EFFECT OF DEFICIT IRRIGATION ON ANTHOCYANIN CONTENT OF MONASTRELL GRAPES AND WINES

EFFET D'UNE IRRIGATION DÉFICITAIRE SUR LA TENEUR EN ANTHOCYANES DES RAISINS ET DES VINS ISSUS DU CÉPAGE MONASTRELL

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Abstract : The results showed that moderately irrigated vines produced berries with a higher anthocyanin content (expressed as mg/100 berries) than non-irrigated vines. These findings suggest that moderate levels of water doses may actually improve the physiological status of vines grown in very dry areas, resulting in higher yields and higher quality grapes. The higher yields were mainly related to larger berry size which led to a lower anthocyanin content when expressed as mg/kg, due to a dilution effect. This fact is also responsible for the lower anthocyanin content of the wines elaborated with grapes from irrigated vines although irrigation per se did not decrease the concentration of anthocyanins in grapes.

Résumé : L'effet d'une irrigation modérée sur des vignes de variété Monastrell cultivées dans une région très sèche du Sud-Est de l'Espagne a été étudié, l'objectif étant d'analyser les variations des concentrations en sucre et en anthocyanes dues à cette irrigation, dans le raisin et le vin élaborés à partir de ces vignes. Le faible rendement de ces vignes, soumises à de sévères contraintes hydriques, peut rendre la viticulture dans ces zones arides une activité non rentable d'un point de vue économique. Ainsi, l'irrigation est une pratique nécessaire pour augmenter la production de ces vignes. Durant la période d'étude, de la nouaison à la vendange du fruit, des plants de vignes ont été irrigués avec trois quantités différentes d'eau, l'objectif étant d'augmenter le rendement des vignes sans compromettre le contenu en anthocyanes des baies et par conséquent la qualité du vin. Les vignes non irriguées ont été utilisées comme référence. L'irrigation a augmenté de manière significative le rendement des vignes, celui des vignes non irriguées étant le plus faible. Cet accroissement n'a pas été excessif, puisque la quantité d'eau utilisée pour l'irrigation est restée faible. Le meilleur rendement vis-à-vis du nombre de grappes par plante et du nombre de grains par grappe a été obtenu avec les vignes les plus irriguées. Sur les deux années d'expérience, il a été établi que le raisin des vignes les plus irriguées présente le contenu le plus élevé en solides solubles totaux par baie (Brix x poids de la baie/100). Ceci peut être dû à une augmentation de la photosynthèse nette qui permettrait une accumulation d'assimilats dans le raisin. De plus, le raisin présentant un niveau plus important d'anthocyanes a été produit par les vignes modérément irriguées, les plants non irrigués étant toujours pris comme référence.
Ces résultats montrent qu'une irrigation modérée peut réellement améliorer l'état physiologique de la vigne cultivées dans des conditions d'extrême sécheresse, et donc donner un meilleur rendement et produire du raisin présentant une teneur plus importante en anthocyanes. Cependant, l'augmentation du rendement obtenue grâce à l'irrigation est principalement liée à un accroissement de la taille de la baie. Ceci provoque une diminution de la concentration en anthocyanes, exprimée en mg/kg de raisins, due à un effet de dilution. De la même manière, les vins élaborés à partir de raisin irrigué souffrent également de ce phénomène de dilution. Pourtant, les résultats indiquent une teneur plus importante en anthocyanes dans la baie de vignes irriguées, ce qui suggère que l'irrigation en elle-même ne diminue pas la teneur en anthocyanes dans le raisin, mais c'est l'augmentation de la taille des grains de raisin qui cause une dilution des anthocyanes et par conséquent une concentration plus faible dans les vins élaborés à partir de ces vignes irriguées. Dans les régions arides, une irrigation modérée paraît nécessaire pour limiter le déficit en eau dont souffrent les vignes et ainsi améliorer son rendement. Mais il est important de trouver une solution pour que cette amélioration de rendement ne soit pas accompagnée d'une augmentation de la taille des grains de raisin, c'est-à-dire d'une dilution des anthocyanes dans les vins.

