GRAPEVINE YIELD, QUALITY AND WATER USE EFFICIENCY RESPONSE TO DEFICIT IRRIGATION

REPONSE DU RENDEMENT DE LA VIGNE, DE LA QUALITE ET DE L'EFFICIENCE D'UTILISATION DE L'EAU A L'IRRIGATION DEFICITAIRE

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ABSTRACT

In order to evaluate the effects of different levels of irrigation water on quality and quantity traits of some commercial grape cultivars in west Azarbaijan state this study was carried out using strip–block design on the base of RCBD with six cultivars (Keshmeshe Sefid, Keshmeshe Qermez, Rishbaba Qermez, Siyah Sardasht, Hossaini and Ghezel Ouzum) and 3 levels of irrigation treatments (100%, 75% and 50%) with 3 replications. The cuttings were taken from stocks cultivars in 2001 and then spading were moved to the field according to design map. The irrigation treatments were done from the forth year and then in the years of 2004-2005 at fruit ripening stage, different traits as weight, length and width of bunch and the qualitative traits including TSS, TA, pH and the volume of the juice were recorded.

Results of combined analysis indicated that the different levels of irrigation had significant effect on TSS, TA, juice volume, pH and berry weight. By applying deficit irrigation, the amount of juice significantly decreased where as the 100% irrigation treatment caused the maximum amount of juice and 50% irrigation (2043 m^3/ha) caused the minimum. The most juice volume was from Siyah Sardasht (45.41ml) and the least from Keshmeshe sefid (38.11ml). Deficit irrigation reduced the berry size too. The effects of irrigation treatments on the length of bunches was significant at 5% level, the longest bunches were in the 75% and 100% treatments and the shortest bunches were in 50%. Water consumption in 100, 75 and 50% water supply treatments were 4086,3064and 2043 m^3/ha. The most and the least water use efficiency was recorded in Siyah Sardasht and Keshmeshi Qermez, respectively.

Key words: *grapevine, deficit irrigation, water use efficiency, quality and quantity.*

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RESUME

Cette étude est menée pour évaluer les effets de différents niveaux de l'eau d'irrigation sur la qualité et la quantité de certaines variétés cultivées de raisin commercial à l'ouest de l'Etat d'Azarbaïdjan. La conception de bande-bloc était utilisée compte tenu de RCBD pour six variétés cultivées (Keshmeshe Sefid, Keshmeshe Qermez, Rishbaba Qermez, Siyah Sardasht, Hossaini et Ghezel Ouzum) avec 3 répétitions de 3 niveaux de traitements d'irrigation (100%, 75% et 50%). Les marcottes ont été prises à partir des variétés cultivées en 2001, puis ont été transférées au champ selon la carte de conception. Les traitements d'irrigation ont été fait à partir de la quatrième année, puis dans les années 2004-2005 au stade de la maturation des fruits, ont été signalés les traits différents tels que le poids, la longueur et la largeur de grappe et les traits qualitatifs tels que TSS, TA, le pH et le volume de jus.

Les résultats de l'analyse combinée a indiqué que les différents niveaux de l'irrigation a eu un effet significatif sur TSS, TA, le volume de jus, le pH et le poids des baies. En appliquant l'irrigation déficitaire, la quantité de jus a diminué de manière significative alors que le traitement d'irrigation de 100% a donné lieu à la quantité maximale de jus et que le traitement d'irrigation de 50% (2043 m3/ha) a donné lieu à la quantité minimum. Le volume maximum de jus était obtenu de la variété de Siyah Sardasht (45.41ml) et le moindre avec la variété de Keshmeshe sefid (38.11ml). L'irrigation déficitaire réduit également la taille de baies. Les effets des traitements d'irrigation sur la longueur des grappes onr été significatifs au niveau de 5%. Les plus longues grappes ont été observées au traitement d'irrigation de 75% et de 100%. Les plus courtes grappes ont été observées au traitement d'irrigation de 50%. La consommation d'eau dans les traitements de 100%, 75% et 50% de fourniture d'eau était de 4086, 3064 et 2043 m3/ha. L'utilisation d'eau la plus efficiente et la moindre efficiente était observée pour les variétés de Siyah Sardasht et de Keshmeshi Qermez respectivement.

