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Development of Irrigation Program using Leaf Water Potential in Royal Table Grape Variety in the Mediterranean Region

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Abstract: This research was conducted over two consecutive years 2009-2010 in the Cukurova conditions of Turkey on Royal table grape variety in order to determine the optimal timing of irrigation for high quality yield using mid-day leaf water potential values. In the study, six different treatments based on irrigation treatments; full irrigation (FI), soil water deficit in the 80 cm within the seven-day intervals was replenished to the field capacity; deficit irrigations, DI_{50}; DI_{75}; and Partial Root-zone Drying PRD_{50} which received, respectively 50, 75 and a control treatment (non irrigated). .Irrigation interval of 7-day used for all irrigated treatments Experimental design is randomized blocks with three replications. In general, irrigation treatments had significant effect on yield at 1% level. The differences can be attributed to varying weather and soil water conditions occurred in the experimental years. Highest yield was obtained from the full irrigation as 28.6 t ha^{-1}, and the lowest yield was obtained non-irrigated control treatment 12.5 t ha^{-1}. Leaf water potential (LWP) were measured throughout the growing season with a pressure chamber. Highest yields of Royal table variety can be obtained when irrigated at LWP value Ψ = -1.17 MPa. The results revealed that LWP can be used for irrigation scheduling of grapes.

Keywords: Grapevine, Leaf water potential, Drip irrigation, Partial root zone drying, Deficit irrigation.

Akdeniz Bölgesinde Royal Sofralık Üzüm Çeşidinde Yaprak Su Potansiyeli Kullanılarak Sulama Programının Oluşturulması

Bu araştırma Royal sofralık üzüm çeşidinde farklı sulama düzeylerinin gün ortası yaprak su potansiyeli (LWP) değerlerini kullanarak en yüksek verim için optimum sulama zamanının belirlenmesi amacıyla 2009-2010 yıllarında Çukurova Bölgesinde yürütülmüştür. Çalışmada, altı farklı sulama konusu ele alınmıştır: Tam sulama konusu (FI), haftalık sulama aralığında 80 cm'lik toprak profilindeki eksik neminin tarla kapasitesine getirildiği konu; kısıntılı sulama DI_{75}, DI_{50} ve PRD_{75}, PRD_{50}; FI konusuna uygulanan suyun sırasıyla %75'inin ve yarısının verildiği konu; susuz konusu ise sulanmayan tanık konu olarak alınmıştır. Sulama aralığı 7 günde bir yapılmıştır. Çalışma tesadüf blokları deneme desenine göre üç yinelemeli olarak yürütülmüştür. Sulama konularının omca verimi üzerine etkileri istatistiksel olarak %1 düzeyinde önemli bulunmuştur. Deneme yılları arasında iklim ve toprak su içeriğine bağlı olarak farklılıklar görülmüştür. En yüksek verim FI konusunda 28.6 t ha^{-1}, en düşük verim sulanmayan tanık konuda 12.5 t ha^{-1} elde edilmiştir. Yaprak su potansiyeli (LWP) yetişme dönemi boyunca basınç odacığı kullanılarak ölçülmüştür. Royal sofralık üzüm çeşidinde gün ortası LWP Ψ = -1.17 MPa değeri sulanmasıyla en yüksek verim alınmıştır. Sonuçta asma bahçelerinde LWP kullanılarak sulama programının oluşturulabildiği görülmüştür.

Anahtar kelimeler: Asma, Yaprak su potansiyeli, Damla sulama, Kısmi kök kuruluğu, Kısıntılı sulama

Introduction

Grapevine is one of the most widespread crops worldwide, and Turkey has an ancient vineyard growth culture. Turkey is ranked 5th in acreage devoted to vineyars (435 000ha), and 6th in the fresh grape pruduction (4Mt) in the world (TUIK, 2016). Mediterranean and Eagean region of Turkey has the most suitable environmental conditions for grape production. Mediterranean region is ranked as second to the Agean region both in acreage and production. Suitable climatic conditions for earliness is of paramount importance for grape production.

Water shortage in the Mediterranean climatic region is the most important factor limiting plant production. High evaporation rate and limited water resources in the Mediterranean region results in water stress in vineyards, and low yields (Jones, 1983; Patakas and Noitsakis, 1997).The previous studies showed that the irrigation increased yield and quality significantly (Matthews and Anderson, 1989; Santos *et al*., 2003, 2005;Gachons *et al*., 2005; Zabihi, 2006; Bozkurt Çolak *et al*., 2017).

Several studies have been carried out on the irrigation techniques to ensure efficient use of water in areas where water resources are limited.The application of drip irrigation in areas where water resources are limited or expensive is also advantageous in terms of uniform water distribution and use of chemicals in the economic direction (Gökçel, 2008).

