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Effects of limited irrigation on the composition of must and wine of Cabernet Sauvignon under semi-arid conditions

by

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S u m m a r y : Effects of irrigation were studied in a Cabernet Sauvignon vineyard in the Priorat region of Spain, in order to determine the effect of sprinkler irrigation on fruit ripening as well as on must and wine composition. The soil water potential was measured at different depths and irrigation was started when the soil water potential decreased to -1480 kPa. At this point, moderate doses of water (25 l/vine) were added every fortnight during July and August. The yield of the irrigated vines increased by 20%. The must obtained from irrigated vines showed higer levels of potassium than that of the non-irrigated vines. Total soluble solids increased earlier and more rapidly in irrigated vines. We also found higher levels of malic acid and the total acidity increased in both, must and wine. However, tannins and anthocyanins, were lower in wines of irrigated grapevines. The later result is possible due to a rainfall which occurred before harvest, since phenolics did not decresase when a similar irrigation was applied in subsequent years.

K e y w o r d s : climate, soil water potential, irrigation, must, wine, quality, Cabernet Sauvignon.

Introduction

Growth of grapevines often decreases under conditions of water deficiency (CHAVES and RODRIGUES 1987). Plant water stress, which mainly occurs in summer during peak evapotranspiration periods (PEACOCK *et al.* 1987), is normally accompanied by a reduction of the rate of photosynthesis and sugar accumulation and frequently by leaf senescence. As continuous irrigation is normally associated with a delay of ripening (BRAVDO *et al.* 1984; LIGETVARI 1986), a lower sugar concentration and a lower content of total phenols of must (ALJIBURY *et al.* 1975; GLORIES 1984) it appears that a slight water stress occurring during fruit ripening might help to get an appropriate level of sugar and phenols required for a good red wine quality. Under the conditions of extensive viticulture irrigation in moderate doses until veraison has been recommended by MÉRIAUX *et al.* (1979).

In order to improve wine quality Cabernet Sauvignon was recently introduced in the Priorat region. The main purpose of this research was to examine the effect of limited irrigation on must and wine quality of Cabernet Sauvignon vines.

Materials and methods

Cabernet Sauvignon vines cultivated near the village of Gratallops (Priorat region, Spain) were selected for this study. According to the Winkler classification this area is situated in region III. The texture of the alluvial soil is clay-loam (USDA classification). The soil has a basic pH and is more than 4 m deep. The average annual rainfall is 450 mm. The potential and the real evapotranspiration is 800 and 500 mm, respectively.

This study was carried out in 1989, with an annual rainfall of 350 mm. During the summer, temperature and humidity data were registered by a psychrometer placed in the middle of the vineyard. The evapotranspiration was measured by a U.S. Weather Bureau Class A evaporimeter tank that was set up next to the vineyard. The reference crop evapotranspiration (ET_o) was calculated using equation (a) and the crop evapotranspiration (ET_c) was obtained by equation (b):

(a) $ET_o = K_p \times E_{pan}$

(b) $ET_c = K_c \times ET_o$

where K_p is the pan coefficient, E_{pan}, mm of water evaporated per day, and K_c, the crop coefficient. The values of the coefficients, $K_p = 0.6$ and $K_c = 0.6$, were determined according to DOORENBOS and PRUITT (1988).

Two small terraces in the same plot with 330 vines each were chosen for this study and the lower one was selected for the sprinkling treatment. Cabernet Sauvignon plants are grafted to *Rupestris* du Lot. The density of plants/ha is 3300. The trellis system consists of one single wire 60 cm from ground level and one double wire at 40 cm from the former. Micro sprinklers with fine-mist nozzles (DS.8855 Regaber) were placed in the rows every 1.20 m. The soil water potential was measured at 20, 40 and 80 cm soil depth. Three blocs of tensiometers were placed in each plot.

The sprinkler irrigation schedule, based on the tensiometer measurements, consisted of 5 doses of 25 l of water per vine applied during July and August. Water was provided when the tensiometer readings were close to -1480 kPa. The plot was watered every fortnight start-

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ing at the beginning of July until the last week of August.

Samples of 250 berries were taken during the 3 weeks before harvest (OUGH and AMERINE 1988; JIMENEZ 1991). Berry samples were crushed with a small hand press and the resulting must was centrifuged in order to analyze titratable acidity, pH and soluble solids following the OIV procedures (1990).

Cabernet Sauvignon grapes were harvested at the same sugar level in both plots, the non-irrigated vines 1 week before of the irrigated ones. Three fermentation arrangements were performed with grapes from each plot. SO_2 was added to the extracted must and then, a commercial yeast strain (p-29 from the Penedes region) was inoculated to start the alcoholic fermentation. After 4 d of skin-contact in containers of 20 l the alcoholic fermentation was achieved in laboratory fermenters of 2 l at 20 °C. The wines were analyzed following the OIV methods (1990). Alcohol content, extract, ash, total acidity, malic acid, volatile acidity, total phenol and nitrogen were determined. Anthocyanins and tannins were analyzed following a method described by RIBÉREAU-GAYON and STONESTREET (1965, 1966). The data were analyzed using the analysis of variance and the Scheffe test.