Keywords : *Vitis vinifera*, wine, water, anthocyanin, deficit irrigation

Mots clés : *Vitis vinifera*, vin, eau, anthocyane, irrigation déficitaire

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INTRODUCTION

The color of grapes is of fundamental importance for the quality of wines. Anthocyanins are responsible for the red color of grapes and wines and their levels are dependent not only on variety but also on climatic conditions and cultural practices (AROZARENA *et al.*, 2002; ESTEBAN *et al.*, 2001; GARCIA-ESCUDERO *et al.*, 1996; PIRIE and MULLINS 1977).

Irrigation is one such cultural practice. Despite the fact that in many areas of Spain summers are characterized by very high temperatures and low rainfall, irrigation was restricted prior to 1996. The low yield of severely stressed vines grown in these areas can make grapegrowing an uneconomic activity, and so irrigation has become a useful practice for improving yield by avoiding severe water stress.

The main purpose of irrigation is to offset crop water deficits and maximize yield. However, irrigation in winegrape vineyards indirectly influences wine quality and composition through its influence on vegetative growth and hence canopy microclimate, fruit metabolism and yield (SIPIORA and GUTIERREZ-GRANDA, 1998).

There is considerable controversy in the literature concerning the positive and negative effects of irrigation on must and wine quality. An excess of irrigation can lead to excessive vegetative growth and crop (BRAVDO *et al.*, 1985; McCARTHY, 1984). Since berry size is increased, a dilution of certain important quality components (color and aroma) may occur (Esteban et al., 2001). Irrigation may also have an indirect effect on anthocyanins. Taking into account that solar radiation is a critical factor in color development in berries (CRIPPEN *et al.*, 1986; GAO *et al.*, 1994; GARCIA-ESCUDERO *et al.*, 1996; ROJAS-LARA *et al.*, 1989; SMART, 1987) excessive irrigation may contribute to increase canopy and the shading of grape clusters (KRIEDEMANN, 1977; McCARTHY *et al.*, 1983; NEJA *et al.*, 1977; SMART *et al.*, 1990).

Severe water stress, on the other hand, tends to decrease vigor but also the sugar and acid content since photosynthetic activity may be compromised (FLEXAS *et al.*, 1999). Indirectly, anthocyanins may also be affected. Phenylalanine ammonia-lyase, the key enzyme of anthocyanin metabolism, is related to carbohydrate metabolism and this reaction is also affected by water stress (ROUBELAKIS-ANGELAKIS and KLIEWER, 1986). Furthermore, inadequate leaf development may lead to very high temperatures in the cluster zones, especially in hot areas, and high temperatures have been correlated with a fall in anthocyanin levels (BERGQVIST *et al.*, 2001).

In semi-arid areas, such as Southeast Spain, with annual rainfall below 300 mm, the question that arises is not irrigation vs. no irrigation, but how much water and when should it be applied to control vegetative growth and maximize fruit quality. The effect of moderate irrigation doses on Monastrell vines, the second most common red grape cultivated in Spain, was studied and the results compared with those of non-irrigated vines, to assess the possibility of increasing yield without adversely affecting grapes anthocyanin content and therefore, wine quality.

MATERIAL AND METHODS

I - VINEYARD SITE

A Monastrell (also known as Mourvedre) vineyard located within the Denomination of Origin of Jumilla (Spain) was selected for the study (38º 23'40" north, 1º 25'30" west). The vineyard was planted in 1997 on 1103