Different water management methods have been developed to increase the water savings provided by drip irrigation. In recent years, limited and partial irrigation can be said to be very effective in water shortage conditions. In the Partial Root-Zone Drying (PRD) method, wet and dry areas are formed in the plant root zone by giving irrigation water from alternative sources.The PRD method was carried out in many orchards (Zhang and Davies, 1990; Tardieu *et al*., 1992; Dry *et al*., 2001; Kang and Zhang, 2004; Chaves *et al*., 2007; Fereres and Soriano, 2007; Ağar, 2010).The PRD method has shown that the amount of water applied decreases considerably, but improves the plant canopy structure which in turn increases the yield more effective than other irrigation strategies.

Leaf water potential is a measure commonly used to describe crop water status and waterstress dynamics. Measurement and knowledge of plant water relations is required to understand the interactions between the plant and the surrounding environment. Water potential gradients help to explain the water flux in the soil-plant-atmosphere continuum. In spite of diurnal fluctuations, leaf water potential can be used to describe the plant water status and as an indicator of overall plant water stress (Hsiao, 1973; Tardieu and Katerji, 1990; Rana *et al*., 2004). For grapevines, leaf water potential has been used for irrigation scheduling by Wample *et al*. (2005) and Deloire *et al*. (2005), among others. Leaf water potential measurements have been made primarily using the pressure chamber technique (Schollander *et al*., 1965).

The objectives of the present study were to: (i) evaluate LWP for differentially irrigated Royal table grapevines (*Vitis vinifera* L.) grown in the Mediterranean region of Turkey; (ii) determine the effect of water stress occurring during the growing season on yield and water use efficiency of grapevines irrigated by a drip system; (iii) compare deficit irrigation (DI) and partial root drying (PRD) strategies on their effects on water relations, growth, and yield of grapevines.

Materials and Methods

The research was conducted during the growing seasons of 2009 and 2010 in the experimental of Viticulture of Department of Horticulture of Faculty of Agriculture at Çukurova University has been conducted. In the province of Adana in the Mediterranean climate zone, winters are mild and rainy and summers are hot and dry. Long-term average precipitation is 670.8 mm, long-term average temperature is 19.1°C and annual evaporation is 1536 mm.The rainfall received during the growing seasons (March through July) was 221 mm in 2009 and 167 mm in 2010.

The soil of the experimental site is classified as sandy-loam. Some physical and chemical properties of the experimental soil are given in Table 1. In the root zone, soil water contents at the field capacity and permanent wilting point are 317 and 131 mm, respectively and available water in the upper 0.80 m of the soil profile depth is 186 mm. The pH of the soil varies between 7.67-7.81; the salt content is 0.402-0.459 dS m^{-1}; mean bulk density 1.37-1.47 g cm^{-3}; the field capacity varies between 25.2-29.4 % and the wilting point is between 9.4-12.7 %.

Table 1. Some features of the research area of soil
Tablo 1. Deneme yeri topraklarının bazı özellikleri

Soil depth (cm)	Texture class	Field capacity (%)	Wilting Point (%)	Bulk Density (g cm^{-3})	pH	E.C. (dS m^{-1})
0-20	SL	25.19	12.71	1.47	7.81	0.459
20-40	SL	29.42	12.20	1.40	7.78	0.423
40-60	SL	27.97	11.91	1.37	7.72	0.402
60-80	SL	29.05	9.37	1.44	7.67	0.440

In the study, six different treatments were considered; namely full irrigation (FI), deficit irrigations (DI_{75} and DI_{50}), partial rootzone drying (PRD_{75} and PRD_{50}) and rainfed (RF). In FI soil water deficit in the 80 cm within the seven-day intervals was replenished to the field capacity. DI_{75}, DI_{50}, and PRD_{75}, PRD_{50} treatments received 75 and 50 % of water applied to FI. In PRD plots, drip laterals on both sides of the vine rows operated alternately. Irrigation interval of 7-day used for all irrigated treatments.

This study was carried on 12 years old Royal table grape variety grafted on American rootstock. Experimental designwas randomized blocks with three replications. Vines were planted at 2.5 m plant spacing and 3.0 m row spacing. Canopies were guyot-trained and rows were oriented in North-south direction. Each sub-plot contained 8 vines (8 * 2.5 m= 20 m) with a plot length of 20 m.

Drip irrigation system was used in the study. In the study, a single drip lateral was laid in each plant row for FI, DI_{75}, DI_{50} treatments, and laterals with inline emitters with discharge rate of 2.3 l h^{-1} spaced at 50 cm intervals were used (Betaplast Corp., Adana, Turkey). In PRD plots, two drip laterals were placed on both sides of the vine rows at 20 cm away from the vine row. The system was operated at 100 kPa throughout the growing season. Water was supplied from the concrete pool with a volume of 200 m^3 by means of a pump.

