Alex. J. Agric. Sci. Vol. 62, No.1, pp. 11-30, 2017

Effects of Seasonal Deficit Irrigation, Potassium Fertilization and Bunch Thinning on Growth, Yield and Quality of Flame Seedless Grapes

Diaa O. El-Ansary
Department of Pomology, Faculty of Agriculture (El-Shatby), University of Alexandria, 21545, Egypt
E-mail: diaa.elansary@alexu.edu.eg
diaaagri@hotmail.com Tel.: +2-01000150804

Received on: 17/1/2017 Accepted: 8/2/2017

ABSTRACT

Impacts of deficit irrigation levels, potassium fertilization, and bunch thinning on grapevine vegetative growth, yield and quality of Flame Seedless table grapes were investigated during 2012 and 2013 seasons. Vines were subjected to seasonal irrigation treatments from bud swell to dormancy including: Standard irrigation (100 % of crop evapotranspiration [ETc]), moderate deficit (80 % of ETc), and sever deficit (60 % of ETc). Effects of two levels of potassium fertilization (0 and 0.58 kg as K_2O per vine per season) and bunch thinning (40 and 30 bunch per vine) were also investigated. Results showed that vine petiole potassium concentration was significantly dependent upon applied irrigation level and was highest in standard irrigated potassium fertilized vines. Shoot length, leaf area and pruning weight responded negatively to irrigation deficit, while bunch thinning increased leaf area in both seasons and pruning weight in the second season with no effect on shoot length, whereas potassium had no effects on vegetative growth. Vine yield, bunch weight and berry diameter increased significantly with increasing irrigation level and with potassium fertilization. Bunch thinning significantly decreased yield in first season only while increased bunch weight and berry diameter. Crop load (yield/pruning) significantly increased by potassium and decreased by thinning with no effect for irrigation. Water use efficiency (yield/irrigation) significantly increased by increasing irrigation level and by potassium fertilization while decreased in first season by thinning. Increasing deficit irrigation level resulted in increased berry juice total soluble solids (TSS) and declined titratable acidity (TA), decreased berry firmness, increased skin anthocyanin and total phenolics, and reduced skin color characteristics values of lightness (L^*), chroma(C^*) and hue angle(h°). Bunch thinning increased berry TSS in first season, did not affect TA and fruit firmness, and increased berry skin anthocyanin and total phenolics, while decreased skin L^* in the first season, C^* and h°. Potassium fertilization increased berry TSS, TA, anthocyanin, total phenolics, did not affect firmness with no consistent effect on skin color characteristics.

Key words: Evapotranspiration, crop load, water use efficiency, color, anthocyanin, total phenolics, firmness.

INTRODUCTION

Similar to many other parts of the world especially in desert locations, the challenge of increased irrigation water scarcity is developing rapidly in Egypt. Water shortage scenarios are threatening the decisions of sustainable investments in the horticulture sector. Therefore, there is a need to detailed knowledge for how far can irrigation water shortage during the whole season manipulate fruit crop yield production with emphasize on its impacts on fruit quality for export markets. Full irrigation is the recommended irrigation strategy for table grapes since maximum yield and berry size is needed (Blanco *et al.*, 2010). Flame Seedless grapes (*Vitis vinifera* L.) is the main table grape cultivar in Egypt for export to European market and is widely distributed in desert areas. Important grape berry quality characteristics in all table grape cultivars include sweetness, acidity, berry size, color, and firmness (Williams *et al.*, 2010). Poor skin color development in red-colored grapes such as Flame Seedless may occur due to high temperature during ripening resulting in reduced market value, and additional cultural practices may be needed to enhance berry quality such as reduced irrigation, leaf removal, bunch thinning and fertilizer adjustments especially nitrogen and potassium (Dokoozalian and Hirschfelt, 1995; Kennedy *et al.*, 2002; Mpelasoka *et al.*, 2003; Okamoto *et al.*, 2003; Peppi *et al.*, 2006). There is a direct effect for deficit irrigation on berry composition and quality characteristics such as sugars, phenolics and anthocyanin as a result of affecting vegetative growth, berry metabolism and crop yield (Ojeda *et al.*, 2002; El-Ansary and Okamoto, 2007; Gamero *et al.*, 2014 and Pinillos *et al.*, 2016). Availability of soil potassium for grapevines are modified by varying applied irrigation regimes that affect soil moisture content (Keller, 2005 and Mpelasoka *et al.*, 2003). Bunch thinning in grape production affects the source-sink ratio and leads to yield reduction without influencing vine leaf surface area and as a consequence, the vine directs its activity towards the remaining bunches and therefore enhances berry quality parameters (Ferrer *et al.*, 2009; Gatti *et al.*, 2012 and Sun *et al.*, 2012). Effects of bunch thinning is influenced by several factors including cultivar, thinning timing, and weather conditions (Prajitna *et al.*, 2007 and Valdés *et al.*, 2009). The aim of this research work was to study the effects of seasonal deficit irrigation regimes, potassium fertilization, and bunch thinning as well as their interactions on vine growth, crop yield and berry quality characteristics of Flame Seedless table grapes.

MATERIALS AND METHODS

1- Plant material, growth conditions, and treatments

This research was implemented in 2012 and 2013 seasons in a private farm located in Marriott region (40 km at Alexandria –Cairo desert road (lat. 30.93°N, long. 29.78 ° E), Egypt. Own- rooted four year- old grapevines of Flame Seedless grapes (*Vitis vinifera* L.) were used in this experiment. Grapevines were grown in raised beds (1.5 m wide and 0.4 m high) and spaced 2 meters between vines and 3 meters between rows. Table 1 presents soil texture, total calcium carbonate and available macronutrients, and Table 2 shows the chemical analysis of soil and water at the beginning of experiment in 2012. Soil texture and all chemical analysis in soil and water were conducted according to the methods described by Richards (1954) and Black *et al.* (1965). A 2.1 m high horizontal shoot-positioned trellis system was used and vines were cane pruned to a level of 15 cane per vine with 12 nodes per each cane after winter pruning. Crop management was practiced according to commercial standard adapted in the area including Dormex spray, Gibberellic acid application and Ethephon spray. A regular pest management program was conducted. Each irrigation treatment in a vine row was drip irrigated by a separate 2 lines of 4 L per hour discharge drippers and a weekly fertigated by fertilizer mix containing all elements except for potassium which was adjusted according to treatment as will be described later. Irrigation was scheduled in 2012 and 2013 seasons based on the method described by Allen *et al.* (1998) by determining irrigation water needs from calculating actual crop evapotranspiration (ETc) from the equation ETc = ETo x Kc, were ETo is the reference crop evapotranspiration (Figure 1-A) and Kc is the table grape crop factor (Figure 1-B). ETo data were collected on a daily basis from the nearest weather station located 45 km from the vineyard site at El-Yashaa village in Tiba region (lat. 30.60 °N, long 30.02 °E). Vines were subjected to seasonal irrigation treatments from bud swell (6 Feb. 2012 & 11 Feb. 2013) to dormancy (3 Nov. 2012 & 5 Nov. 2013) including: Standard irrigation (100 % of ETc), moderate deficit irrigation (80 % of ETc), and sever deficit irrigation (60 % of ETc) as illustrated in Figure 1-C & 1-D. Monthly and total seasonal applied irrigation water data (m^3 per vine) for irrigation treatments in 2012 and 2013 seasons are presented in Figure 2-A & 2-B. Also, the effects of two levels of potassium fertilization: un-fertilized (-K) = 0 kg K_2O per vine per season, and fertilized (+K) = 0.58 kg K_2O, were studied. As for potassium application scheduling for fertilized vines, each vine received 0.58 kg potassium calculated as K_2O in the season in the form of potassium sulphate divided as following: 33% from bud swell to verasion, 36% from verasion to harvest, and 31% from postharvest to dormancy. Finally, the impacts of bunch thinning: un-thinned (-T) = 40 bunch per vine, and thinned (+T) = 30 bunch per vine, were also investigated. The vegetative shoots in all experimental vines were removed before bloom (17 Mar. 2012 & 26 March 2013) and the remaining shoots carrying bunches were adjusted to 40 shoot per vine in early spring, with each shoot carrying one basal bunch. As for bunch thinned vines, 10 bunches were extra thinned from each vine leaving only 30 bunch per vine, compared with standard irrigated vines having all 40 bunch per vine.

2- Sampling and analysis:

Harvest was done in all treatments in 1 Jun. 2012 and 12 Jun. 2013 and all sample analysis procedures were conducted at the Faculty of Agriculture of Alexandria University. To determine leaf petiole potassium at harvest time, a sample of 10 leaves opposite to the bunches form each vine replicate was taken and average potassium content was determined.

Table 1: Soil particle size distribution, total calcium carbonate, and soil macronutrients

Soil Depth (cm)	Particle size distribution (%)			Texture	Total $CaCO_3$ (%)	Available macronutrients (ppm)				
						N				
	Sand	Silt	Clay			NH_4-N	NO_3^{-1}-N	Total N	P	K
0-60	94	0	6	Sand	7.53	150	107	257	6.4	100

Table 2: Chemical analysis of soil and irrigation water

Sample	pH	E.C. (dS/m)	Soluble cations (meq/L)				Soluble anions (meq/L)				SAR (%)
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	SO_4^{--}	HCO_3^-	CO_3^{--}	
Soil	7.95	1.21	7.5	1.2	2.2	1.2	7.0	2.1	3.0	-	5.8
Water	7.85	0.91	3.8	0.3	2.6	2.4	3.5	0.7	4.9	-	2.4

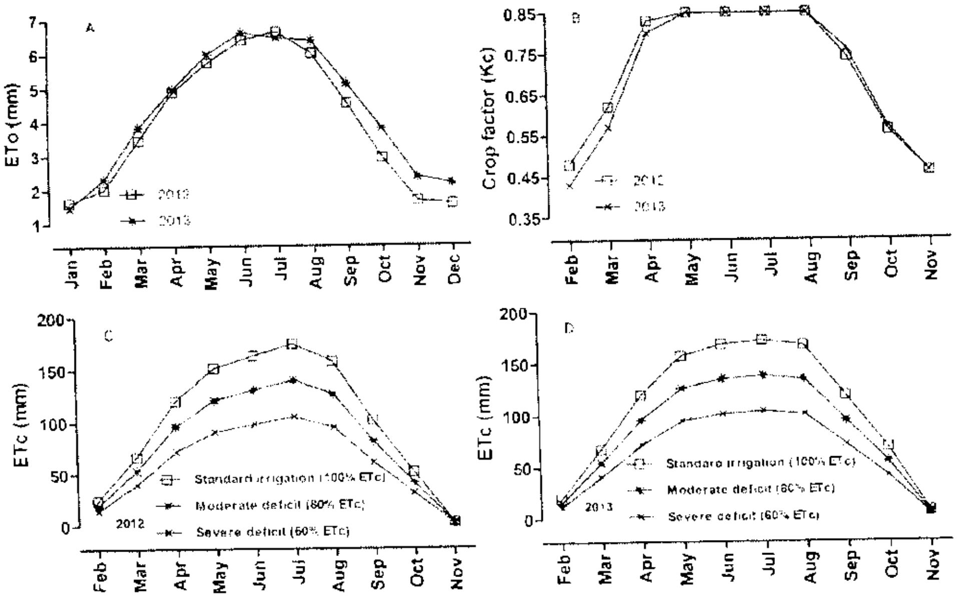

Figure 1: Reference evapotranspiration (ETo) data [A], FAO table grapes crop factors (Kc) data [B], and crop evapotranspiration (ETc) data for Flame Seedless grapes [C & D] during 2012 and 2013 seasons

