CONTRIBUTIONS to SCIENCE, **6** (1): 115–119 (2010)
Institut d'Estudis Catalans, Barcelona
DOI: 10.2436/20.7010.01.89 ISSN: 1575-6343
www.cat-science.cat

Deficit irrigation and rootstock effects on water stress, growth, and grape composition in a Mediterranean climate

Montserrat Nadal, Josep Maria Vernet

Department of Biochemistry and Biotechnology, Rovira i Virgili University, Tarragona, Spain

Resum. Per conèixer els efectes d'un reg deficitari controlat i la resposta a dos portaempelts, 41B i 140 Ruggieri, es va escollir una vinya de quatre anys de la varietat sirà a la denominació d'origen Conca de Barberà (Catalunya, Espanya). La irrigació del vinyet comprenia dos tractaments segons la dosi d'aigua aplicada: moderat i estressat. El reg es va iniciar en mida de baia de gra de pèsol i es va aturar un cop verolat el raïm. Durant la segona etapa de la maduració, les temperatures elevades i la sequera, conjuntament amb la realització d'una poda en verd severa, van conduir a una reducció de la mida de la baia, de l'acidesa, del grau probable i dels antocians de la pell en el tractament d'estrès i el portaempelt 41B. Prolongar el calendari d'irrigació en Syrah pot resultar beneficiós per a millorar la composició i la qualitat del raïm. El potencial hídric foliar pot ser indicador de l'eficàcia del reg.

Paraules clau: irrigació · portaempelt · estrès hídric · rendiment · composició del raïm

Abstract. Irrigation trials were carried out in the Conca de Barberà (Catalonia, Spain) appellation during summer 2007. Two treatments, moderated and stressed, were tested on a four-year-old *Vitis vinifera* vs. Syrah vineyard grafted on 41B and 140 Ruggeri rootstocks. Irrigation extended from the pea berry to the veraison stages, after which it was interrupted to enhance vine stress. Excessive water deficit, extreme climate conditions, and inappropriate cultural practices during the second half of maturation interrupted the accumulation of berry compounds, with a consequent reduction of berry weight, total acidity, soluble solids, and skin anthocyanins on stressed vines/41B. The results of this trial support the implementation of an irrigation schedule that extends the period during which the vines are watered. Leaf water potential could be used as an indicator of the efficacy of irrigation.

Keywords: irrigation · rootstock · water stress · yield · grape composition

Introduction

Wine quality is closely related to the composition and quality of the grapes. Environmental factors, cultural practices, and variety characteristics determine the yield and quality of a vintage. In Mediterranean regions, the high temperatures and low rainfall typical of the growing season can reduce vine water status and compromise vine growth, yield, and grape quality. Under such conditions, low-level irrigation has been shown to minimize the effects of vine stress and improve grape quality [1–4,6,9].

In this study, deficit irrigation was performed, with the schedule determined based on vine-development periods (active growth, veraison, and ripeness). The irrigation regime was monitored using soil-moisture probes, and vine growth by dendrometry. Throughout the growing season, parameters such as water status, yield, and berry composition were evaluated.

Correspondence: Montserrat Nadal, Facultat d'Enologia, Departament de Bioquímica i Biotecnologia, Campus Sesclades, Universitat Rovira i Virgili, Marcel·lí Domingo 7, 43007 Tarragona, Spain. Tel. +34-977558798. Fax +34-977588332. E-mail: montserrat.nadal@urv.cat

Material and methods

Site description and plant material. The trial was carried out from June to September 2007 in a commercial 5-year-old vineyard in Vimbodí (Catalonia, Spain), within the Conca de Barberà appellation (41°22´ N, 1°02´ E; 450 m). Plants of *V. vinifera* vs. Syrah clone 300, grafted on 41-B and 140 Ruggeri (Ru) rootstocks and planted at a row spacing of 1 × 2.6 m (3850 vines/ha), were studied. Pruning was done according to the vineyard manager's practice of a bilateral cordon with 12–14 shoots per vine. The canopy was managed mechanically and manually, including green pruning, cutting of the shoot tips, and removal of immature clusters and leaves. The climate characteristics of the area are presented in Table 1. The soil is calcareous, with a pH 8.0 and an active calcium concentration of 15%. Evapotranspiration (ETo) data were collected from the ADCON weather station placed in the vineyard (transmitting data to ADCON AddVANTAGE PRO 5.00 software every 15 min during the entire season). The ETvine was calculated using a Kc proposed by Peacock [10], based on the proportion of soil surface shaded by the canopy.