Table I - Climatic conditions during 2000 and 2001

Conditions climatiques en 2000 et 2001

Year	Month	Temperature (ºC)			Humidity (%)			Rainfall (mm)		Solar radiation (w/m2)	ETo (mm)
		Mean	Max	Min	Mean	Max	Min	Total	Max	Mean	Mean
2000	April	13.6	18.8	9.8	56.5	95.2	37.4	26.8	14.6	265.1	144
	May	18.3	25.0	13.1	65.8	91.4	42.1	55.0	38.8	300.5	172.4
	June	22.2	28.9	17.3	51.8	76.9	25.8	1.8	1.4	369.9	232.5
	July	24.9	29.3	21.1	47.2	67.3	31.5	11.3	11.3	358.7	238.1
	August	24.6	28.0	21.1	47.0	81.4	24.4	16.7	16.6	305.1	206.7
2001	April	14.9	19.6	10.8	54.6	95.0	30.5	25.1	18.8	300.1	157.8
	May	17.0	22.2	9.9	63.6	94.7	41.0	53.6	17.8	300.1	163.4
	June	23.5	29.0	18.5	43.0	75.2	18.0	2.8	1.9	374.0	241.8
	July	24.7	27.7	21.1	47.3	71.2	23.1	0.5	0.5	346.0	239.3
	August	25.4	28.4	23.2	53.8	77.8	33.4	3.2	3.0	307.2	201.2

Paulsen rootstock in a clay -loam soil of 60 cm depth. Planting density was 2.5 m between rows and 1.25 m between plants. The training system was a bilateral cordon, trellised to a three-wire vertical system. Six two-bud spurs were left at pruning time.

The annual average temperature of this area is 15.5-16 °C, while frost occurs on 25-35 days. During the growing season (from mid April to mid November), the maximum daily temperature exceeds 30 °C on 90 days, average annual rainfall is 290 mm and reference crop evapotranspiration accounts for 830 mm (a water deficit of 540 mm). The viticultural region is in zone IV according to Winkler classification. The climatic data for both seasons are shown in table I.

II - IRRIGATION TREATMENTS

Three drip irrigation treatments were imposed, starting on 15 April and ending on 31 October (table II). Three different irrigation programs in each irrigation treatment were applied : from budburst to fruit set (4/15 to 6/15, vines were irrigated twice a week), from fruit set to veraison (6/15 to 8/15, vines were irrigated three times a week) and from veraison to harvest (8/15 to 10/1, vines were irrigated twice a week). There was one emitter per plant with a deliver rate per emitter of 4 liters per hour. A non-irrigated treatment was included as a control.

The design was a randomized complete block design with four replications. Each treatment plot contained 165 vines (512 m^2).

ET0 was calculated using the method of PRUITT (1986) from the previous 12 years data collected in a meteorological station located in the same vineyard. Vineyard evapotranspiration (ETvine) was estimated using a crop coefficient (Kc) based on those proposed by YAÑEZ *et al*., (1996).

III - ANALYTICAL PROCEDURES

Berry sampling was done weekly from veraison to harvest. Five to six berries from different parts of the cluster and from different cluster on 50 vines per plot were sampled. Berries samples (ca. 300 g) were immediately take to the winery for the analyses. The number of berries and the total weight of each sample were recorded prior to splitting into two subsamples. One subsample was frozen for anthocyanins determination and the other used for the determination of soluble solids as oBrix using an Abbé-type refractometer.

IV - ANTHOCYANINS IN THE SKIN

100 frozen berries were peeled manually and the pulp was separated from the skins. The grape skins were lyophilized and pulverized. Anthocyanin extracts were obtained by maceration of 1.5 g of lyophilized skins in methanol/HCl 0.1N (98/2, v/v).

Table II - Irrigation schedule (m^3/ha)

Calendrier d'irrigation

Date	T1	T2	T3
	m^3/ha	m^3/ha	m^3/ha
(4/15-6/15) Two irrigations per week	235	235	470
(6/16-8/15) Three irrigations per week	624	938	938
(8/16-10/1) Two irrigations per week	214	214	214
Total	1073	1387	1622

The chromatographic analysis was performed using an HPLC system with diode array detection (HP 1100, Hewlett-Packard, Philadelphia). The conditions were as follows: Lichrosphper 100 RP-18 (Merck) 5 µm column, gradient elution with 4.5 % formic acid as solvent A and acetonitrile as solvent B and a flow rate of 1.5 ml/min. The initial solvent system (90 % solvent A and 10 % solvent B) was changed from 90 % solvent A to 88 % in 20 minutes and from 88 % to 0 % in five minutes.