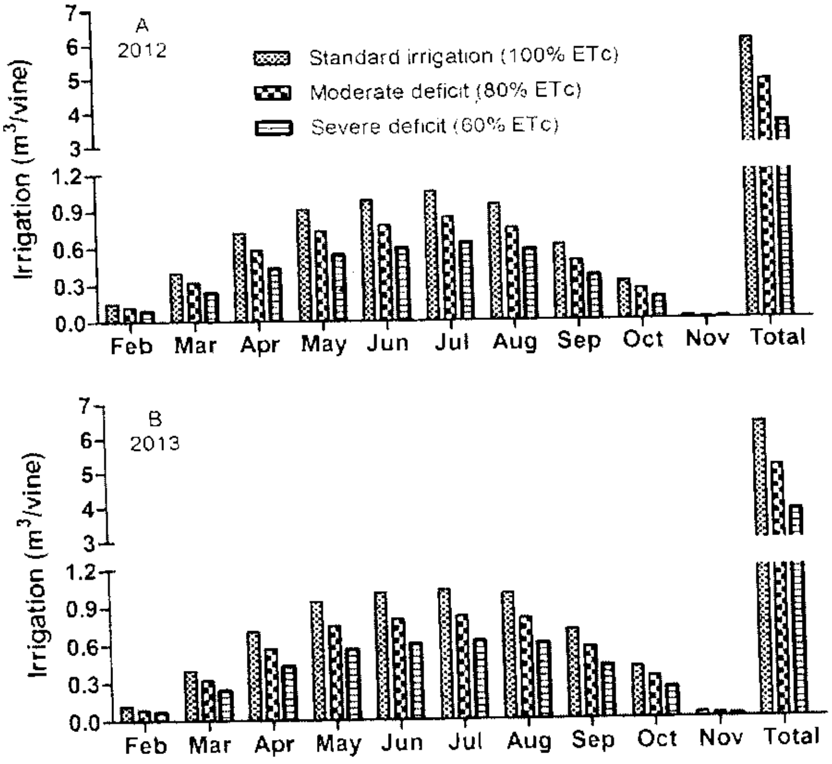

Figure 2: Monthly and total seasonal applied irrigation water (m^3 / vine) of standard irrigation (100 % ETc), moderate deficit irrigation (80% ETc), and severe deficit irrigation (60 % ETc) treatments for Flame Seedless vines during 2012 [A] and 2013 [B] seasons

Petioles were washed with tap water followed by distilled water, dried in a forced- air oven at 65 °C for 48 h, and ground in a stainless steel mill. Ground petioles were ashed in a muffle furnace at 450 °C for 6 h. The plant ash was dissolved in nitric acid solution (1:1, v/v), diluted to a final volume with distilled water, and potassium was analyzed by a flame photometer and expressed as percent dry weight (Jones, 2001). At harvest, bunch weight (g) and total yield for each vine (kg) was recorded and average shoot length (cm) was measured in 10 representative shoots per vine replicate. Average leaf blade surface area (cm^2) was measured in same leaves opposite the bunches by photographing the individual leaf blades by a digital camera with a reference ruler scale then processing the images to measures blade surface area by following the procedures of Image J Software Package Version 1.50i. For measuring quality parameters at harvest, thirty representative berries per replicate were sampled. Fruit diameter (mm) was recorded by a caliper and berry firmness (Newton = N) was measured by a penetrometer (Effegi, Italy) with a 3 mm diameter tip size. Juice total soluble solids (TSS) percent was measured by automatic temperature compensation refractometer (Atago ATC-1, Japan), and titratable acidity (TA) percent was measured by diluting the juice with distilled water and titrating with 0.1 N sodium hydroxide to the phenolphthalein end point and expressed as tartaric acid equivalent. For measuring berry skin total phenolics, berry skins were separated and samples of 1 g skin was homogenized and extracted in 2 % HCl in methanol for 24 h at room temperature in dark conditions. Then extracts were diluted with the same solvent to a suitable concentration for analysis. Total phenolics were measured according to the Folin-Ciocalteu method according to Singleton and Rossi, JR. (1965) and Pastrana-Bonilla *et al.* (2003). Two hundred microliters of skin extract were introduced in a test tube, 1 mL of Folin-Ciocalteu reagent and 0.8 mL of sodium carbonate (7.5 %) were added, and the contents were mixed and allowed to stand for 30 min. Absorption at 765 nm was measured by a spectrophotometer (2800 UV/VIS, Cole Parmer, U.S.A.) and total phenolic contents (mg/g FW) were expressed as gallic acid equivalent (GAE). Berry skin color characteristics were measured by a Minolta Color meter (CR-200, Japan) as CIELAB L*C* h° color system(Commission Internationale de l'Eclairage translated as the International Commission on Illumination). Lightness (L*) represents black to white from 0 to 100, chroma (C*) represents the vividness or dullness of color, and hue angle (h°) to distinguish the red, yellow, green and blue colors. Same berries used to measure skin color were used to measure harvest berry skin anthocyanin. Anthocyanin was extracted (Okamoto *et al.*, 2003) from 0.5 g berry skin sample with 25 ml extraction solution of 50 % acetic acid for 3 min and extraction was repeated 3 times, then the absorbance at 520 nm was measured by a spectrophotometer (2800 UV/VIS, Cole Parmer, U.S.A.). Anthocyanin content was expressed as mg/100 g FW cyaniding-3-monglucoside equivalent (C3GE). Pruning weight (kg) per each replicate was recorded for canes longer than 45 cm after winter pruning. Crop load (yield to pruning ratio) was calculated for each replicate and water use efficiency (WUE) was also calculated from ratio of vine yield (kg) to total applied irrigation per vine per season (m^3).

3- Experimental design and statistical analysis:

A split-split-plot experimental design was used in which irrigation treatment (100 % ETc, 80 % ETc, and 60 % ETc]) was the main plot factor, potassium fertilization (0 and 0.58 kg per vine as K_2O) was the sub-plot factor, and bunch thinning (40 and 30 bunch per vine) was the sub-sub-plot factor. Each of the 12 treatments was replicated 3 times with one vine per replicate. All obtained data were subjécted to statistical analysis by the general linear model (GLM) procedures of IBM SPSS Statistics Version 21 Software package. Analysis of variance (ANOVA) and significance of main effect for each factor was determined at p-value < 0.05 by the L.S.D. test. When there were significant interactions among factors, the effect of one factor was determined at each level of the other factor by separating the means by L.S.D. test at p-value < 0.05 or < 0.01. Furthermore, linear regression analysis was performed for relationships between applied irrigation with yield, berry diameter, firmness, petiole potassium, anthocyanin and phenolics. As well as for thinning and potassium with water use efficiency, bunch weight and berry diameter. Also, between yield with berry diameter and bunch weight, and finally between berry skin anthocyanin with skin total phenolics and skin color characteristics. Regression equation, coefficient of determination (r), and effect size (r^2) values were presented on each regression Figure (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Harvest petiole potassium content:

Petiole K was analyzed to study the effects of potassium fertilization on vine yield and quality as well as to determine whether vine K concentration will be influenced by irrigation and bunch thinning or not. As presented in Table 3 & 4 for both 2012 and 2013 seasons, potassium fertilized vines had significantly higher petiole K than unfertilized vines and K values were 2.23 % and 2.47 % in fertilized vines which were higher by 45.7 % and 58.7 % than unfertilized vines in 2012 and 2013 seasons, respectively. Irrigation treatment had a profound effect on K petiole contents as standard fully

Table 3: Mean values for the effects of deficit irrigation, bunch thinning and potassium fertilization on shoot length, leaf area, vine yield, bunch weight, berry diameter, pruning weight, crop load (yield/pruning) and water use efficiency (WUE; yield/irrigation) in 2012 season

Treatments[1]		Leaf petiole K (%)		Shoot length (cm)		Leaf area (cm^2)		Yield (kg/vine)		Bunch weight (g)		Berry diameter (mm)		Pruning weight (kg/vine)		Crop load		WUE	
		Potassium fertilization (K)																	
Bunch thinning(T)	Irrigation (I)	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K
- T	100 % ETc	1.36	2.70	158.8	160.1	130.3	165.0	10.57	12.90	264.5	322.4	14.8	16.6	0.70	0.75	16.03	17.44	1.74	2.13
	80 % ETc	1.15	2.20	148.3	149.8	121.5	150.3	7.17	8.85	179.3	222.3	12.8	14.5	0.45	0.49	16.10	18.07	1.48	1.82
	60 % ETc	0.99	1.86	126.5	130.1	109.3	135.8	5.63	7.08	139.8	178.5	11.1	12.7	0.32	0.31	17.70	22.85	1.55	1.94
+ T	100 % ETc	1.54	2.47	161.3	168.5	170.3	179.3	10.07	11.92	337.0	394.6	16.8	19.2	0.75	0.79	13.83	17.44	1.66	1.96
	80 % ETc	1.34	2.36	149.3	143.9	160.3	163.5	6.77	7.97	224.3	264.1	15.2	17.1	0.57	0.60	11.93	14.17	1.39	1.64
	60 % ETc	0.86	1.78	128.2	130.2	145.5	150.3	5.37	6.11	180.8	201.1	13.2	14.9	0.42	0.45	13.22	13.69	1.47	1.68
Main effect of irrigation																			
100 % ETc		2.02 a[2]		164.62 a		161.95 a		11.36 a		329.6 a		16.9 a		0.72 a		16.19 a		1.87 a	
80 % ETc		2.76 b		150.10 b		150.30 b		7.69 b		222.5 b		14.9 b		0.52 b		15.07 a		1.58 b	
60 % ETc		1.37 c		128.58 c		136.10 c		6.05 c		175.0 c		13.0 c		0.37 c		16.87 a		1.66 a	
L.S.D.		0.10		2.42		3.13		0.50		11.60		0.56		0.09		2.44		0.12	
Main effect of bunch thinning																			
- T		1.71 a		145.85 a		137.01 b		8.70 a		217.8 b		13.8 b		0.50 a		18.03 a		1.78 a	
+ T		1.72 a		149.68 a		161.90 a		8.03 b		267.0 a		16.1 a		0.58 a		14.05 b		1.63 b	
L.S.D.		0.09		4.02		4.00		0.41		9.48		0.46		0.08		1.99		0.10	
Main effect of potassium fertilization																			
- K		1.21 b		147.41 a		158.40 a		7.59 b		221.0 b		14.0 b		0.54 a		14.80 b		1.55 b	
+ K		2.23 a		148.12 a		140.50 b		9.14 a		263.8 a		15.8 a		0.53 a		17.28 a		1.86 a	
L.S.D.		0.09		3.99		1.20		0.41		9.48		0.46		0.06		1.99		0.10	
Interaction effects																			
I x T		0.06**[3]		NS		NS		NS		1307.3**		NS		NS		NS		NS	
I x K		NS		NS		41.17**		NS		NS		NS		NS		NS		NS	
T x K		NS		NS		1517.1**		NS		NS		NS		NS		NS		NS	
I x T x K		NS		NS		NS		NS		NS		NS		NS		NS		NS	

[1] Irrigation: 100 % ETc (100 % from crop evapotranspiration = standard irrigation), 80 % ETc (moderate deficit irrigation), 60 % ETc (severe deficit irrigation); Bunch thinning: Not thinned (-T) and thinned (+T); Potassium fertilization: Not fertilized (- K) and fertilized (+ K).