Results and discussion

Weather: In 1989 from April to August low precipitation and high temperatures in summer led to a pronounced water deficiency (Tab. 1). The highest evapotranspiration was observed in July corresponding to the highest temperatures and the absence of precipitation. The evapotranspiration was slightly lower in August and it significantly decreased in September. Evapotranspiration and temperature progressively decreased during the period of grape maturation (PEACOCK *et al.* 1987; PRIOR and GRIEVE 1987; VAN ZYL and VAN HUYSSTEEN 1988).

Table 1

Meteorological records 1989

	July	Aug.	Sep.
Temperature (°C)			
mean daily max.	37.1	34.6	28.3
mean daily min.	21.0	21.5	15.8
Rainfall (mm)	0	26.0	22.0
Humidity (day, %)	34	46	53
Humidity (night, %)	75	83	90

Soil water potential: The Figure presents the soil water potential values from irrigated and non-irrigated plots. Most of the values were significantly higher in the irrigated plot than in the non-irrigated plot, differences between the two plots varying between 30 and 50 %. In the non-irrigated plot the soil water potential at 20 and 40 cm of depth reached its lowest value (-1480 kPa) in the second half of July. This value was maintained until the beginning of September and then it progressively increased due to a rainfall and a distinct decrease of evapotrans-piration.

The rainfall was not sufficient to increase the soil water potential at 80 cm of depth above -1480 kPa.

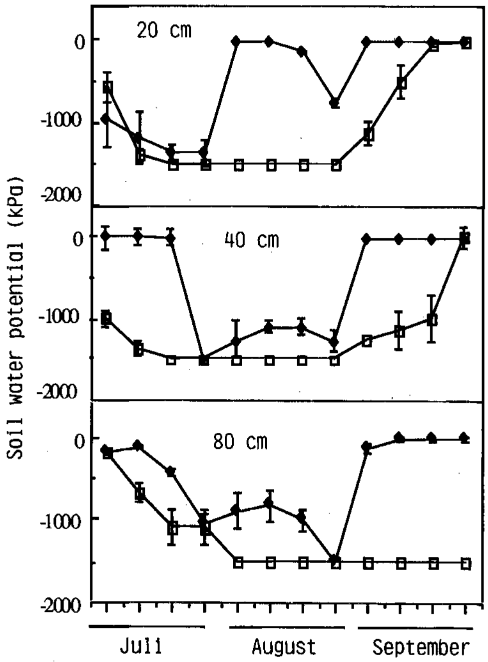

Figure: Soil water potential in summer 1989 at 20, 40, and 80 cm depth in irrigated (◆) and non-irrigated (□) plots. Data are weekly averages ± SE (vertical bars) at p=0.05.

Fruit ripening: During ripening the increase of sugar and the decrease of acids were delayed in non-irrigated vines (Tab. 2). As a consequence, the irrigated vines were harvested one week before the non-irrigated vines. In berries of irrigated vines acidity decreased progressively until the middle of September to ca. 6.3 g tartaric acid/l, whereas in the non-irrigated vines the acidity hardly varied until the end of September, when it decreased to a value of 6.5.

Table 2

Total soluble solids and titratable acidity in berries of irrigated and non-irrigated vines. The results are mean data of 3 samples each. Values followed by different letters differ at p=0.05. Titratable acidity in g tartaric acid/l

Date	Non-irrigated		Irrigated	
	°Brix	Acidity	°Brix	Acidity
08/21	14.6±0.1a	10.6±0.1a	15.1±0.2b	9.6±0.1b
08/28	17.9±0.1a	9.7±0.2a	18.6±0.1b	8.2±0.1b
09/04	17.7±0.2a	7.1±0.1a	18.2±0.2a	8.2±0.1b
09/11	18.4±0.2a	8.1±0.2a	18.6±0.2a	6.3±0.1b
09/19	19.9±0.1a	7.0±0.1a	20.8±0.1b	6.2±0.1b
09/25	20.8±0.1a	7.5±0.2a	21.0±0.1a	6.8±0.1b
09/30	21.2	6.5	-	-

Since climatic factors are known to have an important influence on the onset of ripening, the water stress and high temperatures in 1989 may be responsible for the delay of ripening. As is shown in Tab. 2, moderate water doses supplied during the summer season have advanced fruit maturation, possibly by facilitating CO_2 absorption, sugar transport and sugar accumulation in the berry (GARCIA *et al.* 1991).