Mots clés: *Vigne, irrigation déficitaire, efficience d'utilisation de l'eau, qualité et quantité.*

1. INTRODUCTION

The average rainfall in Iran is the one third of the average rainfall of the world. Lack of good quality and quantity of water sources has a serious impact on crop production especially in arid and semi-arid country like Iran. Iranian main water resources are more than 125 billion cubic meter (bcm) from rainfall and more than 12 bcm of surface runoff that enters to region from Border Rivers. The total arable land is 37 million hectare (Mha), from which only 18.5 Mha are under cultivation at present time. More than 70% of total renewable water resources of the country is being used. Thus, the main limiting factor of crop production is water resources shortage and improper irrigation system. Hence efficient use of irrigation-water has become very important to face the water scarcity nowadays. Water scarcity (in quantity and quality) and the increasing competition for water resources between agriculture and other sectors are forcing growers to consider more seriously the adoption of water saving strategies especially in areas of limited water resources. As a result, improving crop water use efficiency has been a matter of concern to researchers and agronomists in recent years (Abaasi, *et.al*.2000). Among various irrigation approaches, deficit irrigation seems to have most important role for crop production under water shortage. The main objective of deficit irrigation is to achieve a higher water use efficiency as well as reasonable and economic crop production (Sepaskhah *et al*., 2006). Therefore, it is necessary to estimate allowable limit of yield reduction and the water consumption at this level of production. The advantages of deficit irrigation include reduced production costs, energy saving in water exploration and distribution and improving farm condition to avoid physiological disorder.

Irrigation influence yield and quality of grapevine and even the postharvest characteristics (Bravdo *et al*., 1985; Esteban *et al*., 2001; Gomez Del Campo *et al*., 2004). Hence Irrigation has always been a subject of debate. Small water supplements may increase yields and maintain or even improve berry quality (Matthews and Anderson, 1989). On the other hand, irrigation may promote excessive vegetative growth, decrease berry's pigments (color) and decrease sugar content (if applied later in the season). Moreover, a larger leaf area increases transpiration losses and disease problems, mainly fungal disorders (Behboudian and Singh 2001). Published reports show that deficit irrigation strategies can be successfully applied to several important horticultural crops, in particular to those that are typically resistant to water stress in order to improve WUE and save water. Combination of deficit irrigation strategies with other practices like mulching, or protected cultivation may also help to improve WUE and minimize losses in yield or quality in vegetable crops (Kirnak and Demirtas 2006). Grafting on specific rootstocks more adapted to water stress conditions may be another tool to improve crop growth response under artificially imposed mild water stress. Finally, developments in monitoring systems to precisely assess plant water status will facilitate crop management under deficit irrigation. WUE is discussed either in terms of instantaneous measurement of the efficiency of carbon gain per water loss by plants or as the integral of such efficiency over time, expressed as the ratio of biomass accumulation of harvested yield to water use (Bacon, 2004). Deficit irrigation strategies deliberately allow crops to sustain some degree of water deficit and sometimes, some yield reduction with a significant reduction of irrigation water. The classic deficit irrigation strategy (DI) implies that water is supplied at levels below full evapotranspiration (ETc) throughout the season. Deficit irrigation strategies may help to save more water and optimize or stabilize yields and quality in these areas (English, 1990; Chaves *et al*., 2007). However, deficit irrigation practices can be increasingly justified in order to save water, improve nitrate use efficiency, minimize leaching of nutrients and biocide or in view of higher water prices (Miguel Costa, *et al*. 2007). Chaves *et al*., 2007 showed Crop WUE (amount of fruit produced per unit of water applied) in PRD and DI was twice that in full irrigation, as a result of these plants (PRD and DI) having utilized half of the irrigation water for a similar yield in Full irrigation treatments.

Drip irrigation, mulching and protected cultivation have contributed to improve WUE in agriculture by significantly reducing runoff and evapotranspiration losses (Kirnak and Demitras 2006). Deficit irrigation is recommended to vineyards of south western China as proper strategy for reducing consumption of water, improving water use efficiency and quality of grape. They reported that partial root zone drying irrigation method under drip irrigation system improved WUE by 36.5% and the ratio of soluble solids to fruit titratable acidity has been increased about 29% (Du *et al*., 2008). Improving quality of grape and increasing WUE up100% by applying 50% deficit irrigation was reported Chaves *et al*., (2007). The result of one trail about effects of different levels of water irrigation on yield and water use efficiency of grape showed that the irrigation has a significant effect on function where as 25% and 50% deficit irrigation decreased yield by 13% and 43% respectively. The highest WUE obtained by 25% deficit irrigation (Jolaini, 2006). 1.84 kg. m^{-3}). In one another research, the effect of three levels of water requirement (100, 75 and 50%) on vegetative growth and fruiting grape have been studied and founded that water stress cause reduction of yield, size of berry and vegetative growth. The most sugar content obtained with full irrigation treatment (Di Vaio *et al.*, 2001).