[2] Mean; separation within columns by the L.S.D. test at *p-value* < 0.05.

[3] NS: not significant, number of mean squares (MS)*: significantly different at *p-value* < 0.05, MS**: significantly different at *p-value* < 0.01.

Table 4: Mean values for the effects of deficit irrigation, bunch thinning and potassium fertilization on shoot length, leaf area, vine yield, bunch weight, berry diameter, pruning weight, crop load (yield/pruning) and water use efficiency (WUE; yield/irrigation) in 2013 season.

Treatments[1]		Leaf petiole K (%)		Shoot length (cm)		Leaf area (cm^2)		Yield (kg/vine)		Bunch weight (g)		Berry diameter (mm)		Pruning weight (kg/vine)		Crop load		WUE	
		Potassium fertilization (K)																	
Bunch thinning (T)	Irrigation (I)	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K
- T	100 % ETc	1.15	2.91	160.5	163.3	170.5	169.8	9.90	11.79	247.0	291.6	14.1	15.7	0.65	0.74	15.23	15.93	1.56	1.85
	80 % ETc	0.91	2.56	140.5	150.2	161.5	160.9	6.50	8.15	161.6	201.4	12.6	14.1	0.40	0.40	16.34	21.17	1.28	1.60
	60 % ETc	0.76	1.92	125.5	135.3	152.0	150.8	5.32	6.41	133.9	158.1	10.6	12.0	0.30	0.31	17.73	24.60	1.39	1.68
+ T	100 % ETc	1.36	2.78	168.5	170.3	175.1	178.2	9.45	11.58	311.6	387.0	16.0	18.2	0.74	0.82	12.00	14.20	1.48	1.82
	80 % ETc	1.09	2.45	153.4	150.7	162.3	164.9	6.03	8.34	199.3	273.1	14.3	16.4	0.50	0.59	12.30	14.41	1.18	1.64
	60 % ETc	0.82	2.18	130.3	133.3	156.8	153.5	5.04	6.31	164.9	208.2	12.9	14.3	0.38	0.41	13.34	15.55	1.32	1.65
Main effect of irrigation																			
100 % ETc		2.05 a[2]		166.1 a		173.4 a		10.68 a		309.3 a		16.0 a		0.75 a		14.34 a		1.68 a	
80 % ETc		1.75 b		148.7 b		162.4 b		7.25 b		208.9 b		14.4 b		0.47 b		16.05 a		1.42 b	
60 % ETc		1.42 c		131.1 c		153.2 c		5.78 c		166.3 c		12.4 c		0.35 b		17.81 a		1.51 b	
L.S.D.		0.12		4.21		3.30		0.50		10.71		0.64		0.12		3.73		0.10	
Main effect of bunch thinning																			
- T		1.70 a		145.9 b		160.9 b		8.01 a		198.9 b		13.2 b		0.46 b		18.50 a		1.56 a	
+ T		1.78 a		151.3 a		165.1 a		7.79 a		257.4 a		15.4 a		0.58 a		13.63 b		1.52 a	
L.S.D.		0.10		3.00		2.69		0.41		8.74		0.52		0.04		3.04		0.08	
Main effect of potassium fertilization																			
- K		1.02 b		146.7 a		163.0 a		7.04 b		203.1 b		13.4 b		0.50 a		14.49 b		1.37 b	
+ K		2.47 a		150.5 a		163.0 a		8.76 a		253.2 a		15.1 a		0.54 a		17.64 a		1.71 a	
L.S.D.		0.10		3.82		2.69		0.41		8.74		0.52		0.06		3.04		0.08	
Interaction effects																			
I x T		NS[3]		NS		NS		NS		1196.3**		NS		NS		NS		NS	
I x K		0.08*		NS		NS		NS		614.0*		NS		NS		NS		NS	
T x K		NS		123.95*		NS		NS		1763.2**		NS		NS		NS		NS	
I x T x K		NS		NS		NS		NS		NS		NS		NS		NS		NS	

[1] Irrigation: 100 % ETc (100 % from crop evapotranspiration = standard irrigation), 80 % ETc (moderate deficit irrigation), 60 % ETc (severe deficit irrigation); Bunch thinning: Not thinned (-T) and thinned (+T); Potassium fertilization: Not fertilized (- K) and fertilized (+ K).

[2] Mean; separation within columns by the L.S.D. test at *p-value* < 0.05.

[3] NS: not significant, number of mean squares (MS)*: significantly different at *p-value* < 0.05, MS**: significantly different at *p-value* < 0.01.

irrigated vines (100% ETc) had significantly higher K levels from other irrigation treatments in both seasons, followed by moderately deficit vines (80% ETc) and then severely stressed vines (60% ETc) which had the lowest significant K values. Bunch thinning treatment had no effect on petiole K contents in both seasons. As for the interaction effects, there was only a significant interaction effect between irrigation treatments and bunch thinning treatment in 2012, but in 2013 the interaction was only significant between irrigation and potassium treatments. Moreover, Figure 4-A & 4-B illustrates the linear regression relationship between total season applied irrigation water per vine and petiole K levels in both 2012 and 2013 seasons. There was a significant positive correlation between increased irrigation level and petiole K contents as r values were 0.45 and 0.33 in both 2012 and 2013, respectively. The above results suggested that vine K level was strongly dependent upon applied irrigation level. These data are in agreement with results reported by Mpelasoka *et al.* (2003) and Keller (2005), who indicated that K availability to grapevine roots increases with the increase in available soil moisture content.

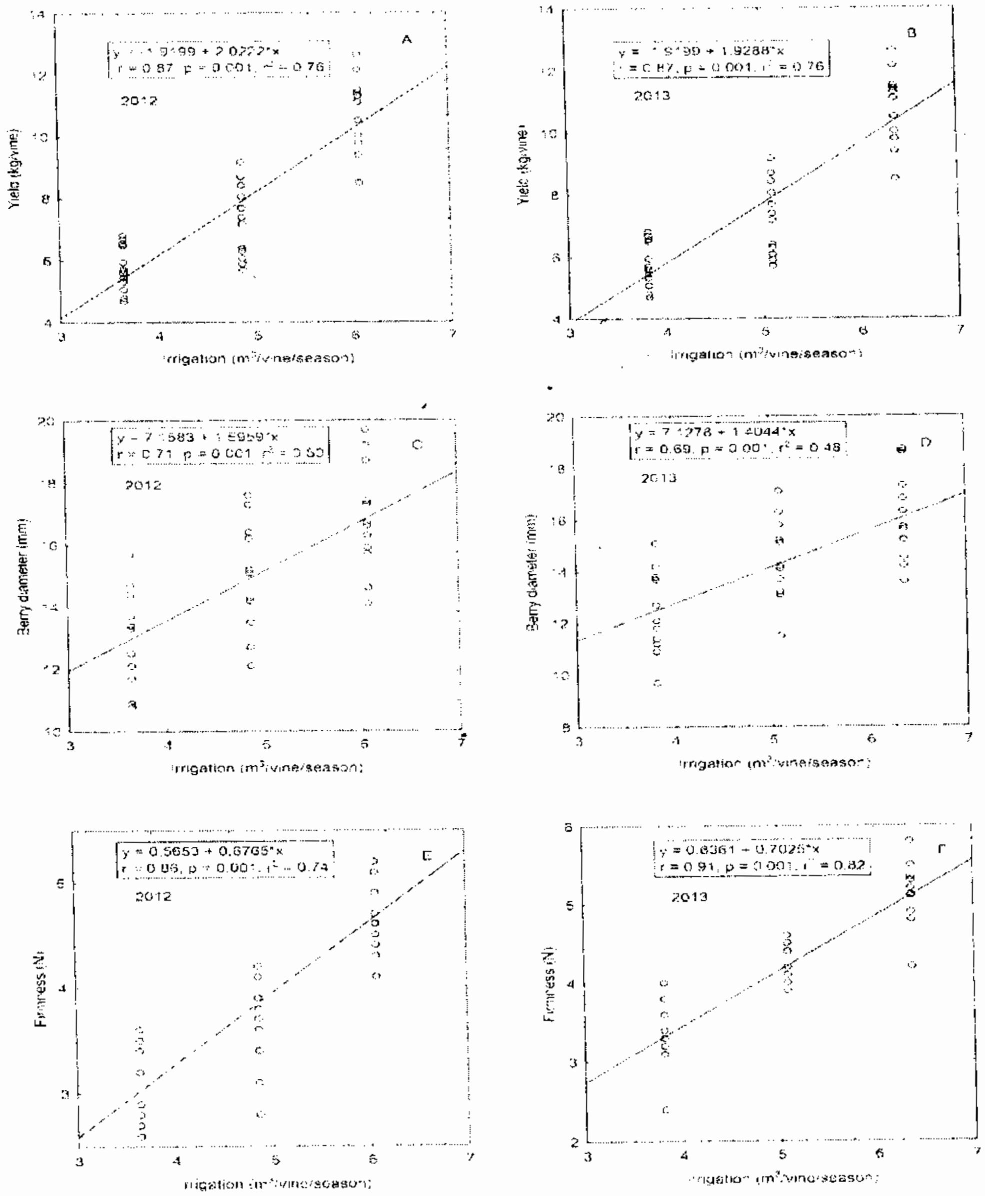

Figure 3: Linear regression analysis for relationships between total seasonal applied irrigation with vine yield [A & B], berry diameter [C & D], and berry firmness [E & F] for Flame Seedless grapes at harvest during 2012 and 2013 seasons