Soil water content was measured by gravimetric sampling method in the first layer of soil profile (0-20 cm), in the 20-80 cm soil depth water content was measured by neutronmeter method with increments of 20 cm and continued until end of the growing season. The aluminum access tubes of 1.0 m in length were installed in the center of vine row and 25 cm away from the vine stem in the experimental sub-plots. A total of 18 access tubes were installed in the study. Neutron meter was calibrated in the site and the calibration equation for the neutron probe was Pv =63.684 CR–10.544 (R^2=0.87**, Pv: volumetric soil water content; CR: count ratio) (Yazar et al., 2010). Crop water use or evapotranspiration (ET) was calculated with the water balance equation (Howell *et al*., 1986). Water use efficiency (WUE) for each treatment was calculated as total yield divided by seasonal evapotranspiration (ET). Irrigation water use efficiency (IWUE) was determined as (Zhang *et al*., 1999);

$$IWUE= (Y_1-Y_{NI})/I$$

Where, Y_1 is the total yield of irrigation treatments (t ha^{-1}), Y_{NI} is the total yield of non-irigation treatment (t ha^{-1}) and I is the amount of irrigation water (mm).

Equal amounts of fertilizer were applied to all treatments. N fertilization was applied during bud break and after the fruit set; and each application 70 kg ha^{-1} N was applied on both sides of a vine row and incorporated into soil. Urea was used as N fertilizer source (% 46 N).

Midday leaf water potential (LWP) was measured with a pressure chamber (PMS Instrument Company, Model 615, Albany, USA) prior to irrigations once a week throughout the growing season (Scholander *et al*., 1965). All measurements were done between 12:30 to 14:30 h, and two leaves were measured per experimental unit. For this purpose the two fully developed sunlit leaves of a plant in each plot and the average of two measurements made on the day was taken as mean the midday leaf water potential value for the plot.

Data were analysed statistically using JMP Statistical software developed by SAS (SAS Institute, Inc., Cary, NC, USA). Treatment means were compared using LSD test (Steel and Torrie, 1980).

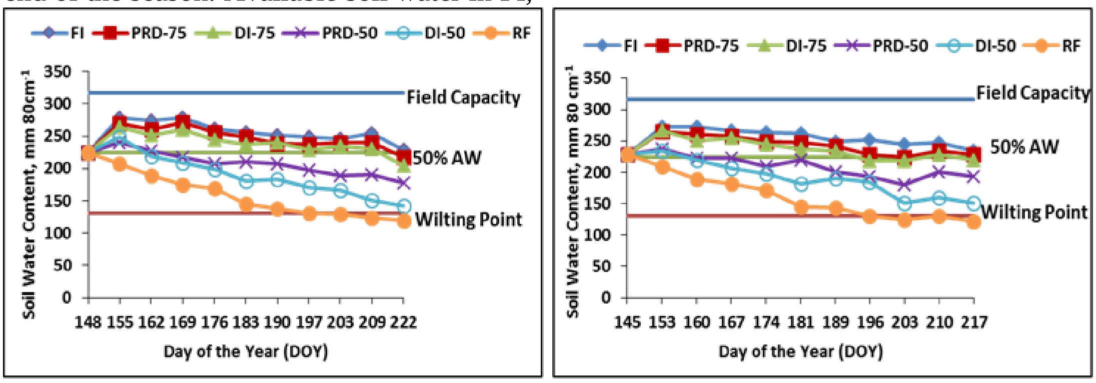
Results and Discussion

The start and end dates of the development periods of the grapevine were observed in the experimental years. Phenological observation dates for experimental years are given in Table 2. The results revealed that after the vegetative stage, the occurrence of flowering, veraison and harvesting stages of grapevine were observed at a later date in the deficit irrigation treatments compared to unstressed treatments (FI).

Table2. Phenological observation dates for experimental years
Tablo 2. Deneme yıllarında fenolojik gözlem tarihleri

Development Periods	2009	2010
Bud Break	26.03.2009	16.03.2010
Flowering	12.05.2009	30.04.2010
Veraison	10.07.2009	25.06.2010
Harvesting	09.08.2009	04.08.2010

Profile soil water storage variations during the three growing seasons for each irrigation treatment are shown in Fig. 1a-b. Temporal variability of soil water content (SWC) in 2009 and 2010 charaterized by an gradual decrease in soil water content in response to deficit irrigations towards the end of the season. Available soil water in FI, PRD_{75} and DI_{75} treatment plots remained above 50% throughout the growing seasons and followed similar trends. On the other hand, in deficit irrigation treatments (DI_{50} and PRD_{50}) SWC remained below the 50% available water.



a b

Figure 1. Soil water storage variation during the Royal table grape variety in the 2009 and 2010 growing seasons in all treatments (a: 2009; b:2010)
Şekil 1. Royal sofralık üzüm çeşidinde 2009 ve 2010 bitki büyüme mevsimi boyunca toprak su içeriğinin değişimi (a:2009, b:2010)

However, SWC in the PRD_{50} plots remained higher than SWC in DI_{50} plots in three experimental years. In RF treatment SWC remained between 50% available water and wilting point during most of the growing season, and fell below with the wilting point towards the end of the season in the experimental years.