Grapevine is one of the well-adapted crops to the Iran Mediterranean climate. Iran is the sixth country in the world in grape orcahrd area (288030 ha) and grape production (2342210 tons). Of the total grape area, 19687 ha are located in West Azerbaijan Province (Anon, 2007) where irrigation is needed for high yield and quality. Fruit quality of grape is an important component for its market value. In order to improve WUE in grapevine production, the response of grapevines to deficit irrigation strategies (DI) has been investigated.

2. MATERIALS AND METHODS

An experiment was conducted in the Kahriz Experimental Station in the West Azarbijan, Iran. The station is located 45 km north of Urmeih (longitude $40^0 07'$ E and latitude $37^0 53'$N). The climate is of the Mediterranean type, with hot and dry summers and cold and snowy winters. Long-term mean annual rainfall is 360 mm year-1, with 100 and 127 mm falling during winter and spring month. Some properties of the soil and irrigation water were determined by the standard procedure are shown in Tables 1 and 2. Fertilizer requirements were estimated on the base of soil analysis results before planting transplants and were incorporated to the soil.

Table 1. Some physical and chemical characteristics of the soil

Soil Depth (cm)	texture	Volume weight ($g.cm^{-3}$)	Field capacity (%)	Wilting point (%)	pH	EC (ds/m)	Organic matter (%)
0-30	Si.L	1.35	24.2	10.9	8.1	0.58	0.58
30-60	Si.L	1.33	24.8	11.8	8.2	0.68	0.55
60-90	Si.L	1.28	25.5	11.3	8.1	1.29	0.55
90-120	Sa.C.L	1.52	18.3	8.4	7.4	2.55	---

Table 2. Physical and chemical properties of water used in experiment

Class	pH	Ec×10^6	$C03^{2-}$	$HCO3^-$	Cl^-	So_4--	Mg^{2+}	Ca^{2+}	Na^+
			meq/Lit						
C2S1	8.2	531	0	3.5	1.5	0.4	1.6	2.7	1.1

The experimental design was a strip–block design on the base of RCBD with three replications per treatment. We selected six varieties of important regional grape (Keshmeshe Sefid, Keshmeshe Qermez, Rishbaba Qermez, Siyah Sardasht, Hossaini and Ghezel Ouzum) treatments and and 3 levels of irrigation treatments (100%, 75% and 50%). The cuttings were taken from stocks cultivars in 2001 and then spadings were moved to the field according to design map. Each replicate (plot) had 24 vines. The vines were spur pruned on a bilateral Cordon system using a vertical shoot positioning with a pair of movable wires. The vineyard has a planting density of 1666 vines h^{-1}, the vines being spaced 3.0 m between and 2.0 m along rows.The water was supplied according to the crop evapotranspiration ($ETc = ET_0$ *

Kc) calculated from the evaporation of a Class A pan (ET_0), corrected with the crop coefficient (Kc), We used the most suitable Kc for our conditions according to farshi *et al*. (1997). The potential ET in each stage of growth determined by using relationship between data from E-pans and ET_0 from lisimetric data (Figure, 1).