In order to enable comparisons of wine compositions, grapes should be harvested when they have reached the same level of sugar (KLIEWER and SCHULTZ 1973; MATTHEWS *et al.* 1990). To obtain wines with ca. 12 % vol. alcohol, the vines from both irrigated and non-irrigated plots were harvested when the grapes had ca. 200 g/l sugar. As is illustrated in Tab. 3, the must had a good balance between sugar and acid content at this time.

Table 3

Yield and must analysis.
Values followed by different letters differ at p=0.05.
(1) g/l tartaric acid

	non-irrigated		irrigated	
Yield (kg/ha)	6270		8580	
Yield (kg/vine)	1.91±0.07	a	2.42±0.05	b
Yield /pruning weight	1.33±0.07	a	1.41±0.08	a
Must analyses				
Sugar (g/l)	203±10	a	198±11	a
Titratable acidity (1)	5.0±0.1	a	5.3±0.2	b
pH	3.43±0.00	a	3.44±0.00	a
Potassium (mg/l)	1580±16	a	1845±22	b

Vine growth and must analysis: The effect of irrigation on yield and must composition is shown in Tab. 3. The yield per ha increased by 37% in the irrigated vines. In addition, yield per vine was 26 % higher when irrigated. However, no differences were found in the yield/pruning weight ratio, indicating a positive effect of the water supply on the vine's vigor. A decrease of berry size and drought symptoms were observed in non-irrigated vines. These results agree with those obtained by other investigators (KLIEWER and SCHULTZ 1973; MATTHEWS and ANDERSON 1989).

As expected, the sugar level in must was similar in both treatments. However, there were small but significative differences in titratable acidity, suggesting an increase of acidity in the must of irrigated vines. The potassium level increased in the must from irrigated vines, whereas the pH did not vary. In general, continuous irrigation has been found to be associated with an increase of acidity and a delay of ripening (MATTHEWS *et al.* 1990).

Data in literature on the effect of irrigation on fruit growth, fruit ripening, must and wine composition are controversial possibly due to different irrigation managements (KLIEWER and SCHULTZ 1973; MATTHEWS *et al.* 1990; GARCÍA *et al.* 1991).

In this study, differences in acidity were not very large. However, the irrigation treatment facilitated sugar accumulation and herewith an earlier ripening. Moreover, the increase in yield was not accompanied by a decrease in sugar content.

Wine analysis: The results of the chemical wine analysis are shown in Tab. 4. Irrigated vines showed significantly lower values of ash, total phenols, anthocyanins and tannins and higher values of malic acid and nitrogen. Frequently, low aroma and flavour are associated with Cabernet Sauvignon wines produced in our region when the alcohol reaches ca. 13 degrees (NADAL 1993).

Table 4

Wine analysis.
Values followed by different letters differ at p=0.05.
(1) g/l tartaric acid; (2) g/l acetic acid; (3) mg/l gallic acid

	non-irrigated		irrigated	
Alcohol (% vol)	10.8±0.02	a	10.6±0.02	b
Extract (g/l)	31.2±0.40	a	30.7±0.30	a
Ash (g/l)	4.1±0.06	a	3.0±0.05	b
Titratable acidity (1)	6.8±0.09	a	6.5±0.07	b
Malic acid (g/l)	1.6±0.03	a	1.8±0.03	b
Volatile acidity (2)	0.35±0.03	a	0.27±0.01	a
Total phenols (3)	1321±30	a	1031±35	b
Tannin (mg/l)	2460±10	a	1850±13	b
Anthocyanin (mg/l)	615±50	a	497±24	b
Total nitrogen (mg/l)	115±5.7	a	158±8.8	b

The high malic acid concentration in wines from the irrigated vines was associated with a high level of potassium in the must (see Tab. 3). This is in accordance with KLIEWER and SCHULTZ (1973) and HEPNER and BRAVDO (1985). The increase of potassium is probably due to an improvement of the uptake and transport to the berries as has been previously reported (BRAVDO *et al.* 1984; HEPNER and BRAVDO 1985). BOULTON (1980) found a relationship between malate synthesis and potassium uptake. He reported that the additional malic acid synthesis may occur due to berry enlargement with an exchange of protons for potassium.

Total phenols decreased by 22% in wines produced from irrigated vines. KLIEWER and SCHULTZ (1973) and LIGETVARI (1986) have reported decreases of the total phenol content associated with an increase of crop level by different irrigation treatments. Since in our study the last irrigation was applied ca. 4 weeks before harvest, September rainfall might have contributed to this decrease.

Water stress and high temperatures have a strong influence on the synthesis of phenolics due to a reduction of photosynthesis (GUILLOUX 1981). In addition, high temperatures inhibit phenylalanine ammonia-lyase activity (ROUBELAKIS and KLIEWER 1986). Therefore, the increase of yield/ha by irrigation as well as the climatic conditions affecting the water status in vines, may have caused the decrease of the phenolic compounds (MATTHEWS and ANDERSON 1989).

Conclusions

Our results indicate that moderate irrigation during July and August, when water stress is more severe, can be beneficial for vine growth and wine quality.

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