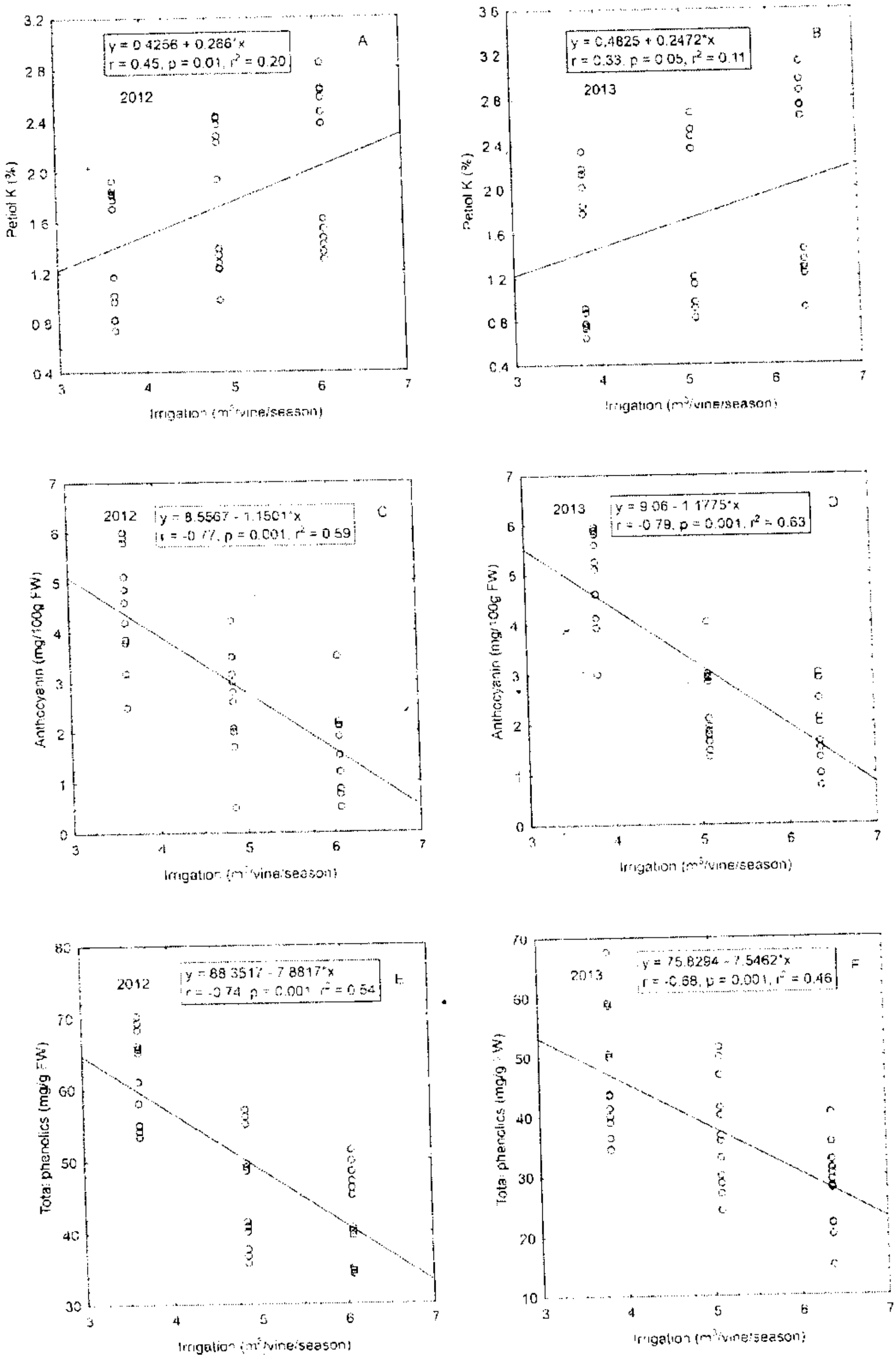

Figure 4: Linear regression analysis for relationships between total seasonal applied irrigation with harvest leaf petiole potassium [A & B], berry skin anthocyanin [C & D], and berry skin total phenolics [E & F] for Flame Seedless grapes during 2012 and 2013 seasons

Shoot growth, leaf area and pruning weight:

Data in Table 3 & 4 indicated that the shoot length and leaf blade surface area of the experimental grapevines tended to respond negatively to deficit irrigation. There was a gradual decrease in shoot length and leaf area of vines with increasing deficit irrigation level. This decline was clear in both seasons. There were significant differences among irrigation treatments in both seasons for leaf area and shoot length with highest values in standard irrigated vines, followed by moderately stressed and finally severely stressed vines. Shoot length values were reduced in 80 % ETc irrigated vines by 8.82% and 10.48 % and in 60 % ETc irrigated vines by 21.89 % and 21.07% in 2012 and 2013, respectively, as compared with 100 % ETc standard irrigated vines. The corresponding reduction percents for leaf area as compared with standard irrigation in 80 % ETc irrigated vines were 7.19 % and 6.34 % and in 60 % ETc irrigated vines were 15.96 % and 11.65 % in 2012 and 2013, respectively. Similar results were also reported by Dayer *et al.* (2013). Concerning the effect of bunch thinning on shoot length and leaf area, results presented in Table 3 & 4 indicated that thinning had no effect on shoot length, however, crop thinning significantly increased leaf area in both seasons. This results were consistent with those reported by Dayer *et al.* (2013), as they found that un-thinned vines showed 30 % lower total leaf area than thinned vines whereas shoot length was not affected. In addition, potassium fertilization had no effect on shoot growth and no consistent effect on leaf area. Similarly, interaction effects among deficit irrigation, bunch thinning and potassium fertilization on vegetative growth were not consistent in both seasons. Pruning weight differed significantly among irrigation treatments (Table 3 & 4). Values for pruning weight for vines irrigated with 80 % ETc and 60 % ETc were lower than that of 100 % ETc by 27.8 and 48.6 %, respectively in 2012, and by 37.3 and 53.3 %, respectively in 2013. The reduction in vine pruning weight by irrigation deficit may be attributed to the reduction in carbohydrate reserves (Dayer *et al.*, 2013). This reduction impacts the upper limit capacity of vine in the following season which limits the amount of yield the vines can ripen (Holzapfel *et al.*, 2010). Furthermore, bunch thinning significantly increased pruning weight only in the second season, whereas potassium fertilization had no effect on pruning weight in both seasons. Also, there were no interactions among treatments in both seasons.

Yield, bunch weight, berry diameter, crop load (yield/pruning) and water use efficiency (yield /irrigation):

Results presented in Table 3 & 4 showed that there were significant differences among irrigation treatments, thinning treatments, and potassium fertilization treatments. 100 % ETc irrigated vines had the highest yield of 11.36 & 10.69 kg/vine, bunch weight of 329.6 & 309.3 g, and berry diameter of 16.9 & 16 mm in 2012 & 2013, respectively, followed by 80 % ETc irrigated vines, whereas 60 % ETc irrigated vines had the lowest values. Yield was reduced as compared with standard irrigation in 80 % ETc irrigated vines by 32.3% and 32.1 % and in 60 % irrigated vines by 46.7 % and 45.9 % in 2012 and 2013, respectively. Linear regression analysis in Figure 3 showed that there was a very significant positive relationship between increased applied irrigation with vine yield (r values of 0.87 in both seasons), and between increased applied irrigation and berry diameter (r values of 0.71 & 0.69 in 2012 & 2013 seasons, respectively). Yield reduction due to irrigation treatments can be explained by the reduced bunch weight and berry diameter with similar trends in both seasons. As demonstrated in Figure 7, there was a very significant positive linear regression correlation between vine yield and bunch weight (r values of 0.86 & 0.85 in 2012 & 2013, respectively) and between vine yield and berry diameter (r values of 0.7 & 0.73 in 2012 & 2013, respectively). As for the effects of thinning, results of Table 3 & 4 show that bunch thinned vines had significantly lower yield in 2012 only (8.03 kg/vine) compared with un-thinned vines (8.70 kg/vine), while differences were not significant in the second season. However, bunch weight in thinned vines (267.0 and 257.4 g) and berry diameter (16.1 & 15.4 mm) of 2012 & 2013 seasons, respectively, were significantly higher than un-thinned vines (bunch weight of 217.8 & 198.9 g, and berry diameter of 13.8 & 13.2 mm, in 2012 and 2013, respectively). The reduction in vine yield due to bunch thinning was compensated by increased bunch weight and berry diameter. As presented in Figure 6, there was a significant negative correlation between thinning and bunch weight (r values of -0.33 & -0.40 in 2012 & 2013, respectively), and a very significant negative correlation between thinning and berry diameter (r values of -0.52 & -0.51 in 2012 & 2013 seasons, respectively). Potassium fertilized vines (Table 3 & 4) had higher significant yield of 9.14 and 8.76 kg / vine as compared with un-fertilized vines of 7.59 and 7.04 kg / vine in 2012 and 2013 seasons, respectively. This increase could be attributed to the significant increases in bunch weight and berry diameter obtained in both seasons. As shown in Figure 5, the positive linear regression correlation between potassium fertilization and bunch weight was only significant in the second season (r value of 0.34), while the positive correlation between potassium and berry diameter was significant in both season (r value of 0.42 & 0.40 in 2012 & 2013, respectively).

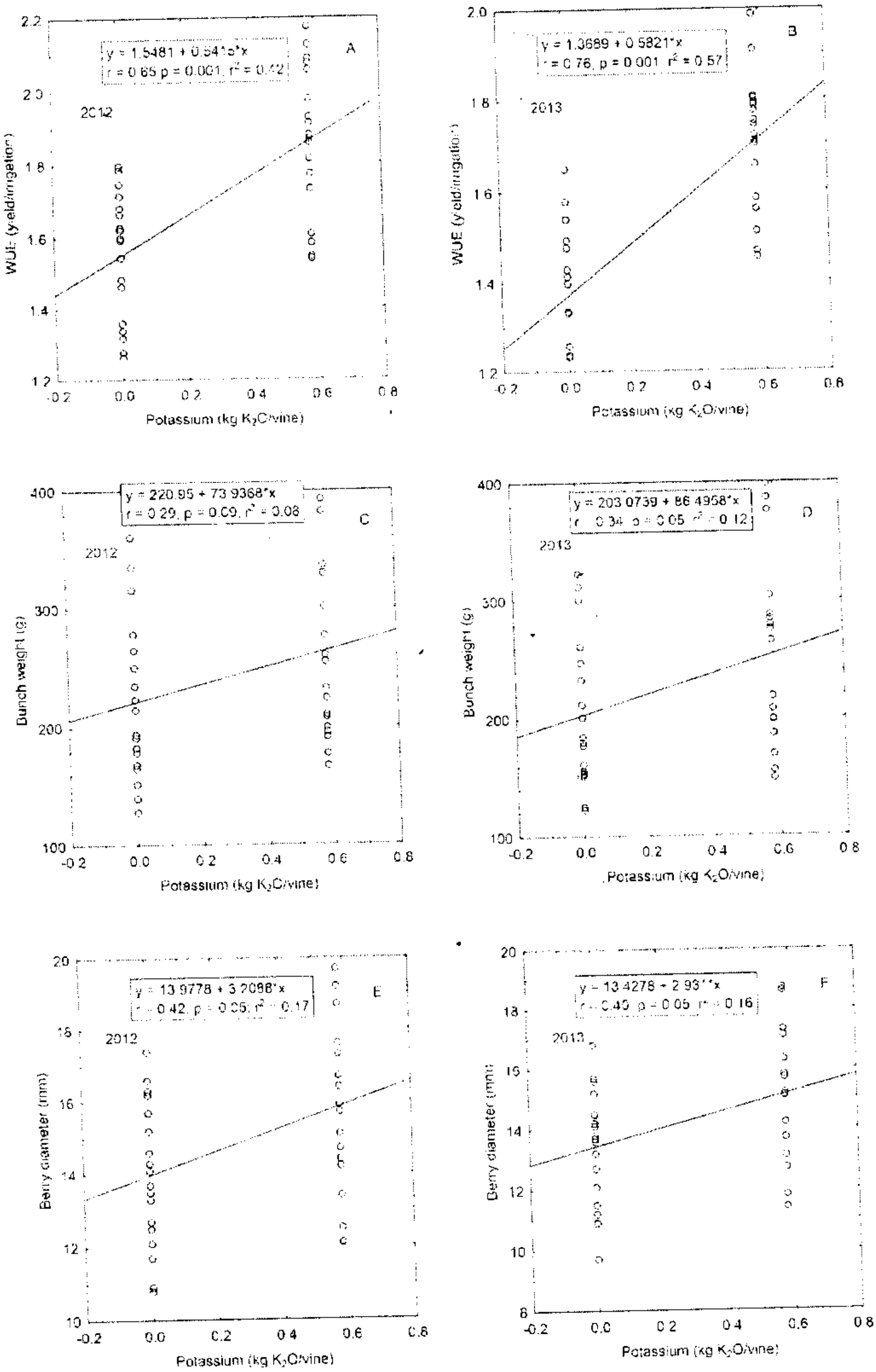

Figure 5: Linear regression analysis for relationships between potassium fertilization with water use efficiency (WUE) [A & B], bunch weight [C & D], and berry diameter [E & F] for Flame Seedless grapes at harvest during 2012 and 2013 seasons