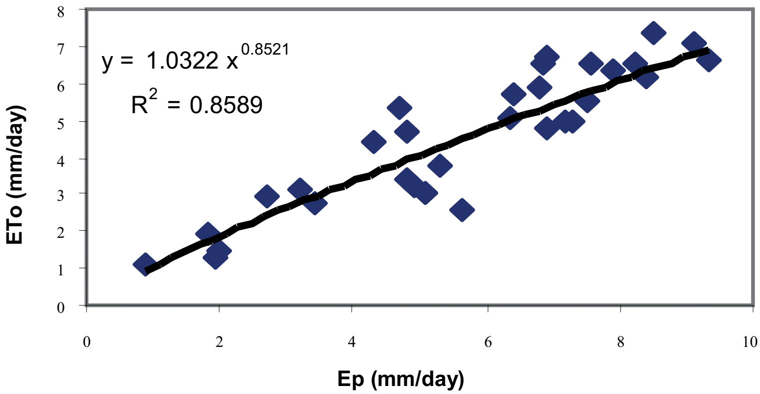

Fig. 1. relationship between lisimeter and E-pan data in Kahriz Estation

The irrigation treatments were: full irrigation (FI,100% of the ETc was supplied), 25% deficit irrigation; (DI 25% 75% of the ETc was supplied) and 50% deficit irrigation (DI 50%, 50% of the ETc was supplied). Duration irrigation was considered according to the soil texture and facilities from 3 to 7 days. Irrigation water was applied with drip emitters (4 L h^{-1}), two per vine, positioned 30 cm from the vine trunk (out to both sides of the rows) and distributed on both sides of the root system. Cumulative rainfall during the experimental period (May until the mid September) was 44 mm in 2004 and 100 mm in 2005 growing season. The total amount of water supplied to FI, DI25% and DI50% were are 2451, 1839 and 1226 liter per every vine trunk respectively. In this condition water efficiency was considered 90%.

The irrigation treatments were done from the forth year and then in the years of 2004-2005 at fruit ripening stage, different traits as weight, length and width of bunch and the qualitative traits including TSS, TA, pH and the volume of the juice were recorded. The data were subjected to analysis of variance with MSTAT-C software and Duncan's multiple range tests also used to compare means.

3. RESULTS

Results of combined variance analysis indicated that the different levels of irrigation had significant effect on TSS (at 5% level), TA, pH, juice volume, berry weight and width, bunch width and weight, annual vegetative growth and yield at 1% level. According to table 3 the most and the least yield were obtained by 100% and 50% irrigation, respectively. In other words deficit irrigation causes reduction of function. This is in agreement with the results reported by Jolaini (2006). The effect of 25% deficit irrigation on yield was not significant. Deficit irrigation increased TSS and pH and the majority of them were from DI50% treatment. Juice volume and berry weight in full irrigation treatment were the most and by applying deficit irrigation, their amount have been decreased significantly. Having water stress by

50% makes the grape become smaller. The effect of DI25% on length and width of grape was not significant. The branch weigh in Di75% treatment (287.2 gr) was more than two other irrigation regimes. The highest vegetative growth obtained from FI treatment and deficit irrigation affected significantly vegetative growth (table 3).

Table 3. Mean comparison of some characteristics of grapevine in irrigation treatment.

Characteristics	Irrigation treatment			LSD
	50%	75%	100%	
Yield/ha (ton)	7.59 b	10.7 a	10.91 a	1.433
TSS (%)	22.00 a	21.20 a	20.81 b	0.804
pH	3.42 a	3.44 ab	3.22 b	0.148
Juice voulum (ml)	40.75 c	42.24 b	42.88 a	0.553
Berry Weight (gr)	2.82 b	2.99 ab	3.22 a	0.298
Bunch weight (g)	260.4 c	287.2 a	277.4 b	8.7
Bunch length (cm)	20.07 b	20.99 a	21.26 a	0.752
Bunch width	9.76 b	10.74 a	10.83 a	0.712
Vegetative growth (cm)	136.2 c	177.2 b	200.1 a	12.22

Mean with similar letters in each column are not significantly different

Water consumption in 100, 75 and 50% of water requirement supply treatments were 4086, 3064 and 2043 m^3 per hectare respectively. Reduction amount of irrigation from 100% to 75% and 50% caused product yield decreased from 100% to 98.1% and 69.5% respectively. In this way with 25% and 50% reduction in water use there was only 1.9% and 30.5% reduction in product yield respectively (Table 4).

Deficit irrigation improved water use efficiency. The rate of increasing water use efficiency with less deficit irrigation was more than intensity water stress. 25% deficit irrigation caused water use efficiency increase by 30.7% but DI50% treatment increased WUE only 8.6% in comparison with DI25% (table 4). Hence we recommend DI25%.