Table 1. Climate characteristics (2007 season)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Temperature	6	8.3	8.9	11.8	16.1	19.3	21.7	21.2	18.1	13.3	8.7	4.6
Rainfall	6.2	19.2	18.4	151.8	51.4	36.6	1.4	19	10.6	58.2	0	27.8
r humidity	78.4	71.2	59.4	76.7	60	62.8	60	61	68.2	74.9	69.9	81.6

Experimental design. Experimental blocks were established for three rows grafted on 41B rootstocks and three rows grafted on 140Ru rootstocks. The irrigation system was divided into two areas, allowing two treatments simultaneously: moderate (RM) and deficit (RD). Each of the four treatments were carried out in triplicate. The irrigation schedule was dependent upon the vine development stage. Starting on 19 June, during active growth, irrigation was set at 40% ETvine for the RM treatment and 20% ETvine for the RD treatment; in July, it was reduced to 25% ETvine and 13% ETvine on the RM and RD blocks, respectively. Veraison occurred on 6 August and marked the end of irrigation. To enhance the ripening process, a single irrigation was carried out on 15 September with 40% ETvine and 20% ETvine for RM and RD blocks, respectively. The irrigation system was composed of integrated pressure-compensated droppers (UNIWINE 17/120, 2.6 l/h) placed between the vines.

Measurements and analysis. Leaf water potential was measured weekly at 7:00 h and 11:30 h (local time) using a Scholander chamber. Plant sensors (Verdtech PLANTSENS) placed on two vines per block registered vine growth by measuring trunk diameter taken every 15 min throughout the period. To evaluate the leaf area, the length of the main nerve of the leaf was measured and the leaf area calculated according to a first-order polynomial equation. Six spurs of one arm per vine of the lateral cordon were chosen for the measurements. The main nerve of every 2 leaves in each spur was measured.

Grape composition. Every week, beginning at veraison, 400 grapes were sampled randomly for ripeness control as follows: 100 berries were weighed and the probable degree (gap), titratable acidity (ATT), and pH were analyzed. The anthocyanin concentration in the skins was determined by preparing extracts at pH 1 (8 methanol: 2 HCl) and measuring the absorbance at 535 nm [11].

Results and Discussion

The results of the global irrigation trial were analyzed with respect to vine development, water vine status, and mesoclimate conditions, and yielded a defined pattern for all measured parameters.

Leaf water potential (Ψ) measured at 9:00 h (solar time). Statistical differences in Ψ between RM and RD treatments were recorded during the entire season (Fig. 1). Measurements of Ψ at 5:00 h had the same patterns as those at 9:00 h (data not shown).

Beginning on 19 June (day 47 after bloom), during the first irrigation period, moderate irrigation and gentle climate maintained Ψ at a high level, with very few significant differences. The minimum values of Ψ at this stage were close to –0.6 MPa for both the RM and RD plots. During the second phase, which began on 1 July (day 59 after bloom), the irrigation schedule was reduced. Deficit irrigation and higher temperatures progressively increased the water deficit, such that Ψ dropped and differences among the irrigation treatments were significant. The Ψ of RD blocks diminished earlier than the Ψ of RM blocks, reaching the lowest values for 41B rootstock; –1.21