Interaction effect among treatments was only observed for bunch weight data, and was significant only for irrigation with bunch thinning in 2012 season but in 2013 data interaction were significant for irrigation with thinning, irrigation with potassium, and thinning with potassium, while no interactions were observed for the three factors in both seasons. Moreover, no significant effect for deficit irrigation on crop load in both seasons (Table 3 & 4), bunch thinning significantly decreased crop load by 22.07 % and 26.32 %, whereas potassium fertilization significantly increased crop load by 16.76 % and 21.74% in 2012 and 2013, respectively. Additionally, no interaction effects were observed among the three factors on crop load. Data of water use efficiency (WUE) presented in Tables 3 & 4 revealed that WUE was highest in 100 % ETc irrigated vines and was only significantly higher than 80 % ETc irrigated vines in 2012 and was significantly higher than both 80 % ETc and 60 % ETc irrigated vines in 2013. Long term application of deficit irrigation significantly reduced yield in water deficient vines and thus greatly affected yield weight to applied irrigation ratio. Bunch thinning significantly reduced WUE in the first season only, and there was a non-significant positive linear regression correlation between thinning and WUE as r values were 0.29 and 0.10 in 2012 and 2013, respectively (Figure 6-A & 6-B). Potassium fertilization significantly increased WUE in both seasons by 20 % and 24.82 % in 2012 and 2013, respectively. Figure 5-A & 5-B demonstrated that the positive linear regression correlation between potassium and WUE was highly significant with r values of 0.65 and 0.76 in 2012 and 2013, respectively. Interaction effects were not significant among all experimental factors in both seasons for WUE. Several studies reported that vine yield increased linearly with increasing irrigation level (Marsal *et al.*, 2008 and Netzer *et al.*, 2009). Crop load is an indicator of grapevine balance and grape berry quality is affected when its value exceeds 10 (Salón *et al.*, 2005). Reduction of crop load by a suitable bunch thinning increases berry size, over-cropping reduces berry size due to decreased available assimilates, and under-cropping also reduced berry size due to increased vegetative growth (Mpelasoka *et al.*,2003). Potassium fertilized vines had an increased WUE due to the significant yield increase as a result of increased bunch weight and berry diameter. Potassium plays an essential role for grapevine growth and grape production as it regulates vine water relations, activates enzymes and transport through cellular membranes, and promotes translocation of photosynthates into berries (Mpelasoka *et al.*, 2003).

Berry quality characteristics:

Data presented in Table 5 & 6 showed that 60 % ETc irrigated vines had the highest significant value for total soluble solids (TSS) of 20.6% and 21 % in 2012 and 2013, respectively, compared with other irrigation treatments. TSS of 80% ETc irrigated vines (19.7 %) was not significantly different from standard irrigated vines in 2012 but was significant (19.4 %) in 2013. There was a significant effect for thinning on TSS in the first season only. Potassium fertilization increased TSS significantly in both seasons from 18.7 % and 17.8 % in un-fertilized vines to 21% and 21.1 % in fertilized vines in 2012 and 2013, respectively. No interaction effects on TSS among treatments occured. Increased TSS due to deficit irrigation can be attributed to the reduction in vegetative growth which redirects assimilates to berries, as a result of berry dehydration leading to increased TSS concentration, by osmoregulation, and/or due to the effect of ABA produced from roots on fruit ripening (El-Ansary and Okamoto, 2005). Increased sugar accumulation in thinned vines in first season and in potassium fertilized vines could be due to reallocation of photosynthates between the source and sink promoting higher allocation of sugars to bunches (Mpelasoka *et al.*, 2003 and Santesteban *et al.*, 2011). Titratable acidity (TA) results presented in Table 5 & 6 showed that 60 % ETc irrigated vines had significantly lower TA values of 0.61 % and 0.68 % than TA values of 100 % ETc standard irrigated vines of 0.76 % and 0.78 % in 2012 and 2013, respectively. TA values of 80 % ETc irrigated vines was not significantly different from 60% irrigated vines in 2012 but was significantly different from standard irrigated vines, and the reverse was true in 2013. Thinning treatment had no effects on TA in both seasons. Potassium treatment increased TA values significantly in both seasons as compared with un-fertilized vines. No interaction effects among all treatment factors for TA were found. Malic and tartaric acids are the major organic acids contribute to grape berry acidity during ripening (Matthews and Anderson, 1988 and Esteban *et al.*, 2002). Acidity loss in berry juice during ripening increases under irrigation deficit partially due to increased bunch temperature as a result of reduced vine vegetative growth (Souza et al, 2005). The increased TA in berry juice of potassium fertilized vines could be attributed to increased partitioning of photosynthates from leaves to bunches through the sink-source relationship (Bravdo *et al.*, 1985) as potassium contributes to water and solute translocation into berries especially for malate and tartarate (Mpelasoka *et al.*, 2003).

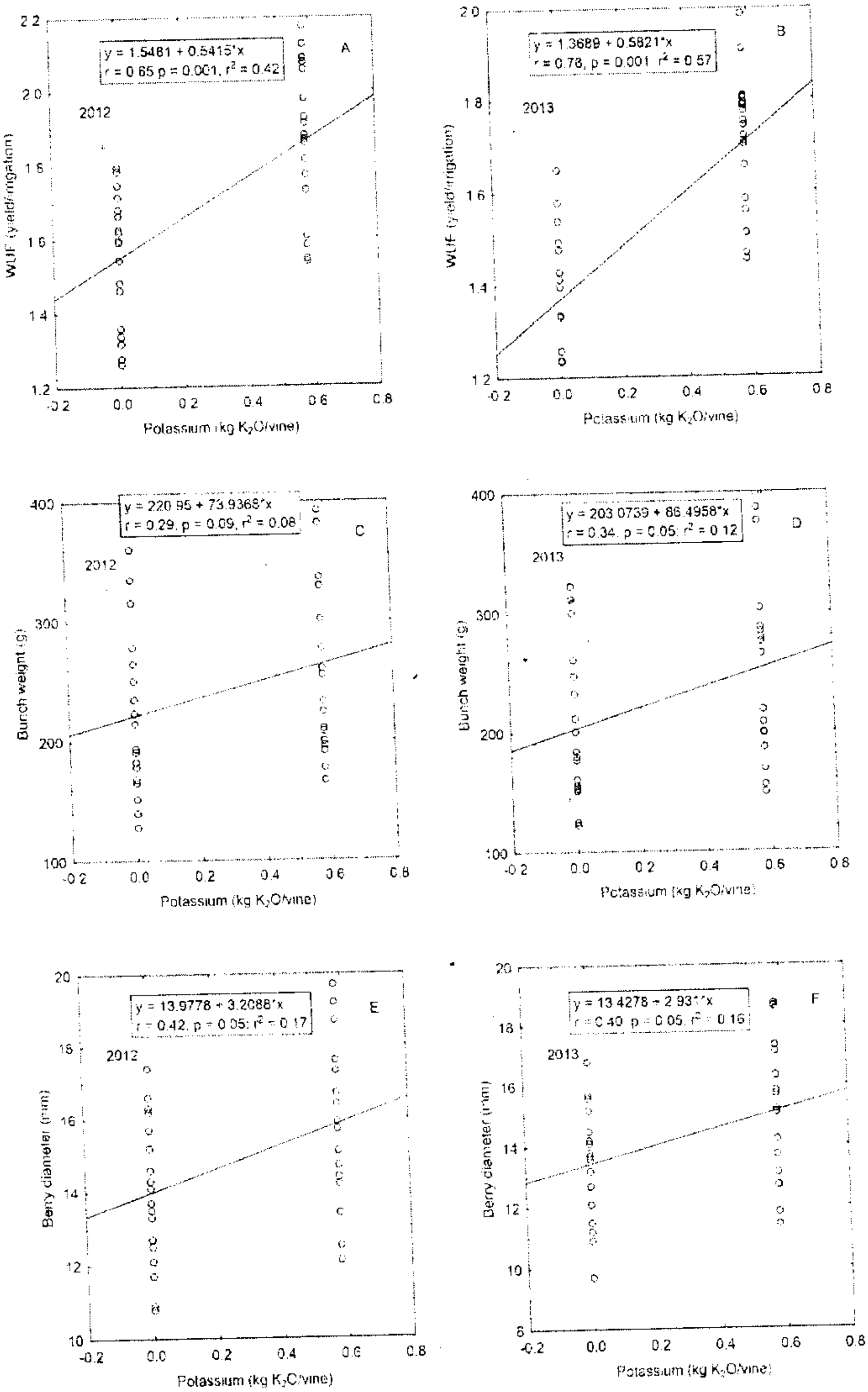

Figure 6: Linear regression analysis for relationships between bunch thinning with water use efficiency (WUE) [A & B], bunch weight [C & D], and berry diameter [E & F] for Flame Seedless grapes at harvest during 2012 and 2013 seasons

Table 5: Mean values for the effects of deficit irrigation, bunch thinning, and potassium fertilization on fruit juice total soluble solids (TSS) and titratable acidity (TA), fruit firmness, skin color (L^*, C^*, and h°), anthocyanin and total phenolics in 2012 season.