The amount of total irrigation water, seasonal evapotranspiration (ET), yield, water use efficiency (WUE) and irrigation water use efficiency (IWUE) values for the different treatments are given in Table 3.In the first year of the research, the irrigation was started on 28.05.2009 (DOY-148) and ended on 28.07.2009 (DOY-209). Water was applied to the full irrigation (FI) in total 599 mm, PRD_{75} in 449 mm, DI_{75} in 449 mm, PRD_{50} and DI_{50} in 300 mm water. Water was not applied to the control. In the second year of the experiment, the irrigation started on 25.05.2010 (DOY-145) and ended on 28.07.2010 (DOY-210). Water was applied to the full irrigation (FI) in total 612 mm, PRD_{75} and DI_{75} in 459 mm, PRD_{50} and DI_{50} in 300 mm, respectively. Water was not applied to the control. A total of 10 irrigation applications were made in each experimental year.

The total precipitation for the period from bud break to harvesting is in the first year of the study (2009) 221 mm and in the second year (2010) total precipitation 167 mm. Grapevine evapotranspiration (ET) varied from 331 mm in RF to 820 mm in FI treatment plots in the 2009, from 274 mm in RF to 773 mm in FI in the 2010 (Table 3). The seasonal evapotranspiration (ET) increased with the increasing amount of irrigation. Conventional DI_{50} and DI_{75} treatments resulted in slightly higher ET than PRD_{50} and PRD_{75} treatments despite receiving the same amount of irrigation water.

The yields of grapevine in harvested plots were determined by weighing and the average grapevine yields obtained from the subjects were determined. Data on the yield are presented in Table 3. Table 4 provides statistical analysis results on yield of grapevine. Yield values ranged from a low of 14.5 t ha^{-1} in RF to highest 35.3 t ha^{-1} in the FI in 2009 and ranged from a low of 10.5 t ha^{-1} in RF to highest 21.9 t ha^{-1} in the FI in 2010. Irrigation levels resulted in significantly different yields ($P < 0.01$). The FI treatments in three years resulted in significantly higher yields. Water stress reduced grapevine yield significantly. Tangolar *et al*. (2015) studied the effect of different bud loads and irrigations applied at different leaf water potential levels on Kalecik Karası grape varieties. The increase in grape yield of irrigated vines in relation to nonirrigated ones was 53.3 and 54.3%. It is well established that crop growth and yield decrease with increasing water stress (Yazar *et al*., 2010). Therefore, deficit irrigation can contribute to save water in irrigated table grapevine production. Our results are in agreement with those obtained by Yazar *et al*. (2010) who demonstrated that water stress resulted in a reduction of fresh fruit yield and fruit size of table grapevines of Flame Seedless, Italia, and Alphonse Lavalle in the Mediterranean region of Turkey. Şener and İlhan, (1992) in the Aegean region, obtained a yield of 25.6 t ha^{-1} from the full irrigation on Round Seedless table grape variety.

The values of water use (WUE) and irrigation water use efficiency (IWUE) in the study year are given in Table 3. Generally, as the applied irrigation water increases, WUE and IWUE values decrease. WUE values ranged froma low of 3.18 kg m^{-3} in DI_{50} to highest of 4.51 kg m^{-3} in the PRD_{75} in 2009 and ranged from 2.27 kg m^{-3} in DI_{50} to 3.84 kg m^{-3} in the RF in 2010. Table 4 provides statistical analysis results on WUE and IWUE of grapevine ($P<0.01$). PRD_{75} resulted in greater WUE values than FI treatment in the experimental years. Ağar (2010) reported the highest WUE value in PRD_{50} treatment as 3.78 kg m^{-3} for Kings Ruby table grape. Gündüz *et al*. (2008) reported WUE values for fully irrigated grapevines in Aegean conditions varying between 4.28 and 8.71 kg m^{-3}.