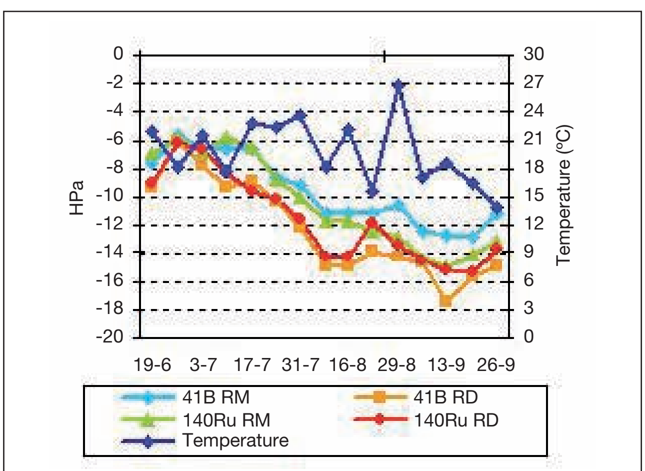

Fig. 1. Leaf water potential and air temperature (2007). (RM) moderate irrigation, (RD) deficit irrigation.

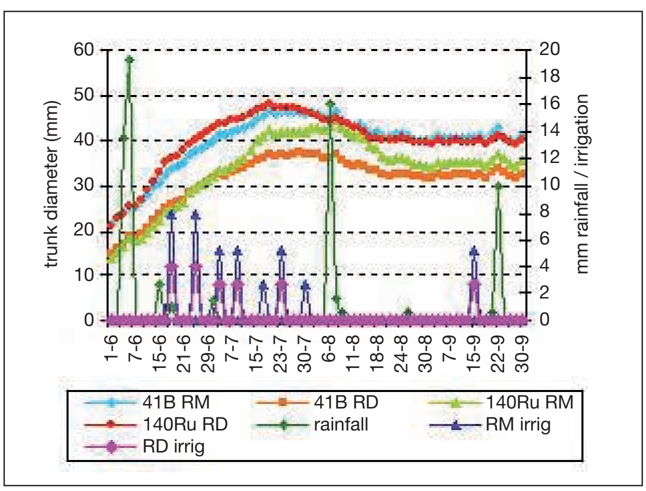

Fig. 2. Vine growth during the summer 2007. (RM) moderate irrigation, (RD) deficit irrigation.