Detection was carried out at 525 nm. The identity of the different chromatographic peaks was confirmed from their spectral characteristics and the amount of anthocyanins was expressed as malvidin-3-glucoside using malvidin-3-glucoside chloride (Extrasynthése, France) as external standard for quantification. Total anthocyanins were calculated as the sum of the chromatographic areas corresponding to the five anthocyanin monoglucosides and the acetoyl and coumaroyl derivatives.

V - MICROVINIFICATIONS PROCEDURES

For each season, harvest was done the same day, when grapes from all treatments reached at least 23 °Brix. 100 kg of fruit from each irrigation treatment was harvested on the same day. The fruit from each treatment was crushed, destemmed and SO_2 was added (80 mg/kg). Then it was separated into three equal lots which were inoculated with selected yeasts (Fermirouge, Gist-Brocades, DSM, Netherlands). Fermentation temperature was maintained at 25 °C. The wine lots were punched down twice daily until the end of alcoholic fermentation (seven days). The skins were pressed off on day 15. Malolactic fermentation occurred without inoculation after the alcoholic fermentation had finished. After malolactic fermentation had finished the wines were cold stabilized and bottled prior to analysis.

Anthocyanins and chromatic parameters in wine: Color intensity was measured as the sum of the absorbances at 420, 520, and 620 nm and tone as the ratio between the absorbance of the wine sample at 520 nm and 420 nm. For the determination of total anthocyanins in wine, the method of the decoloration with SO_2 described by RIBÉREAU-GAYON *et al.* (1998) was used.

VI - STATISTICAL DATA TREATMENT

Significant differences among wines and for each variable were assessed with an analysis of variance (ANOVA) using Statgraphics 2.0 Plus.

RESULTS AND DISCUSSION

The vineyard in this study is located in a semi-arid area and the controlled use of irrigation is necessary, not to avoid excessive vegetative growth, but to allow the vine to develop sufficient canopy and leaf area to sustain berry growth and maturation, taking into account that at the beginning of August, predawn water potential in non-irrigated vines reached values of -1.5 Mpa in 2000 and -1.2 Mpa in 2001 and at midday, leaf water potential was around -1.93 Mpa for non-irrigated vines both years and around -1.6 Mpa for irrigated vines (De la HERA-ORTS *et al.*, 2004), values that suggest severe water stress at midday. Considering that photosynthesis decreases when water potentials reaches -0.5 Mpa and ceases around -1.2 Mpa (HARDIE and CONSIDINE, 1976), the observed values of predawn potential show that photosynthesis may be impaired the hottest months.

However, although water is very scarce and expensive and therefore only small volumes can be applied (in the experiment reported here, the equivalent of 21, 47, and 93 mm of rainfall in the three periods), the effect of these moderate irrigation treatments on the anthocyanin content of the berries, one of the main quality factor in red winegrapes, needs to be determined.

Regulated deficit irrigation is a term for the practice of regulating or restricting the application of irrigation, causing the vine water use to be below that of a full watered vine (McCARTHY, 1992). It is often practiced for the entire growing season in vineyards where water supply is limited. In this situation, irrigation water must be managed to avoid excessive water stress at critical times during season. McCARTHY (1998) established that from budbreak to flowering water stress must be reduced to a minimum. If water stress occurs budbreak will be uneven and shoot growth will be stunted. Certain Mediterranean areas are described as semi-arid and in these regions irrigation is required between budburst and flowering to ensure sufficient canopy development and a satisfactory fruit set.

From the moment of fruit set, several irrigation strategies has been applied, either from fruit set to veraison, veraison to harvest or over both periods (GOODWIN and JERIE, 1992 ; MATTHEWS *et al.*, 1987; MATTHEWS and ANDERSON, 1988; NAOR *et al.*, 1993; PONI *et al.*, 1993; PONI *et al.*, 1994 ; SIPIORA and GUTIERREZ GRANDA, 1998). In semi arid areas, severe water stress can occur from fruit set to harvest. In the experiment reported here, irrigation was only applied to minimize the water stress, to allow a good canopy to develop, to prevent the senescence of lower and interior leaves, and allow the fruit to mature properly, while providing adequate berries exposure to sunlight to the berries.