		TSS (%)		TA (%)		Firmness (N)		L^*		C^*		h^0		Anthocyanin (mg/100g FW		Total phenolics (mg/g FW)	
Treatments[1]		Potassium fertilization (K)															
Bunch thinning(T)	Irrigation (I)	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K
- T	100 % ETc	17.2	19.4	0.72	0.75	4.8	4.6	36.47	35.90	19.50	19.80	18.2	85.9	1.20	1.53	46.11	34.60
	80 % ETc	18.0	20.4	0.63	0.70	3.8	3.6	34.73	34.30	16.62	16.40	69.9	54.2	2.00	2.60	40.89	36.80
	60 % ETc	19.0	21.4	0.57	0.65	2.8	3.3	33.63	33.70	14.00	13.91	52.5	41.4	3.18	4.86	58.12	54.20
+ T	100 % ETc	19.1	21.6	0.75	0.81	4.6	4.9	35.83	35.23	18.00	17.88	86.3	80.6	2.13	2.11	49.90	40.11
	80 % ETc	19.0	21.3	0.61	0.72	3.9	3.7	34.27	33.70	14.00	13.90	66.5	51.1	2.80	3.15	56.11	49.13
	60 % ETc	20.1	22.0	0.58	0.62	3.3	2.9	31.87	32.67	12.50	11.10	49.9	40.3	4.20	5.90	69.30	65.65
Main effect of irrigation																	
100 % ETc		19.3 b[2]		0.76 a		4.73 a		35.86 a		18.29 a		67.73 a		1.74 c		42.68 c	
80 % ETc		19.7 ab		0.66 b		3.74 b		34.25 b		15.23 b		60.42 b		2.64 b		45.73 b	
60 % ETc		20.6 a		0.61 b		3.08 c		32.97 c		13.00 c		46.77 c		4.54 a		61.82 a	
L.S.D.		1.16		0.06		0.34		0.84		1.40		3.42		0.68		1.01	
Main effect of bunch thinning																	
- T		19.2 b		0.67 a		3.81 a		34.79 a		16.70 a		62.95 a		2.56 b		45.12 b	
+ T		20.5 a		0.68 a		3.89 a		33.93 b		14.31 b		53.67 b		3.38 a		55.03 a	
L.S.D.		0.95		0.05		0.30		0.68		1.41		2.99		0.55		0.83	
Main effect of potassium fertilization																	
- K		18.7 b		0.64 b		3.87 a		34.47 a		15.85 a		57.20 b		2.59 b		46.75 b	
+ K		21.0 a		0.71 a		3.83 a		34.25 a		15.16 a		59.41 a		3.36 a		53.41 a	
L.S.D.		0.95		0.05		0.30		0.68		1.18		1.80		0.55		0.83	
Interaction effects																	
I x T		NS[3]		NS		NS		NS		NS		65.12**		NS		66.87**	
I x K		NS		NS		NS		NS		NS		388.17**		NS		38.18**	
T x K		NS		NS		NS		NS		NS		69.21**		NS		NS	
I x T x K		NS		NS		NS		NS		NS		84.68**		NS		NS	

[1] Irrigation: 100 % ETc (100 % from crop evapotranspiration = standard irrigation), 80 % ETc (moderate deficit irrigation), 60 % ETc (severe deficit irrigation); Bunch thinning: Not thinned (- T) and thinned (+T); Potassium fertilization: Not fertilized (- K) and fertilized (+ K).

[2] Mean; separation within columns by the L.S.D. test at *p-value* < 0.05.

[3] NS: not significant, number of mean squares (MS)*: significantly different at *p-value* < 0.05, MS**: significantly different at *p-value* < 0.01.

Table 6: Mean values for the effects of deficit irrigation, bunch thinning, and potassium fertilization on fruit juice total soluble solids (TSS) and titratable acidityTA), fruit firmness, skin color(L^*, C^*, and h°), anthocyanin and total phenolics in 2013 season.

		TSS (%)		TA (%)		Firmness (N)		L^*		C^*		h^0		Anthocyanin (mg/100g FW)		Total phenolics (mg/g FW)	
Treatments[1]		Potassium Fertilization (K)															
Bunch thinning (T)	Irrigation (I)	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K	- K	+ K
- T	100 % ETc	16.1	18.8	0.75	0.81	5.1	5.1	35.40	35.00	17.90	15.12	85.5	75.1	1.50	1.63	22.15	31.20
	80 % ETc	17.4	20.9	0.72	0.77	4.2	4.2	33.57	33.13	13.21	11.80	49.1	15.2	1.65	1.79	30.11	40.20
	60 % ETc	18.8	22.4	0.66	0.72	3.2	3.4	32.20	31.43	10.11	9.50	46.2	42.1	4.13	5.11	39.11	40.15
+ T	100 % ETc	16.9	19.9	0.76	0.79	5.3	5.0	35.57	34.63	17.22	17.11	84.2	85.3	2.11	2.50	27.90	30.39
	80 % ETc	17.9	21.5	0.69	0.78	4.1	4.3	33.30	31.63	13.80	13.50	60.1	60.1	2.92	2.95	36.93	41.55
	60 % ETc	19.8	22.9	0.63	0.72	3.4	3.3	32.47	31.73	15.20	13.80	40.1	32.1	4.60	5.89	50.10	59.12
Main effect of irrigation																	
100 % ETc		17.9 c[2]		0.78 a		5.11 a		35.23 a		16.83 a		82.52 a		1.94 b		27.91 c	
80 % ETc		19.4 b		0.74 a		4.20 b		32.92 b		13.07 b		54.14 b		2.33 b		37.20 b	
60 % ETc		21.0 a		0.68 b		3.33 c		31.96 c		12.15 b		40.14 c		4.93 a		47.12 a	
L.S.D.		0.96		0.05		0.34		0.70		1.89		2.13		0.56		6.50	
Main effect of bunch thinning																	
- T		19.1 a		0.74 a		4.20 a		33.51 a		15.10 a		60.06 a		2.64 b		33.82 b	
+ T		19.8 a		0.73 a		4.22 a		33.22 a		12.94 b		57.81 b		3.50 a		41.00 a	
L.S.D.		0.79		0.04		0.28		0.57		1.86		2.20		0.45		5.31	
Main effect of potassium fertilization																	
- K		17.8 b		0.70 b		4.22 a		33.76 a		14.57 a		61.21 a		2.82 b		34.38 b	
+ K		21.1 a		0.76 a		4.21 a		32.98 b		13.47 a		56.66 b		3.31 a		40.44 a	
L.S.D.		0.82		0.04		0.28		0.57		1.95		1.89		0.45		5.31	
Interaction effects																	
I x T		NS[3]		NS		NS		NS		NS		4.91*		NS		NS	
I x K		NS		NS		NS		NS		NS		NS		NS		NS	
T x K		NS		NS		NS		NS		NS		7.68*		NS		NS	
I x T x K		NS		NS		NS		NS		NS		33.16**		NS		NS	

[1] Irrigation: 100 % ETc (100 % from crop evapotranspiration = standard irrigation), 80 % ETc (moderate deficit irrigation), 60 % ETc (severe deficit irrigation); Bunch thinning: Not thinned (- T) and thinned (+T); Potassium fertilization: Not fertilized (- K) and fertilized (+ K).

[2] Mean; separation within columns by the L.S.D. test at *p-value* < 0.05.

[3] NS: not significant, number of mean squares (MS)*: significantly different at *p-value* < 0.05, MS**: significantly different at *p-value* < 0.01.

Berry firmness was only significantly influenced by irrigation treatment factor in both seasons. 60 % ETc irrigated vines had the significantly lowest berry firmness values of 3.08 N and 3.33 N, followed by 80% ETc irrigated vines of 3.74 N and 4.20 N, whereas 100 % ETc irrigated vines had the significantly highest berry firmness values of 4.73 N and 5.11N in 2012 and 2013 seasons, respectively. A very significant positive linear correlation between increased applied irrigation and berry firmness values as indicated from r values of 0.86 and 0.91 in 2012 and 2013, respectively, (Figure 3-E & 3-F). However, no interaction effects on berry firmness were observed in both seasons. Berry firmness is responsive to irrigation events and vine water status, and reduced berry firmness in deficient vines occurs as a result of water loss from berry to vine or atmosphere leading to decreased turgor pressure (Bernstein and Lustig, 1981 and El-Ansary *et al.*, 2005). In addition, berry skin total phenolics (Table 5 & 6) was significantly higher in 60 % irrigated vines (61.82 & 47.12 mg/g), followed by 80 % ETc irrigated vines (45.73 & 37.2 mg/g), and was lowest in 100 % ETc irrigated vines (42.68 & 27.91 mg/g) in both seasons (2012 & 2013). It can be seen in Figure 4 (E & F) that, berry skin total phenolics had a very significant negative correlation with increased irrigation level (r values of -0.74 & -0.68 in 2012 and 2013, respectively). Bunch thinned vines had significantly higher berry skin total phenolics as compared with un-thinned vines in both seasons, and similar trend was for potassium fertilized vines as compared with un-fertilized vines. As for berry skin anthocyanin, data presented in Table 5 & 6, 60 % ETc irrigated vines had the highest significant values of 4.54 & 4.93 mg/100g, followed by 80 % ETc irrigated vines of 2.64 & 2.33 mg/100g, while 100 % ETc irrigated vines had the lowest significant values of 1.74 & 1.94 mg/100g in 2012 and 2013, respectively. A very significant negative linear regression correlation (Figure 4-C & 4-D) was observed between increased irrigation level and berry skin anthocyanin content (r values -0.77 & -0.79 in 2012 and 2013, respectively). Berries of thinned vines had significantly higher skin anthocyanin contents as compared with un-thinned ones. Potassium treated vines had berries with significantly higher anthocyanin content in their skins as compared with un-treated vines. As for the interaction effects among treatments, no significant interactions were found in both seasons. Berry skin anthocyanin contents had a similar trend as influenced by irrigation, thinning and potassium treatments compared with skin total phenolics values, and this can be explained by the very significant positive linear correlation presented in Figure (7-E & 7-F) between berry skin anthocyanin and berry skin total phenolics (r values 0.79 & 0.63 in 2012 and 2013, respectively). Grapevines subjected to water deficit stress had berries with increased total phenolics (El-Ansary and Okamoto, 2007) and anthocyanin (Bucchetti *et al.*, 2011 and Santesteban *et al.*, 2011). This is due to direct promotion of phenolic (Ojeda *et al.*, 2002) and anthocyanin (Roby *et al.*, 2004) biosynthesis pathways. Water deficit during the berry growth leads to smaller berries but with concentrated skin total phenolics and anthocyanin (Ojeda *et al.*, 2002 and Koundouras *et al.*, 2006). Also, bunch thinning (Guidioni *et al.*, 2002) and potassium fertilization (Reynolds *et al.*, 2005) enhance berry skin anthocyanin concentration. Berry skin color characteristics data presented in Table 5 &6 revealed that, lightness (L*), chroma(C*), and hue angel (h°) values were significantly higher in 100 ETc standard irrigated vines as compared with other deficit irrigated treated vines in both seasons. 60% ETc irrigated vines had the lowest significant values for L*, C*, and h° as compared with 100 ETc irrigated vines and with 80% ETc irrigated vines, except for C* in the second season where no differences were found between 80% and 60% ETc irrigated vines. As presented in Figure 8, there were significant negative relationships between increased berry skin anthocyanin and skin L*, C*, and h° values indicating that color characteristics values are sensitive color indicators and can be used effectively to measure changes in berry skin anthocyanin to monitor the development of red color in Flame Seedless grapes (r values for L*-0.74& -0.61, C* -0.75 & -0.39, and h°-0.33& -0.72, in 2012 & 2013, respectively). Bunch thinned vines had berries with significantly lower L*, C* and h° values as compared with un- thinned control in both seasons except for L*value in the second season were it didi not differ significantly from control (Table 5 &6). Data of potassium treated vines for color characteristics were not consistent with no significant differences in C* in both seasons. There were significant interactions among all factors for h° in both both seasons except for irrigation and potassium in the second season, but no interactions were found among all treatments for L* and C* values in both seasons (Table 5 &6). Previous research on pigmentation of Flame Seedless grapes reported that skin anthocyanin concentration had a profound effect on lightness and hue angle of berries (Peppi *et al.*, 2006).