Table 4. Water use efficiency in irrigation treatments

Irrigation Treatments	Yield/ ha (ton)	Water consumption (m^3/ha)	WUE (kg/m^3)
50% water requirement	7.59b	2043	3.72
75% water requirement	10.69a	3064	3.49
100% waterrequirement	1.91a	4086	2.67

Water use efficiency was deferent in kinds of varieties so that Siyah Sardasht has the most (3.95 kg.m^{-3}) and Keshmeshe Qermez has the least of WUE (table 5).It is acknowledged that the timing and intensity of the response to soil and atmospheric water deficits, namely in what concerns stomatal control, depends greatly on varieties. This has profound implications in irrigation management, in particular the timing and amount of irrigation to optimize source–sink relationships, in order to achieve optimal fruit quality in each variety (Chaves *et al*., 2007).

Table 5. Water use efficiency in grapevine cultivars

Cultivars	Yield/ ha (ton)	Water consumption (m^3/ha)	WUE (kg/m^3)
Keshmeshe Sefid	9.63	3064	3.14
Rishbaba	8.87	3064	2.89
Siyah Sardasht	12.09	3064	3.95
Hossaini	9.55	3064	3.12
Keshmeshe Qermez	8.39	3064	2.74
Ghezel Ouzum	9.85	3064	3.21

4. DISCUSSION

Effect of deficit irrigation on some factors such as pH, TSS, juice volume, length and width of bunch, weight of berry and bunch, yield and vegetative growth was significant. The maximum and minimum yield was obtained from plots irrigated with full requirement and 50 % of full water requirement (DI50%), respectively and it is accorded by researches of Zabihi and Azarpajouh (2004). The maximum vegetative growth and berry weight obtained by full irrigation treatment. Generally in water stress condition volume and number of cells in fruit is less than natural state (without water stress) and because of slow grow of leaf area material form photosynthesis activity is less than lack of water stress. This is one of the main reasons of low weight and falling yield in deficit irrigation treatments. Dwindling soil water content in early growing season, where rate of vegetative growing of grape is great, cause reduction of leaf area (Escalona *et al*., 2003). Although the most function obtained of full irrigation treatment but the heaviest grape cluster was found in 25% deficit irrigation treatment. In full irrigation vegetative growth is more. Whereas the falling in of blossom and berry on bunch with high growing is more so average weight of grape cluster in supplying 100% water requirement treatment has been decreased (Winkler, 1974). Water stress increased the soluble solids and fruit titratable acidity that is in agreement with the results ported by Colapietra (1989). Some researchers believe that the in drought conditions the hormone of abscisic acid increases and this hormone increase the sugar of fruit (Shawky *et al*., 1997). Some of the researchers reported that water stress reduces photosynthesis and production of sugar and with the continuing of intensive stress it's possible that the ripping of fruits be lately (Escalona *et al*., 2003). Chiltivaichelan *et al*., (1987) showed that deficit irrigation don't have significantly affect on soluble solids. They reported that the highest growing in full irrigation and the lowest growth of grape in 50% supplying water requirement was observed. Its obvious that water is need to division of plant cells and growing and in the case of limitation water growth will be reduced. Slow development of stress is associated with a loss of acidity and a rise in pH and soluble solids. More rapid onset of stress causes these processes to be arrested as fruit dehydration and raisining occur. High levels of stress will result in abscission of shoot tips, which, if followed by over-irrigation, may stimulate lateral shoot growth. Such growth creates a competitive sink for photosynthesis and delays fruit maturation. Late-season irrigation, following water stress, can also reduce cane and vine acclimation increasing the potential for low-temperature injury. Such vines are unlikely to have adequate viable buds the following season. Were exposed to extremely low temperatures, they often show reduced survival of buds, trunks and cordons.

The fitness between vegetative growth and fruiting and also between number of leaves and cluster in quality and quantity of grapes production is important. Siyah Sardasht with the most yield, the least vegetative growth and the highest water use efficiency is the best variety of grape in our region.

5. CONCLUSIONS

Deficit irrigation can be successfully utilized for the production of important cultivars of grape in West Azerbaijan province to reduce vegetative growth and improve the water use efficiency. DI25% had caused 25% saving of water used without negative influencing crop yield or fruit composition. Siyah Sardasht had the highest resistant to water stress and reduction of yield was the least through deficit irrigation in comparison with five other cultivars so we suggest Siyah Sardasht for planting grape in area that faced with shortage water resource if its considered to construction vineyard.

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