a) Productive parameters

Irrigation significantly increased yield (table III) while non-irrigated vines produced the lowest yield. Even vines irrigated with the lowest water doses (T1) doubled the non-irrigated vines yield. T3 produced the greatest num-

Table III - Mean values of the productive parameters of the non-irrigated vines and those irrigated with three different water doses

Moyennes des paramètres de production des vignes non irriguées et des vignes irriguées, avec trois quantités d'eau différentes

Productive parameter	Year	NI	T1	T2	T3
Yield (kg per vine)	2000	0.9 a	1.9 b	2.5 c	3.3 d
	2001	0.9 a	1.8 b	1.8b	2.6 c
Clusters per vine	2000	15.9 a	18.0 a	21.5 b	21.5 b
	2001	11.8 a	14.3 bc	12.7 ab	15.8 c
Berries per cluster	2000	88.0 a	109.2 b	116.2 b	121.3 b
	2001	95.4 ns	115.9 ns	116.3 ns	123.7 ns
Cluster weight (g)	2000	55.18 a	105.49 b	119.37 b	154.45 c
	2001	76.19 a	127.94 b	141.79 c	162.23 d
Berry weight (g)	2000	0.63 a	0.97 b	1.03 b	1.27 c
	2001	0.80 a	1.10 b	1.22 bc	1.34 c

Different letters within the same row mean significant differences ($p<0.05$) - ns: not significant

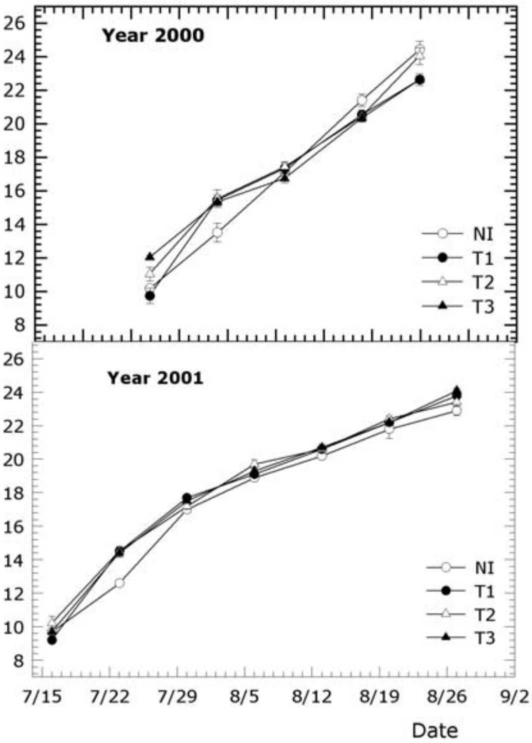

Figure 1 - Evolution of °Brix of berries from the different irrigation treatments during maturation.

Évolution du degré Brix des baies selon les différents traitements d'irrigation pendant la maturation

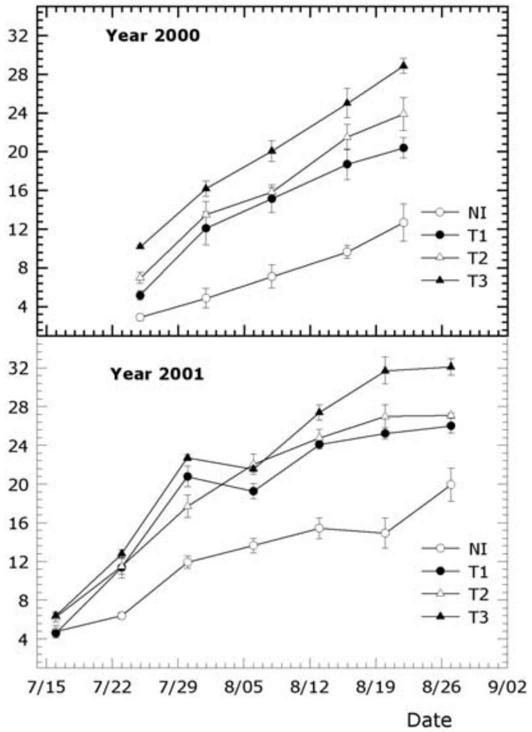

Figure 2 - Evolution of solutes per berry of berries from the different irrigation treatments during maturation.