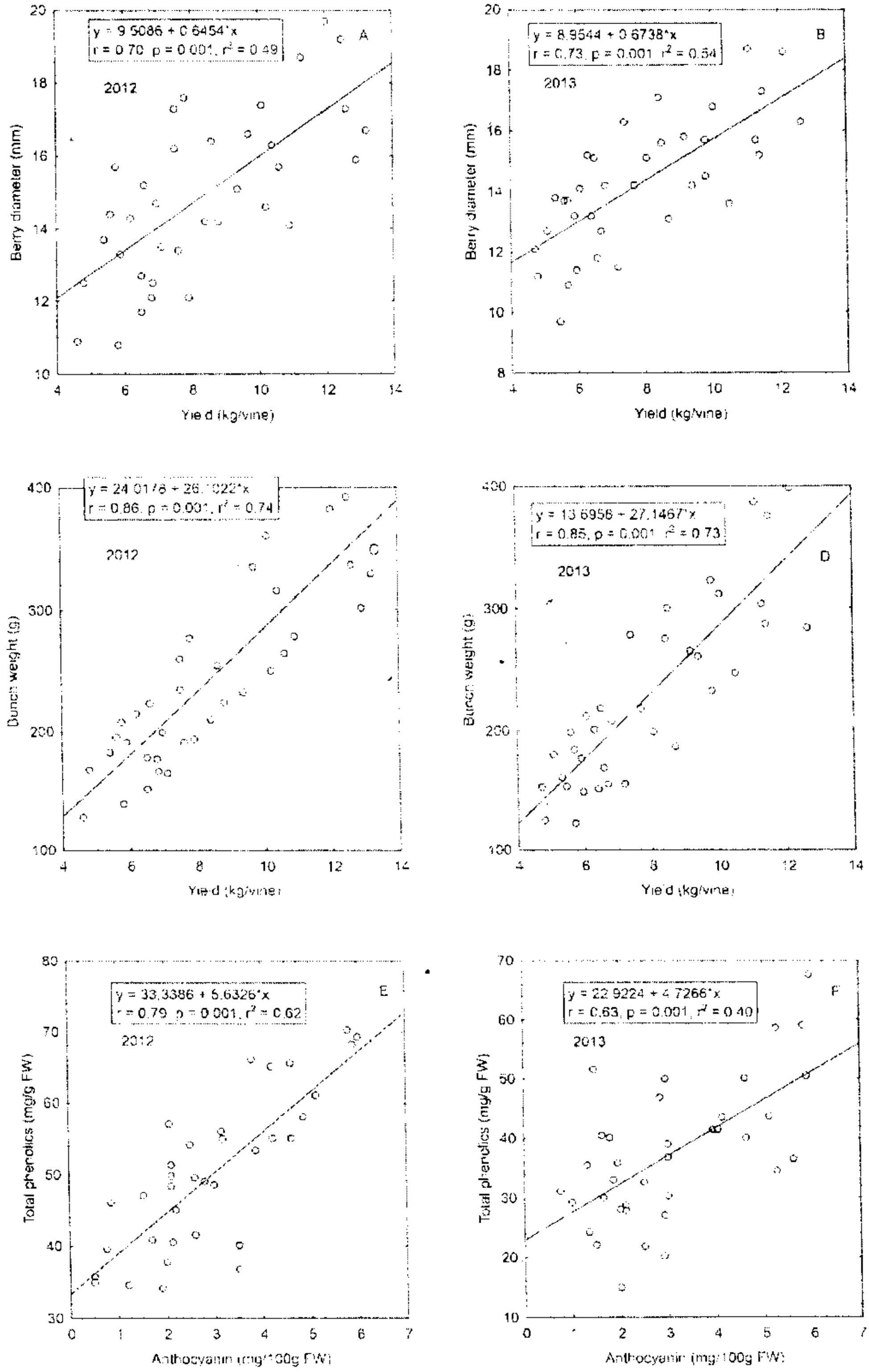

Figure 7: Linear regression analysis for relationships between vine yield with berry diameter [A & B] and bunch weight [C & D], and between berry skin anthocyanin with berry skin total phenolics [E & F] for Flame Seedless grapes at harvest during 2012 and 2013 seasons

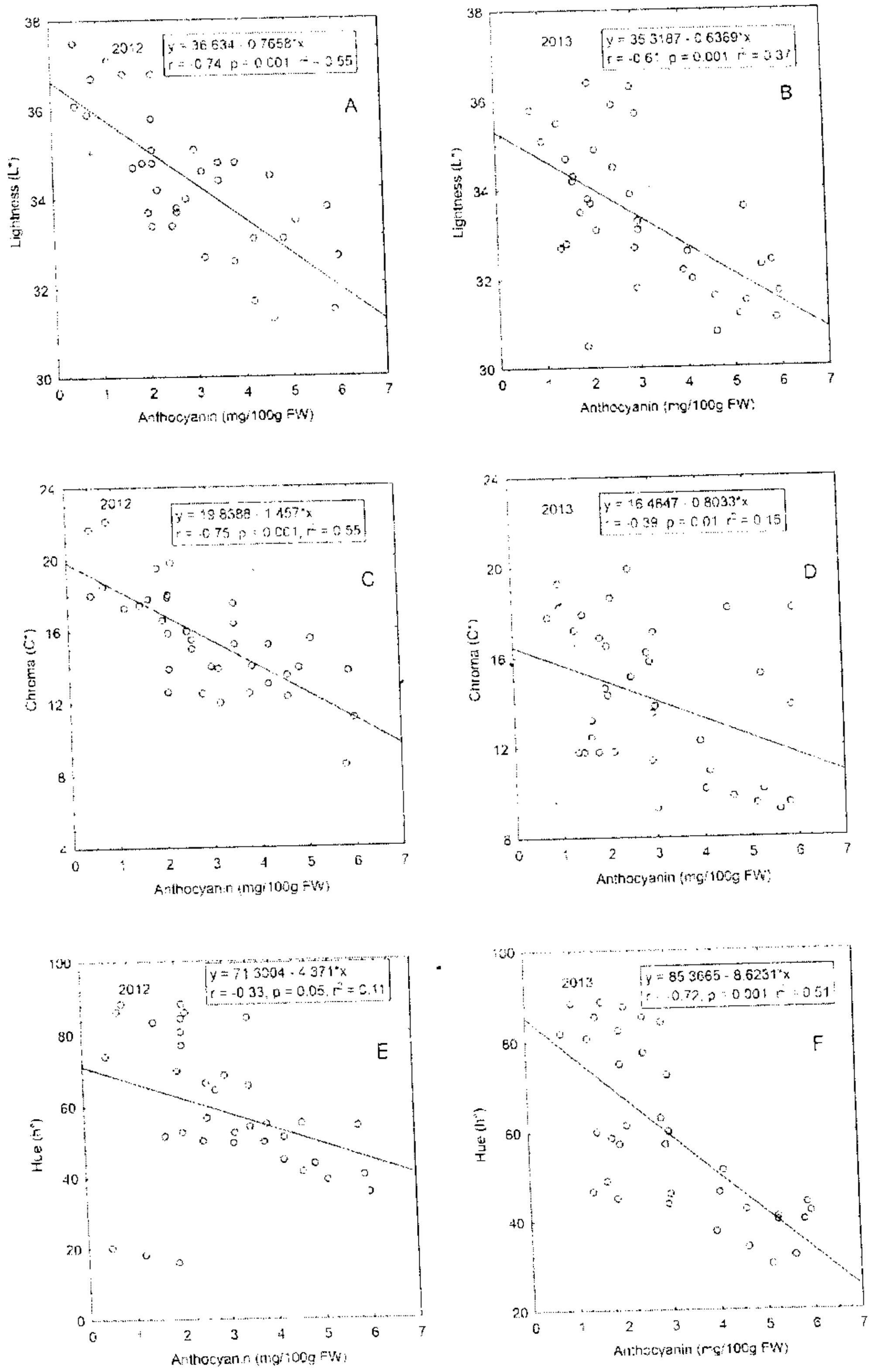

Figure 8: Linear regression analysis for relationships between berry skin anthocyanin with berry skin lightness (A & B), chroma (C & D), and hue angle (E & F) for Flame Seedless grapes at harvest during 2012 and 2013 seasons

CONCLUSION

Research results indicated that under conditions of this study, it is possible to produce high marketable quality grapes with the required standards for export with only 32 % reduction in yield by using 20 % less irrigation water during the whole production season as compared with standard practice irrigation. Additional bunch thinning and potassium application treatments can enhance accumulation of berry total soluble solids and the development of red coloration.

REFERENCES

Allen R. G., S. L. Pereira, D. Raes and M. Smith. **1998**. Crop Evapotranspiration, Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage paper No 56. FAO, Water Resources, Development and Management Service, Rome, Italy.

Bernstein, Z. and I. Lustig. **1981**. A new method of firmness measurement of grape berries and other juicy fruits. Vitis, **20**:15-21.

Black, C. A., D. D. Evans, J. L. White, L. E. Ensminger and F. E. Clark. **1965**. Methods of Soil Analysis. Part 1. Physical and Mineralogical Properties, Including of Statistics of Measurement and Sampling. American Society of Agronomy, Inc., Madison Publisher, Wisconsin, USA.

Blanco, O., J. M. Faci and J. Negueroles. **2010**. Response of table grape cultivar 'Autumn Royal' to regulated deficit irrigation applied in post-veraison period. Span. J. Agric. Res., **8**: 76–85.

Bravdo, B., Y. Hepner, C. Loinger, S. Cohen and H. Tabacman. **1985**. Effect of crop level and crop load on growth yield, must and wine composition, and quality of Cabernet Sauvignon. Amer. J. Enol. Vitic., **36**: 125–131.

Bucchetti, B., M. A. Matthews, L. Faldignella, E. Peterlunger and S. D. Castellarin. **2011**. Effect of water deficit on Merlot grape tannins and anthocyanins across four seasons. Sci. Hort., **128**: 297-305.

Dayer, S., J. A. Prieto, E. Galat, J. Perez peña. **2013**. Carbohydrate reserve status of Malbec grapevines after several years of regulated deficit irrigation and crop load regulation. Aust. J. Grape Wine Res., **19**:422–430.

Dokoozalian, N. K. and D. Hirschfelt. **1995**. The influence of cluster thinning at various stages of fruit development on Flame Seedless table grapes. Amer. J. Enol. Vitic., **46**: 429-436.

El-Ansary, D. O. and G. Okamoto. **2007**. Effects of deficit irrigation strategies on vine water status, canopy and cluster temperatures, fruit total phenolics, and the color of Muscat of Alexandria table grapes. Scientific Reports of the Faculty of Agriculture, Okayama University, **96**: 29-35.

El-Ansary, D. O., S. Nakayama, K. Hirano and G. Okamoto. **2005**. Response of Muscat of Alexandria table grapes to post-veraison regulated deficit irrigation in Japan. Vitis, **44**: 5-9.