Table 3. Royal table grape variety yield, irrigation, ET, WUE and IWUE values under different treatments

Tablo 3. Royal sofralık üzüm çeşidinde farklı konularda verim, sulama suyu miktarı, su kullanım randımanı ve sulama suyu kullanım randımanı değerleri

Years	Treatments	Irrigation (mm)	ET (mm)	Yields (t ha^{-1})	WUE (kg m^{-3})	IWUE (kg m^{-3})
2009	FI	599	820	35.2 a	4.30 b	3.45 a
	PRD_{75}	449	680	30.6 b	4.51 a	3.59 a
	DI_{75}	449	700	25.1 c	3.59 d	2.36 c
	PRD_{50}	300	573	23.3 c	4.07 c	2.93 b
	DI_{50}	300	608	19.3 d	3.18 e	1.60 d
	Rain-fed	0	331	14.5 e	4.38 b	-
2010	FI	612	773	21.9 a	2.84 bc	1.86 a
	PRD_{75}	459	625	18.8 b	3.00 b	1.81 a
	DI_{75}	459	634	16.1 c	2.54 de	1.22 b
	PRD_{50}	307	508	13.7 d	2.70 cd	1.04 c
	DI_{50}	307	551	12.5 d	2.27 e	0.65 d
	Rain-fed	0	274	10.5e	3.84 a	-

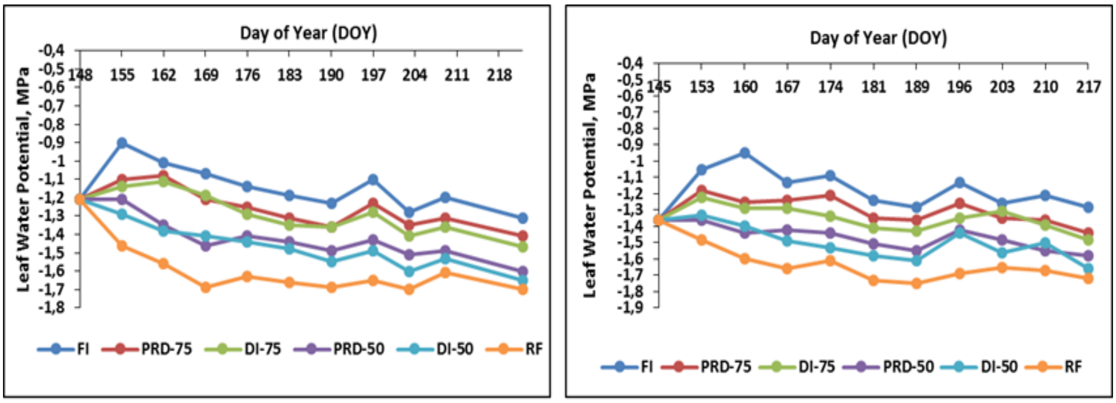
** LSD grouping at 1% level, * LSD grouping at 5 % level

Table 4. Statistical analysis results on yield, WUE and IWUE of royal table grape variety under different treatments in the experimental years

Tablo4. Deneme yıllarında royal sofralık üzüm çeşidinde verim, su kullanım randımanı ve sulama suyu kullanım randımanı değerlerinin istatistiksel analiz sonuçları

Years	Statistical Analysis	Yields (t ha^{-1})	WUE (kg m^{-3})	IWUE (kg m^{-3})
2009	CV(%)	1.577	0.094	3.2
	P (Probability)	0.0001**	0.0001**	0.0001**
	LSD (0.05)	3.5	1.3	0.169
2010	CV(%)	1.340	0.187	3.1
	P (Probability)	0.0001**	0.0001**	0.0001**
	LSD (0.05)	4.7	3.6	0.079

Leaf water potential (LWP) values varied depending on weather conditions and soil water content. Irrigation treatments have affected the mid-day LWP values significantly. The variations in LWP prior to irrigations under different treatments during the growing seasons are shown in Fig. 2a–b. The LWP values decreased with increasing water stress. In the first year of the study (2009), the values indicated are -0.9 to -1.31 MPa for FI; -1.08 to -1.41 MPa for PRD_{75}; -1.11 to -1.47 MPa for DI_{75}; -1.21 to -1.60 MPa for PRD_{50}; -1.21 to -1.65 MPa for DI_{50}; and in the non-irrigated area between -1.21 and -1.70 MPa. In the second year of the study (2010), the values indicated are -0.95 to -1.28 MPa for FI; -1.18 to -1.44 MPa for PRD_{75}; -1.22 to -1.48 MPa for DI_{75}; -1.36 to -1.58 MPa for PRD_{50}; -1.33 to -1.66 MPa for DI_{50}; and in the non-irrigated area between -1.36 and -1.75 MPa. Towards the end of the season, LWP values were found to be relatively lower. This can be explained by the aging of the leaves.



a b

Figure 2. Leaf water potential variation during the Royal table grape variety in the 2009 and 2010 growing seasons in all treatments (a: 2009; b:2010)

Şekil 2. Royal sofralık üzüm çeşidinde 2009 ve 2010 bitki büyüme mevsimi boyunca yaprak su potansiyeli değişimi

Full irrigated vineyards in the mid day leaf water potential (Ψl) -10 bars (-1.0 MPa) value stress threshold has been accepted as. Ψl'nin -12 bars (-1.2 MPa) and -14 bars (-1.4 MPa) to be of moderate stress, -16 bars (-1.6 MPa) and larger negative values are represented by the extreme stress (Williams and Araujo, 2002; Girona *et al*., 2005).