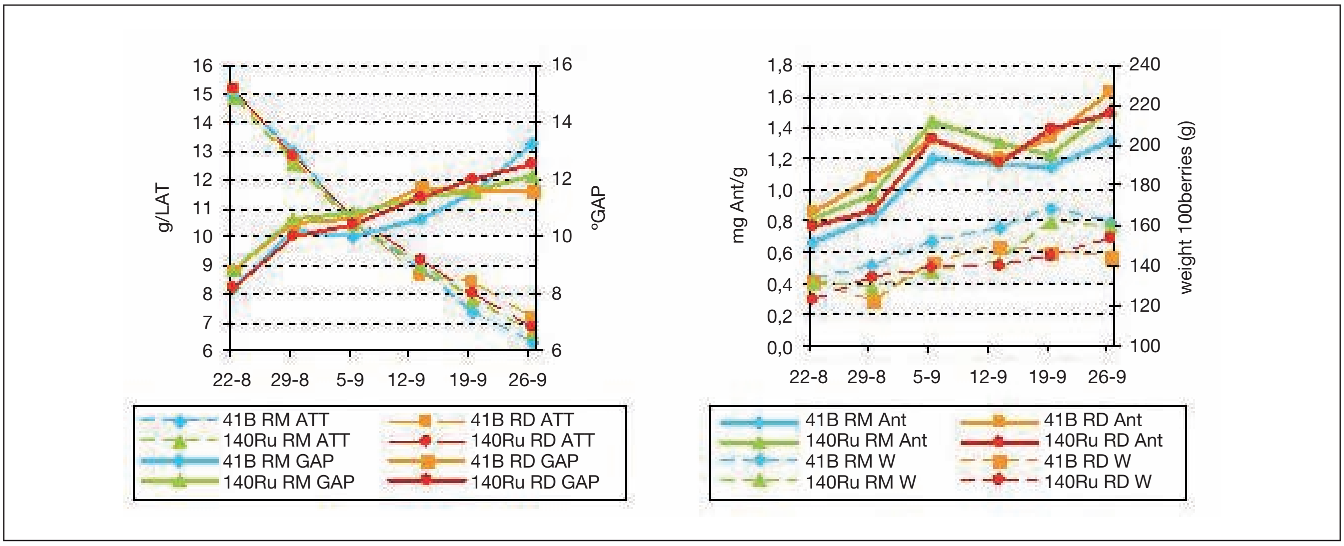

Fig. 3. Evolution of berry composition: acidity (ATT) and probable degree (gap); berry weight (w) and skin anthocyanins (Ant). (RM) moderate irrigation, (RD) deficit irrigation.

MPa for RD and –0.91 MPa for RM treatments at the end of July. There were no differences between rootstocks. The third period started at veraison (6 August, day 95 after bloom). To enhance vine water stress during ripening, irrigation was interrupted such that the vines were under the influence of mesoclimate conditions only. During this period, the Ψ continued to diminish, reaching about –1.15 MPa for RM and –1.45 MPa for RD blocks. The drop in average temperatures in the middle of August prevented the decrease of Ψ, which was more evident in RD treatments. By contrast, an important rise in temperature together with the low humidity at the end of August and beginning of September (days 120–125 after bloom) produced a new decrease in Ψ and, as a consequence, differences between rootstocks. The Ψ of 140Ru plots were –1.52 MPa while the Ψ of 41B blocks had a more pronounced drop, especially in response to RD treatment, reaching –1.75 MPa. 140 Ru rootstock is able to maintain. For a period of eight days in August, the differences between the day/night temperatures were very erratic. At the end of the month, pronounced changes were observed such that during the first and second week of September, sugar accumulation in the berry decreased, probably due to the mesoclimatic conditions and to the reduction of vine foliage [5]. As a result, an additional irrigation was carried out to ensure grape ripeness.

Vine growth. The same patterns distinguishing the three periods with respect to leaf water potential were observed for vine growth (Fig. 2). Throughout the first period, there was a marked increase in trunk diameter with all treatments. Daily trunk dilations, registered by dendrometry, were positive and high. The differences between irrigation blocks were small (1.29% higher in the RM group) but greater between rootstocks, with 19.4% more growth registered for 140Ru than for 41B. During the second phase, the slope of vine growth decreased until it completely stopped at the end of July in all treatments, indicating the proximity of veraison. Daily dilations of the trunk were positive. Differences between irrigation increased during this stage such that the RM blocks grew 11.7% more than the RD blocks. Between rootstocks, the differences diminished such that the growth of 140Ru was only 4.2% higher than that of 41B. The last period (August) began with a decrease in trunk diameter: 13.9% for 41B rootstocks and 16.8% for 140Ru rootstocks. The decrease was 2.9% greater in the RD treatment group. Daily dilations were negative, evidencing the loss of water, and were followed by a stationary period until harvest, when global growth was 20.2% higher for the 140Ru rootstock and 17.2% higher for RM irrigation treatments. The decrease in August was due to a decrease in transpiration and to the lignification process of the spurs. These results demonstrate that irrigation and rootstock were influenced by irrigation differences. It thus can be concluded that 140Ru rootstock is more vigorous than 41B, while deficit irrigation results in diminished vine growth.