Esteban, M. A., M. J. Villanueva and J. R. Lissarrague. **2002**. Relationships between different berry components in Tempranillo (*Vitis vinifera* L.) grapes from irrigated and non-irrigated vines during ripening. J. Sci. Food Agric., **82**: 1136–1146.

Ferrer, M., G. Gonzalez Neves, G. Camussi and G. Echeverria. **2009**. Effect of cluster thinning at fruit set and veraison, over productive, vegetative and enological parameters in (Vitis vinifera L.) cv. Tannat. Progres Agricole et Viticole, **126**:12-18.

Gamero, E., D. Moreno, I. Talaverano, M. H. Prieto, M. T. Guerra and M. E. Valdes. **2014**. Effects of irrigation and cluster thinning on Tempranillo grape and wine composition. S. Afr. J. Enol. Vitic., **35**: 196-204.

Gatti, M., F. Bernizzoni, S. Civardi and S. Poni. **2012**. Effects of cluster thinning and pre-flowering leaf removal on growth and grape composition in cv. Sangiovese. Amer. J. Enol. Vitic., **63**: 325–332.

Guidioni, S., P. Allara and A. Schubert. **2002**. Effect of cluster thinning on berry skin anthocyanin composition of *Vitis vinifera* L. cv Nebbiolo. Amer. J. Enol. Vitic., **53**: 244 - 226.

Holzapfel, B. P., J. P. Smith, S. K. Field and W. J. Hardie. **2010**. Dynamics of carbohydrate reserves in cultivated grapevines. Horticultural Reviews, **36**:143–211.

Jones, J. B. **2001**. Laboratory guide of conducting soil tests and plant analysis. CRC Press. New York, Washington D.C., USA.

Keller, M. **2005**. Deficit irrigation and vine mineral nutrition. Amer. J. Enol. Vitic., **56**: 267-283.

Kennedy, J. A., M. A. Matthews and A. L. Waterhouse. **2002**. Amer. J. Enol. Vitic., **63**: 268-274.

Koundouras, S., V. Marinos, A. Gkoulioti, Y. Kotseridis and C. van Leeuwen. **2006**. Influence of vineyard location and vine water status on fruit maturation of nonirrigated cv. Agiorgitiko (*Vitis vinifera* L.). Effects on wine phenolic and aroma components. J. Agric. Food Chem., **54**: 5077-5086.

Marsal J., M. Mata, J. del Campo, A. Arbones, X. Vallverdú, J. Girona and N. Olivo. **2008**. Evaluation of partial root-zone drying for potential use as a deficit irrigation technique in commercial vineyards according to two different pipeline layouts. Irrig. Sci., **26**:347–356.

Matthews, M. A. and M. M. Anderson. **1988**. Fruit ripening in *Vitis vinifera* L.: Responses to seasonal water deficits. Amer. J. Enol. Vitic., **39**: 313-320.

Mpelasoka, B. S., D. P. Schachtmann, M. T. Treeby and M. R. Thomas. **2003**. A review of potassium nutrition in grapevines with special emphasis on berry accumulation. Aust. J. Grape Wine Res., **9**:154-168.

Netzer Y., C. Yao, M. Shenker, B. A. Bravdo and A. Schwartz. **2009**. Water use and the development of seasonal crop coefficients for Superior Seedless grapevines trained to an open-gable trellis system. Irrig. Sci., **27**:109–120.

Ojeda, H., C. Andary, E. Kraeva, A. Carbonneau and A. Deloire. **2002**. Influence of pre- and postveraison water deficit on synthesis and concentration of skin phenolic compounds during berry growth of vitis vinifera cv. Shiraz. Amer. J. Enol. Vitic., **53**: 261-267.

Okamato, G., H. Onishi and K. Hirano., **2003**. The effect of different fertilizer application levels on anthocyanoplast development inberry skin of Pione grapevines (*V. vinifera* x *V. labrusca*). Vitis, **42**: 117-121.

Pastrana-Bonilla, E., C. C. Akoh, S. Sellappan and G. Krewer. **2003**. Phenolic content and antioxidant capacity of Muscadine grapes. J. Agric. Food Chem., **51**: 5497-5503.

Peppi, M. C., M. W. Fidelibus and N. Dokoozlian. **2006**. Abscisic acid application timing and concentration affect firmness, pigmentation, and color of ‘Flame Seedless’ grapes. HortScience, **41**: 1440-1445.

Pinillos, V., F. M. Chiamolera, J. F. Ortiz, J. J. Hueso and J. Cuevas. **2016**. Post-veraison regulated deficit irrigation in ‘Crimson Seedless’ table grape saves water and improves berry skin color. Agric. Water Manage., **165**: 181-189.

Prajitna, A., I. E. Dami, T. E. Steiner, D. C. Ferree, J. C. Scheerens and S. J. Schwartz. **2007**. Influence of cluster thinning on phenolic composition, resveratrol, and antioxidant capacity in Chambourcin wine. Amer J. Enol.Vitic., **58**: 346-350.

Reynolds, A. G., W. D. Lowrey, and C. De Savigny. **2005**. Influence of irrigation and fertigation on fruit composition, vine performance, and water relation of Concord and Niagara Grapevines. Amer. J. Enol. Vitic. **56**:110-128.

Richards, R. L., (ed.). **1954**. Diagnosis and Improvement of Saline and Alkali Soils. Agriculture Handbook No. 60, U.S. Gov. Printing Office, Washington, USA.

Roby, G., J. F. Harbertson, D. A. Adams and M. A. Matthews. **2004**. Berry size and vine water deficits as factors in winegrape composition: Anthocyanins and tannins. Aust. J. Grape Wine Res., **10**: 100-107.

Salón J. L., C. Chirivella and J. R. Castel. **2005**. Response of cv. Bobal to timing of deficit irrigation in Requena, Spain: water relations, yield and wine quality. Amer. J. Enol. Vitic., **56**:1–8.

Santesteban, L. G., C. Miranda and J. B. Royo. **2011**. Regulated deficit irrigation effects on growth, yield, grape quality and individual anthocyanin composition in *Vitis vinifera* L. cv. ‘Tempranillo’. Agric. Water Manage., **98**: 1171–1179.

Singleton, V. L. and J. A. Rossi, JR. **1965**. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Amer. J. Enol. Vitic., **16**: 144-158.

Souza, C. R., J. P. Maroco, T. P. Santos, M. L. Rodrigues, C. M. Lopes, J. S. Pereira and M. M. Chaves. **2005**. Grape berry metabolism in field-grown grapevines exposed to different irrigation strategies. Vitis, **44**: 103-109.

Steel, R. G. D. and J. H. Torrie. **1980**. Principal and procedures of statistics. 2nd edition, McGraw-Hill Book Company, New York, USA.

Sun, Q., G. L. Sacks, S. D. Lerch and J. E. Van den Heuvel. **2012**. Impact of shoot and cluster thinning on yield, fruit composition, and wine quality of Corot noir. Amer. J. Enol. Vitic., **63**: 49-56.

Valdés, E., D. Moreno, E. Gamero, D. Uriarte, M. H. Prieto, R. Manzano, J. Picón and D. Intrigliolo. **2009**. Effects of cluster thinning and irrigation amount on water relations, growth, yield and fruit and wine composition of Tempranillo grapes in Extremadura (Spain). J. Int. Sci. Vigne Vin., **43**: 67-76.

Williams, L. E., D. W. Grimes and C. J. Phene. **2010**. The effects of applied water at various fractions of measured evapotranspiration on reproductive growth and water productivity of ‘Thompson Seedless’ grapevines. Irrig. Sci., **28**: 233–243

الملخص العربي

تأثيرات النقص الموسمي لمياه الري والتسميد البوتاسي وخف العناقيد على النمو والمحصول وجودة العنب فليم سيدلس

ضياء اسامة الأنصاري

قسم الفاكهة – كلية الزراعة (الشاطبي) – جامعة الاسكندرية – الاسكندرية – ٢١٥٤٥ – مصر

تم دراسة تأثيرات مستويات نقص الري والتسميد البوتاسي وخف العناقيد على النمو الخضري والمحصول وجودة عنب المائدة فليم سيدلس خلال موسمي ٢٠١٢ و٢٠١٣م. ولقد تم تعريض الشجيرات لمعاملات نقص موسمي لمياه الري بداية من إنتفاخ البراعم وحتى سكونها وتتضمنت: الري القياسي (١٠٠٪ من البخر نتح للمحصول)، النقص المتوسط (٨٠٪ من البخر نتح للمحصول)، والنقص الشديد (٦٠٪ من البخر نتح للمحصول). كما تم دراسة تأثيرات مستويين من التسميد البوتاسي (صفر و٠,٥٨ كجم في صورة أكسيد بوتاسيوم لكل شجيرة في الموسم) ومستويين من خف العناقيد (٤٠ و٣٠ عنقود لكل شجيرة). هذا وقد أظهرت النتائج أن تركيز البوتاسيوم في أعناق أوراق الشجيرات إعتمدت معنوياً على مستوى الري المطبق وكان الأعلى في الشجيرات المعاملة بالري القياسي والتسميد البوتاسي. طول الأفرخ ومساحة سطح الأوراق ووزن خشب التقليم تأثر سلبياً بنقص الري، بينما أدى خف العناقيد إلى زيادة مساحة سطح الأوراق في الموسمين وزيادة وزن خشب التقليم في الموسم الثاني فقط بدون تأثير على طول الأفرخ. لم يؤثر التسميد بالبوتاسيوم على النموات الخضرية بينما زاد محصول الشجيرة ووزن العنقود وقطر الحبة معنوياً بزيادة مستوى الري مع التسميد البوتاسي. أدى خف العناقيد إلى إنخفاض معنوي في المحصول في الموسم الأول فقط بينما إزداد وزن العنقود وقطر الحبة. زاد الحمل المحصولي (المحصول / التقليم) معنوياً بالتسميد البوتاسي بينما قل بخف العناقيد ولم يتأثر بالري. زادت كفاءة إستخدام المياه (المحصول / الري) معنوياً بزيادة مستوى الري وبالتسميد البوتاسي بينما أدى خف العناقيد إلى قلتها في الموسم الأول. أدى زيادة مستوى الري الناقص إلى زيادة المواد الصلبة الذائبة الكلية وانخفاض الحموضة في عصير الحبة، وانخفاض صلابة الحبة، وزيادة محتوى جلدها من الأنثوسيانين والفينولات الكلية، وقلت قيم خصائص اللون لجلد الحبة وهي L^* و C^* و h°. هذا وأدى خف العناقيد إلى زيادة المواد الصلبة الذائبة الكلية فى الموسم الأول، ولم يؤثر على حموضة وصلابة الحبة، وزيادة الإنثوسيانين والفينولات الكلية في جلد الحبة، بينما إنخفضت قيم L^* في الموسم الأول وقيم وصلابة الحبة، وزيادة C^* و h°. التسميد البوتاسى أدى لزيادة المواد الصلبة الذائبة الكلية والحموضة والإنثوسيانين والفينولات الكية في الحبة، ولم يؤثر على الصلابة ولم يكن له تأثير ثابت على خصائص لون جلد الثمرة.