As a general guideline, grapevines without any water stress would present midday Ψs values above to - 1.0 MPa, moderate water restriction can be found at values from-1.0 to- 1.2 MPa and values from -1.2 to -1.5 MPa corresponds to severe water stres (Sibille *et al*., 2007; Cifre *et al*., 2005; Ferreyra *et al*., 2003; Williams and Araujo, 2002; Tregoat *et al*., 2002; Lampinen *et al*., 2001). The link between midday Ψs and berry quality attributes was shown by Tregoat *et al*. (2002), who found a strong correlation between this parameter and anthocyanins, phenols and malic acid content in barries. These authors also found good correlations between midday Ψs and grape berry weight and yield. Acevedo-Opazo *et al*. (2010) reported that for higher quality grape yields irrigation should be scheduled on mild stress (1.0-1.2 MPa).

Yazar *et al*. (2010) determined the optimal timing of irrigation for high quality yield using mid-day leaf water potential values for Italia, Alphonse Lavallee, Ergin Çekirdeksizi and Flame Seedless varieties. In the study, for different treatments based on various threshold levels of leaf water potential, were considered: (I_1: Ψl = -1.0 MPa; I_2: Ψl = -1.3 MPa; I_3: Ψl = -1.6 MPa) and non-irrigated control treatment (I_4). Highest yields of Alphonse Lavallee, Ergin Çekirdeksizi ve Flame Seedless varieties can be obtained when irrigated at leaf water potential value of -1.0 MPa (-10 bar); on the other hand, highest yield in Italia variety can be obtained when irrigatedat at leaf water potential value of -1.3 MPa (-13 bar).

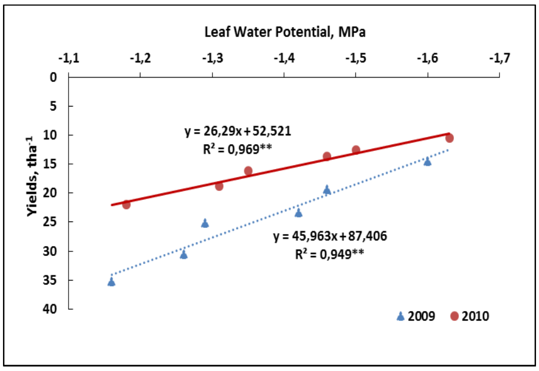


Figure 3. The relationship between yield and mean LWP values fordifferent irrigation treatments

Şekil 3. Farklı deneme konularında LWP ile verim arasındaki ilişki

The relationship between yield and mean LWP values for different irrigation treatments were presented in Fig. 3. Significant linear equations were developed for yield vs LWP. As the amount of applied irrigation water decreased, the evapotranspiration rates of the crop decreased, resulting in decreased leaf water potential and subsequent reductions in yield and growth. These results confirm many earlier studies on different crops. Thus, the LWP values proved to be a good indicator of plant water status for Royal table grapevine.

Conclusions

The following suggestions can be made in the light of results obtained from two years of study in order to determine optimal irrigation program by using leaf water potential in the Royal table grape variety applied by drip irrigation method in Mediteranean Region.

It is clear from the study that the variability of the climate parameters observed in the research years caused the applications to have different effects on the yield factor in the experimental years.

In two years of the study, the highest yield was obtained from the full irrigation.As the amount of applied irrigation water increased, the yield increased.Compared with the PRD applications with deficit irrigation, the yields obtained in the PRD treatments were found to be higher than the conventional DI irrigation. In addition, conventional DI_{50} and DI_{75} treatments resulted in slightly higher ET than PRD_{50} and PRD_{75} treatments despite receiving the same amount of irrigation water.

Soil water deficit in the rootzone depth should bereplenished to field capacity in irrigations in no water shortage exists. However, in case of water scarcity, PRD application with water savings as compared to full irrigation might be a suitable strategy for irrigation of grapevines in the Mediterranean region.

The LWP values decreased with increasing water stress. A significant linear relationship between LWP and yield was obtained. The results revealed that Royal table grapevine should be irrigated at LWP values between -1.17 (-11.7 bar) for high and good quality yields. Thus, LWP can be used for irrigation scheduling for grapevine.

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References

Acevedo-Opazo, C., Ortega-Farias, S., Fuentes, S., 2010. Effect of grapevine (*Vitis vinifera* L.) water status on water consumption, vegetative growth and grape quality: An irrigation scheduling application to achieve regulated deficit irrigation. Agricultural Water Management 97, 956-964. doi: 10.1016/j.agwat.2010.01.025.