Leaf area per vine. Cultural practices hardly influences the foliar surface and canopy structure, such that the leaf area was

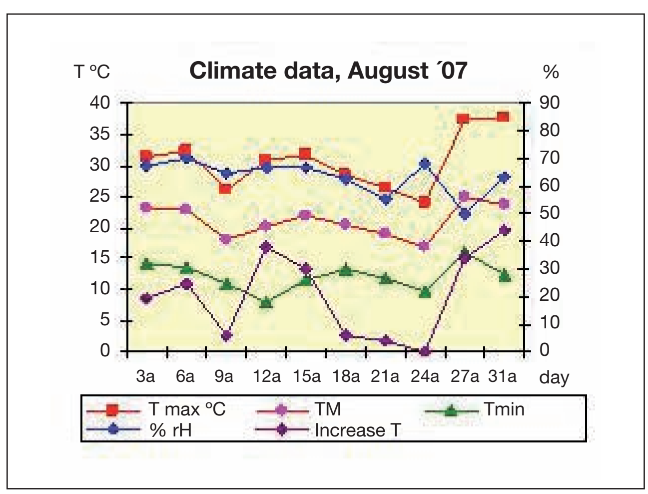

Fig. 4. Temperatures (maximum, minimum, average) and relative humidity of August 2007. Increased T calculated by percentage of the increment considering the lowest temperature average (16.8° C).

Table 2. Yield and grape composition at harvest

Harvest	pD	ATT	pH	kg/ vine	Berry weight	Grape weight
41B RM	13.27	6.50	3.35	5.68	1.62	182.7
41B RD	11.57	7.77	2.99	6.00	1.44	117.8
Irrigation effect	*	*	**	ns	ns	ns
140Ru RM	12.57	6.63	3.13	6.79	1.67	181.4
140Ru RD	12.13	7.00	3.39	6.09	1.61	181.3
Rootstock effect	ns	ns	ns	ns	**	ns
Interaction	**	**	ns	ns	**	ns

pD = probably degree; ATT = titratable acidity; and yield components.
Variance analysis and Fisher test with *$P < 0.05$; **$P < 0.001$. Data are mean values of triplicates.

noticeably reduced at ripeness because of severe lateral immature grape thinning. Measurements showed that foliar surface was about 3 m^2/vine at pea berry stage, 2.5 m^2/vine at veraison, and 1.25 m^2/vine at ripeness. The inadequate canopy harmed the ripening process, leading to variations in berry composition and quality [12].

Grape composition. Ripening was characterized by an increase in water stress throughout the entire observation period. The grape sugar content (as opposed to the acidity content) increased at the beginning and during the first part of the ripening process until the first week of September (Fig. 3). Due to the high temperatures registered at the end of August and, probably combined with the large differences in day/night temperature (Fig. 4), sugar accumulation stopped 3 weeks before harvest, while leaf water potentials decreased concurrent with dehydration of the berries. The extreme drought at the end of the ripening process resulted in vine defoliation, which could explain the imbalance in berry composition [2,6,7].

The anthocyanin concentration increased for all treatments during August, followed by a shift to a faint decrease. This pattern was probably due to a metabolic depression caused by the intense water deficit [7]. At harvest, there were significant differences according to irrigation treatments and in 41B rootstocks, with the anthocyanin concentration higher in RD plots than in RM plots. Differences in sugar content were significant only for 41B (13.2° RM; 11.6° RD) and for the pH of both rootstocks, being lower in the RD treatment groups (Table 2). Berry weight increased regularly until 13 September and did not show significant differences between irrigation treatments, except in the two last controls, with higher weights on the RM plots. At harvest, berry weight decreased in all treatments, most likely due to dehydration of the berries, as already observed by other authors for this variety [9,8].

Conclusions

Moderate irrigation had a greater effect on rootstock 41B than on rootstock 140Ru. Under deficit irrigation, 41B grew less and had a lower leaf potential, a lower sugar content, and a higher acidity than 140Ru. The anthocyanin content of 41B was higher under drought conditions as a consequence of the decrease in weight (shrinkage of berries).

Water stress in the last period of ripeness, because of the increase and variability in temperature, impeded progressive accumulation of the quality compounds that affect berry weight and the balance of berry composition at harvest. Thus, an extended irrigation after veraison is recommended for syrah grapevines in order to improve grape composition and quality. Dendrometry data cannot be used as indicators for irrigation during and after veraison.

Acknowledgements

We thank Cal Celdoni and, especially, Albert Magrinyà for their technical assistance, Rachel Ritchie for the English revision, and The National Project CICYT (ref. AGL 2008 04525-CO2-O2) for financial support.