Évolution des solutés par baie de raisins selon les différents traitements d'irrigation pendant la maturation

ber of clusters per vine, although not always statistically more than the other irrigated treatments. Irrigation also led to larger number of berries per cluster and the cluster weight of T3 vines was double than that of non-irrigated vines

The berry weight of T3 vines was significantly greater than that of the other three treatments. It is accepted that one of the main results of irrigation is an increase in berry size and weight (BRAVDO *et al.*, 1985 ; FREEMAN and KLIEWER, 1983; GARCIA-ESCUDERO *et al.*, 1997a; MATTHEWS and ANDERSON, 1988; McCARTHY, 1984). Berry size is important in determining the extraction and/or the dilution of the cell contents, which are clearly the primary site of several important solutes for winemaking. Large diameter fruit has a greater solvent-to-solute ratio as a result of the lower surface-to-volume ratio compared with smaller fruit (MATTHEWS and ANDERSON, 1988), and the role this plays in winegrape quality parameters, such as sugar and anthocyanin accumulation, needs to be studied.

b) Evolution of degré Brix and anthocyanins during ripening

There was a steady increase in °Brix during 2000 but two different phases were observed during 2001 (figure 1) when, after an initial rapid increase during the first three weeks, the rate of increase in oBrix slowed. In 2000, the rise in °Brix was similar for the four treatments and at the last sampling date, non-irrigated and T2 berries had similar °Brix. In 2001 the grapes of the irrigated vines had higher oBrix than non-irrigated vines throughout the maturation period.

Irrigated grapes had higher total soluble solids per berry (°Brix x berry weight/100) in both years (figure 2) as also found by ROBY and MATTHEWS (2004) and this may be due to a higher net photosynthesis that allowed the accumulation of solutes. A moderate water supply is necessary to maintain a satisfactory plant activity and therefore to ensure the accumulation of sugar, possibly because CO_2 absorption, sugar transport and sugar accumulation in the berry are facilitated (BRAVDO *et al.*, 1985 ; GARCIA-ESCUDERO *et al.*, 1997b ; NADAL and AROLA, 1995).

BUDIN (1983) reported that anthocyanin accumulation occurs in three phases, starting with a slow increase, followed by a rapid and linear increase and ending in a

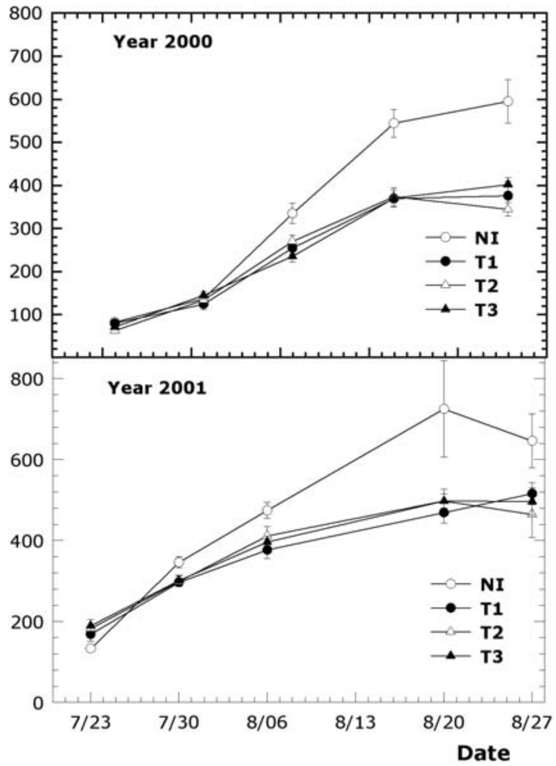

Figure 3 - Evolution of anthocyanins (mg/kg) from the different irrigation treatments during maturation
Évolution des anthocyanes (mg/kg) selon les différents traitements d'irrigation pendant la maturation