Ağar, S., 2010. Çukurova koşullarında kısmi kök kuruluğu ve kısıntılı damla sulama programlarının kings ruby sofralık üzüm çeşidinin verimi, kalite ve su kullanım randımanına etkileri. Ç.Ü. Fen Bilimleri Enstitüsü Tarımsal Yapılar ve Sulama Anabilim Dalı yüksek lisans tezi, Adana, 85 sayfa.

Bozkurt Çolak, Y., Yazar, A., 2017. Evaluation of Crop Water Stress Index on Royal Table Grape Variety under Partial Root Drying and Conventional Deficit Irrigation Regimes in the Mediterranean Region. Scientia Horticulturae. 224:384-394.

Chaves, M.M., Santos, T., Souza, C.R., Ortu˜no, M.F., Rodrigues, M.L., Lopes, C., Maroco, J., Pereira, J.S., 2007. Deficit irrigation in grapevine improves water-use efficiency while controlling vigour and production quality. Ann. Appl. Biol. 150, 237–252. doi: 10.1111/j.1744-7348.2006.00123.x.

Cifre, J., Bota, J., Escalona, J.M., Medrano, H., Flexas, J., 2005. Physiological tools for irrigations scheduling in grapevines (Vitis vinifera L.). An open gate improve water-use efficiency? Agric. Ecosyst. Environ. 106, 159–170.

Deloire, A., Ojeda, H., Zebic, O., Bernard, N., Hunter, J.J., Carboneau, A., 2005.

Influence de l'etat hydrique de la vigne sur le style de vin. Progres Agricole et Viticole, v.122, p.455-462.

Dry, P.R., Loveys, B.R., McCarthy, M.G., Stoll, M., 2001. Strategic ırrigation management in australian vineyards. J. Int. Sci. Vinge Vin. 35, 129-139.

Fereres, E., Soriano, M.A., 2007. Deficit irrigation for reducing agricultural water use. J Exp Bot 58: 147–159.

Ferreyra, R., Selle´ s, G., Ruiz, R., Selle´ s, I., 2003. Efecto del estre´s hı´drico aplicado en distintos perı´odos de desarrollo de la vid cv. Chardonnay en la produccio´n y calidad del vino. Agric. Te´ c. 63, 277–286.

Gachons, C.P., Leeuwen, C.V., Tominaga, T., Soyer, J.P., Gaudillere, J.P. and Dubourdieu, D., 2005. Influence of water and nitrogen deficit on fruit ripening and aroma potential of *Vitis Vinifera* L. Cv. Sauvignon Blanc in field conditions. J. of the Sci. of Food Agric., 85(1): 73-85.

Girona, J., Mata, M., del Campo, J., Arbones, A., 2005. The use of midday leaf water potential for scheduling deficit irrigation in vineyards. Irrigation Science 24:115-127.

Gökçel, F., 2008. Çukurova koşullarında yarı ıslatmalı (PRD) ve kısıntılı damla sulama programllarının II. ürün mısır verimi ve su kullanma randımanına etkileri. Ç.Ü. Fen Bilimleri Enstitüsü Tarımsal Yapılar ve Sulama Anabilim Dalı yüksek lisans tezi, Adana, 68 sayfa.

Gündüz, M., Korkmaz, N., 2008. Damla sulama ile sulanan bağda farklı sulama uygulamalarının verim ve bazı kalite özelliklerine etkisi. Ege Tarımsal Araştırma Enstitüsü dergisi. Anadolu 18 (1).

Hsiao, T.C., 1973. Plant responses to water stress. Annual Review of Plant Physiology, v.24, p.519-570.

Howell, T.A., Musıck, J.T., Tolk, J.A., 1986. Canopy temperature of irrigated winter wheat. transactions of the ASAE, Vol. 29(6):1692-1699.

Jones, H.G., 1983. Plants and mikroclimate: A quantitative approach to environmental Plant physiology. Cambridge univ. Pres. U.K.

Kang S.Z., Zhang, J., 2004. Controlled Alternate Partial Root-Zone Irrigation: Its physiological consequences and impact on water use efficiency. Journal of Experimental Botany 55(407): 2437-2446.

Lampinen, B.D., Shackel, K.A., Southwick, S.M., Olson, W.H., 2001. Deficit irrigation strategies using midday stem water potential in prune. Irrig. Sci. 20, 47–54.

Matthews, M.A., Anderson, M.M., 1989. Reproductive development in grape (Vitis vinifera L.): responses to seasonal water deficits. Am J Enol Vitic 40: 52–60.

Patakas, A., Noitsakis, B., 1997. Cell wall elasticity as a mechanism to maintain favorable water relations during leaf ontogeny in grapevines. Am. J. Enol. Vitic., 48(3): 352-358.

