evapotranspiration, scheduling, maturity, wine profiles

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