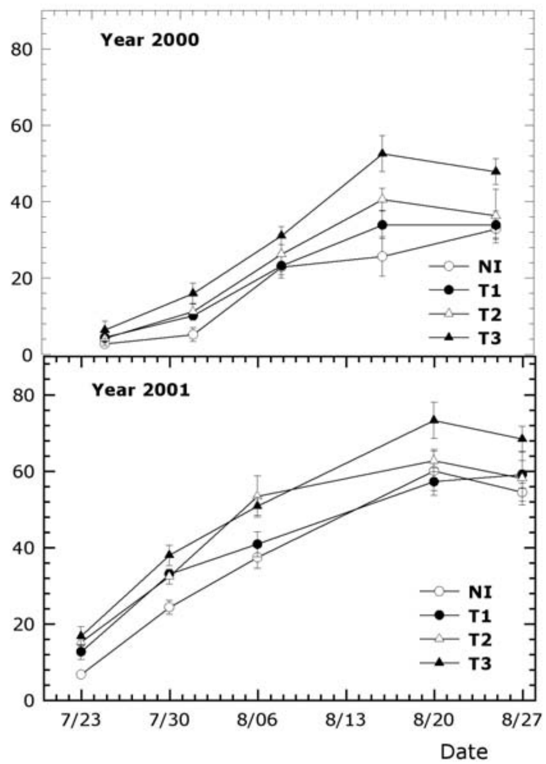

Figure 4 - Evolution of anthocyanins (mg/100 berries) from the different irrigation treatments during maturation.
Évolution des anthocyanes (mg/100 berries) selon les différents traitements d'irrigation pendant la maturation

stabilization phase. Similar results are reported here (figures 3 and 4), with total anthocyanins peaking 20-30 days after veraison and then stabilizing. A drop in concentration prior to physiological maturation was observed by GONZALEZ-SAN JOSE *et al.* (1990). FERNANDEZ-LOPÉZ *et al.* (1992) and ROGGERO *et al.* (1986) found that anthocyanin synthesis ended before sugar synthesis. Similar results were found in our experience, with non-irrigated grapes accumulating the highest concentration of anthocyanins. When the results are expressed as anthocyanin content per berry (figure 4), the grapes from T3 (the most irrigated vines) reached the highest values, results coincident with those of ROBY and MATTHEWS (2004) for Cabernet Sauvignon grapes. These differences between the results, when expressed on a concentration basis or on a per berry basis, can be attributed to a dilution effect. The lower anthocyanin content per berry in non-irrigated grapes could be explained taking into account the severe water deficit suffered by non-irrigated vines (De la HERA-ORTS *et al.*, 2004), together with very high temperatures that compromise anthocyanin synthesis. The experimental site experienced more than 90 days of temperatures over 30 °C, and under such conditions, fully exposed berries could exceed ambient temperature by 9 °C (SPAYD *et al.*, 2002). When temperature is over 37 °C, sugar accumulation is inhibited, the decrease in malic acid is very rapid and the formation of anthocyanins is limited (BERGQVIST *et al.*, 2001), either through degradation, inhibition of synthesis or both effects (SPAYD *et al.*, 2002).

c) Anthocyanins and chromatic parameters in Monastrell wines

The chromatic parameters were measured in the wines at the moment of bottling. Best chromatic characteristics were obtained in the wines elaborated from non-irrigated grapes since, in both years, the anthocyanin content was higher in these wines (figure 5) while no differences were found in wines from the three irrigation treatments. The analysis of the chromatic parameters (table IV) gave the same results, the wine from the non-irrigated vines showing the highest color intensity and the lower tone, and differences in color intensity were also found depending on the water doses, wines from T3 grapes in 2000 and T2 and T3 grapes in 2001 showing lower color intensity. BRAVDO *et al.* (1985) also reported that irrigation reduced wine quality, not only wine color but also aroma and taste.