References

[1] Esteban MA, Villanueva MJ, Lissarrague JR (2002) Relationships between different berry components in Tempranillo (*Vitis vinifera* L.) grapes from irrigated and non-irrigated vines during ripening. J Sci Food Agric 81:409-420
[2] García Escudero D, Santamaría P, López R, Palacios I (1991) Aplicación de dosis moderadas de agua en el proceso de maduración del cv. Tempranillo en Rioja. Vitivinicultura 2, 1:30-34
[3] Goldhamer D, Fereres E (2001) Irrigation scheduling protocols using continuously recorded trunk diameter measurements. Irrigation Science 20:115
[4] Gurovich LA (2006) El dendrómetro como indicador directo de la irrigación óptima de las vides entre envero y vendimia. Viticultura/Enologia Professional 105:13-20
[5] Kliewer WM, Fuller RD (1973) Effect of time and severity

of defoliation on growth of roots, trunk, and shoots of "Thompson Seedless" grapevines. Am J Enol Viticult 24: 59-64

[6] Nadal M, Arola L (1995) Effects of limited irrigation on the composition of must and wine of Cabernet Sauvignon under semi-arid conditions. Vitis 34:151-154

[7] Nadal M, Lampreave M (2007) Influencia del riego en la maduración polifenòlica de las bayas. Experiencia del riego en la comarca del Priorat, DO Montsant. In: Baeza Trujillo P, Lissarrague JR, Sánchez de Miguel P (ed) Fundamentos, aplicación y consecuencias del riego en la vid. Agrícola Española, Madrid, pp. 231-256

[8] Nadal M, Volschenk N, Hunter JJ (2004) Phenolic extraction during fermentation as affected by ripeness level of Syrah/R99 grapes. Int confer on Viticultural Zoning 2004, Cape Town, South Africa

[9] Ojeda H, Andary C, Kraeva E, Carbonneau A, Deloire A (2002) Influence of pre- and postverais on water deficit on synthesis and concentration of skin phenolic compounds during berry growth of *Vitis vinifera* cv. Shiraz. Am J Enol Vitic 53:261-267

[10] Peacock WL, Christensen LP, Andri HL (1987) Development of a drip irrigation schedule for average-canopy vineyards in the San Joaquin Valley. Am J Enol Vitic 38: 113-119

[11] Ribéreau-Gayon P, Glories Y, Maujean A, Dubourdieu D (2000) The Handbook of Enology (vol. 2): The chemistry of wine and stabilization and treatments. John Wiley & Sons, Chichester, England

[12] Smart R (1985) Principles of Grapevine Canopy Microclimate Manipulation with Implications for Yield and quality, a Review. Am J Enol Vitic 36:230-239

About the authors

Montserrat Nadal has a Ph.D. in Biology from the University of Barcelona. She is Professor of Viticulture in the Department of Biochemistry and Biotechnology at Rovira i Virgili University in Tarragona, a position she has held since December 1988. She currently manages the experimental winery of the Oenology Faculty of the University of Tarragona (since May 2004), and is a producer of commercial wine in the well known Priorat AOC region in Tarragona, Spain. Her research interests include soil, climate change and irrigation effects on grape composition with particular focus on the phenol content of grapes and the impact on the quality of wine. She currently participates in 12 National Research Programs, has worked in 17 projects with companies related to the fields of Oenology and Viticulture, and has published 30 scientific papers in national and internationals journals.

Josep Maria Vernet has a Master's degree in Oenology from Rovira i Virgili University, in Tarragona. He has carried out research in viticulture at the Victor Segalen University in Bordeaux and is currently a wine maker assistant, responsible of the viticulture and oenology departments, at the "*Castell del Mirall*" winery, in the Penedes AOC region (Catalonia, Spain). He has worked in different wineries in Tarragona (Montsant AOC, Conca de Barbera AOC, and Terra Alta AOC) and in Mendoza, Argentina.