Rana, G., Katerji, N., Introna, M., Hammami, A., 2004. Microclimate and plant water relationship of the ‘‘Overhead’’ table grape vineyard managed with three different covering techniques. Sci Hortic 102:105–120.

Santos, T.P., Lopes, C.M., Rodrigues, M.L., Souza, C.R., Maroco, J.P., Pereira, J.S., Silva, J.R., Chaves, M.M., 2003. Partial rootzone drying effects on growth and fruit quality of field-grown grapevines (*Vitis vinifera*). Funct Plant Biol 30: 663–671.

Santos, T.P., Lopes, C.M., Rodrigues, M.L., Souza, C.R., Silva, J.R., Maroco, J.S., Pereira, J.S., Chaves, M.M., 2005. Effects of partial rootzone drying irrigation on cluster microclimate and fruit composition of castelão field-grown grapevines. Vitis 44: 117–125.

Scholander, P.F., Hammel H.T., Bradstreet E.D., Hemmingsen E.A., 1965. Sap pressure in vascular plants. Science 148:339–346.

Şener, S., İlhan, İ., 1992. Aşağı gediz havzasında yuvarlak çekirdeksiz üzümün su tüketimi ile sulamanın verim ve kaliteye etkileri. menemen arastırma enstitüsü müdürlüğü yayınları Menemen. Genel Yayın No. 182, Rapor Serisi No: 121, 55 s.

Sibille, I., Ojeda, H., Prieto, J., Maldonado, S., Lacapere, J.-N., Carbonneau, A., 2007. Relation between the values of three pressure chamber modalities (midday leaf, midday stem and predawn water potential) of 4 grapevine cultivars in drought situation of the southern of France. Applications for the irrigation control. In: Proceedings of XVth Conference GESCO, Porec, Croatia, pp. 685–695.

Steel, R.G.D., Torrie, J.H., 1980. Principles and procedures of statistics, 2nd ed. McGraw-Hill, New York.

Tangolar, S., Tangolar, S., Topçu, S., 2015. Effects of different bud loads and irrigations applied at different leaf water potential levels on kalecik karası grape variety. Turkish Journal of Agriculture and Forestry 39: 887-897.

Tardieu, F., Katerji, N., 1990. Relations entre l´état hydrique du sol, le potentiel de base et d´autres indicateurs de la cointraint hydrique chez le mais. Agronomie, v.10, p.617-626.

Tardieu,F., Zhang, J., Davies, W., 1992. What ınformation is conveyed by an aba signal from maize roots in drying soils? Plant Cell. Enviro. 15: 185-191.

Tre´goat, O., Van Leeuwen, C., Chone´ , X., Gaudillere, J.P., 2002. Etude du re´ gime hydrique et de la nutrition azote´e de la vigne per des indicateurs physiologiques. Influence sur le comportement de la vigne et la maturation du raisin (Vitis vinifera L. cv. Merlot, 2000, Bordeaux). J. Int. Sci. Vigne Vin. 36, 133–142.

TÜİK, 2016. Türkiye'de yıllık tarımsal üretim. Türkiye İstatistik Kurumu, Ankara www.turkstat.gov.tr. (Last Access Date: 12.07.2018).

Wample, R.L., Willians, L., ADAMS, D., 2005. Wine grape irrigation management in the San Joaquin Valley of California. In: Symposio Internatıonal Del Manejo De Riego Y Suelo En Vides Para Vino Y Mesa, 1., Santiago de Chile, 2005. Proceedings. Santiago de Chile: INIA, p.38-46.

Williams, L.E, ve Araujo, F.J., 2002 Correlations among predawn leaf, midday leaf stem water potential and their correlations with other measures of soil and plant water status in vitis ninifera. J. Am. Soc. Hort. Sci. 127 (3):448-454.

Yazar, A., Tangolar., S., Sezen, S.M., Bozkurt Çolak, Y., Bilir, H., Gençel, B., Sabır. A., 2010. Yaprak su potansiyeli kullanılarak çukurova koşullarında yüksek kaliteli verim için optimum sulama zamanının belirlenmesi. TÜBİTAK 106O747 Nolu Proje Sonuç Raporu, 110s.

Zabihi, H.R., 2006. Grape responses to different soil moisture regimes, Acta Hort., 652: 233-237.

Zhang, J., Davies, W., 1990. Changes in the Concentration of ABA in Xylem Sap as a Function of Changing Water Status can Account for Changes in Leaf Conductance and Growth. Plant Cell. Enviro. 13: 277- 285.

Zhang, H., Wang, X., You, M., Liu, C., 1999. Water-yield relations and water-use efficiency of winter wheat in the North China Plain. Irric. Sci. 19, 37-45.