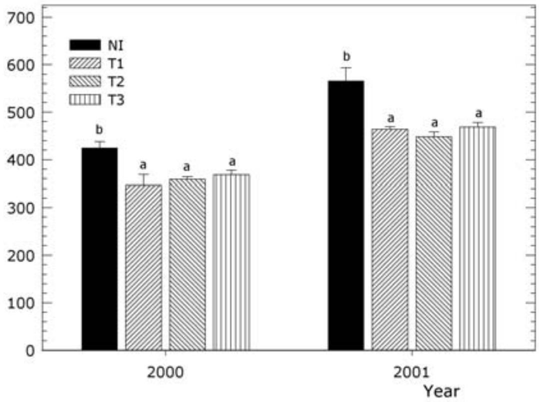

Figure 5 - Anthocyanin content in wines elaborated from the grapes of the different irrigation treatments (mg/L).
Teneur en anthocyanes dans les vins élaborés à partir de raisin provenant de vignes irriguées (mg/L), selon différentes modalités

Our results, which indicate higher anthocyanin content per berry in irrigated grapes, suggest that irrigation per se did not cause anthocyanin levels to decrease in the berry skin; rather, it was the dilution effect due to the larger berry size that caused the lower anthocyanin content in wines from irrigated vines. In very dry areas, moderate irrigation appears to be necessary to limit the severe water stress that vines suffer and to improve the very low yield from non-irrigated vines, but solutions to eliminate the resulting dilution effect need to be found. McCARTHY (1984) found that the thinning of irrigated vines resulted in a significant improvement in wine quality. The problem in this case is that the yield from irrigated vines would be similar to that of non-irrigated vines. One such way of reducing crop load per vine while still maintaining productivity per hectare may be to plant more vines per unit area. BRAVDO *et al.* (1985) suggested another option for increasing yield but not berry size which was to increase the number of bud spurs left during winter pruning time. But the number of vines per unit area or the number of bud spurs during winter pruning time are limited and controlled for the production of wines under the Origin Denomination of Jumilla and, consequently, under these conditions, the application of water will result in an increase in berry weight and a lower content of anthocyanins in wine. We should limit the application of water to the minimum doses that allow an increase in yield with only a small decrease in wine color intensity.

Other possibility we should try is a modification in the irrigation program. One option could be irrigating the vines from budbreak to fruit set enough to provide a good canopy, but reducing the amount of applied water from fruit set to veraison, as is now widely practiced on the variety Shiraz in Australia (McCARTHY, 1997 ; COOMBE and McCARTHY, 2000 ; KRIEDEMANN and GOODWIN, 2003), to reduce potential berry size, since water stress during that period reduces the number of cells per berry, and that will limit the future berry size. McCARTHY (1997) showed that berry weight decreased about 17 % when irrigation was limited prior veraison and there was no compensatory increase in berry weight when irrigation was resumed. Moreover, he stated that with this strategy, the concentration of anthocyanins was enhanced. The other option is the application of the partial root drying technique (PRD), a technique that requires that the roots are simultaneously exposed to both wet and dry zones. This results in the stimulation of some of the responses normally associated with water stress such as reduced vigor and transpiration but does not result in changes in plant water status and crop yield is relatively unaffected compared with control vines (irrigated with twice the amount of water) (LOVEYS *et al.*, 2000). Partial rootzone drying, together with an increase water use efficiency, has also shown a positive effect on fruit and wine quality. DRY *et al.* (2001) showed that °Brix was virtually identical for control and partial rootzone drying vines in a two years experiment and berries from partial rootzone drying-treated vines had significantly higher berry anthocyanins and phenolics than controls. Therefore, partial rootzone drying could have a positive effect on the synthesis or accumulation or both of secondary metabolites and investigations on the application of PRD in our vineyards are already in progress.

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Table IV - Mean values of the chromatic parameters of the wines from non-irrigated vines and from those irrigated with three different water doses

Moyennes des valeurs des paramètres chromatiques des vins provenant de vignes non irriguées et de vignes irriguées avec trois quantités d'eau différentes

Chromatic parameter	Year	NI	T1	T2	T3
Color intensity	2000	12.6d	10.8c	9.33b	8.2a
	2001	17.2c	13.1b	11.8a	12.5a
Tone	2000	0.66a	0.82b	0.90b	0.84b
	2001	0.50ns	0.57ns	0.57ns	0.58ns

Different letters within the same row mean significant differences ($p<0.05$) ; ns: not significant

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