Effect of Irrigation and Fertigation Strategies on Growth, Yield, Quality and Water Use Efficiency of Drip Irrigated Grapevine

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ABSTRACT: Grapevine irrigation and fertigation are becoming important practices to ensure grape yield and yield quality in regions affected by limited water availability. Therefore the present study aimed to determine water requirement for Superior seedless grapevine under environmental conditions of Nubaria area, and to determine the effect of different water regime and fertigation practices on vine growth, fruit yield and quality and water use-efficiency. There are three irrigation treatments i.e. 60, 80 and 100% of reference evapotranspiration (I_1, I_2 and I_3) and two fertigation programs i.e. farm fertigation program (F1) and new proposed fertigation program (F2). Irrigation was applied through surface drip irrigation and fertilization was supplied throughout irrigation system as nutrient solution in irrigation water. The results of vegetative growth are significantly affected by irrigation and fertigation treatments. The irrigation treatment (80% of ET_0) reached the maximum value of all vegetative parameters in which increased by 53.76, 29.85, 59.97, 57.17, 62.50, 12.45 and 19.53% for Cane No, Spure No, Buds No, Shoots No, Bunch No., Bud Break and Fertility. The proposed fertigation program (F2) was superior over the farm fertigation program (F1). The results indicated that irrigation regime significantly affected these characters. Increasing irrigation up to 80% of potential evapotranspiration (ET_0) increased the cluster weight by about 20.28% with the farm fertigation program (F1) and by about 49.00% with proposed fertigation program (F2) as compared to the farm irrigation and fertigation practices (IF1). The present results recommended irrigation of grapevine with 80% of ET_0 and fertigation with proposed fertigation program (F2) to obtain the best grapevine yield. The proposed fertigation program (F2) was superior over farm fertigation program (F1) by 6.53, 14.69, 37.71, 8.11, 8.88 and 14.75 %, for TSS, total sugar, reducing sugar, weight of 100 berries, volume of 100 berried and volume of juice, respectively. It is clear that WUE has increased in case of water deficit compared with farm irrigation practice, and it is increased significantly with 80% of ET_0 in comparison with non-stressed treatment (100% of ET_0). The results illustrated that irrigation and fertigation treatments significantly affected the grapevine petioles nutrients content except for sodium content. All nutrients content were found to be adequate for plant and grapevine did not suffer from nutrients deficiency according the standard values. The results of the present study recommend irrigation of grapevine at 80% of reference evapotranspiration to save about 24% of irrigation water. Also recommends fertigation of grapevine with new proposed fertigation program to obtain an increase of yield by about 46.89%.

Keywords: irrigation deficit, grapevine, water management, fertigation, drip irrigation, nutrients content

INTRODUCTION

Limited water sources in the area necessarily lead to deficit irrigation. Deficit irrigation can be defined as an agricultural water management system in which less than 100% of the potential evapotranspiration (ET_0) can be provided by the stored soil water and irrigation, during the growing season. Irrigation management desire selecting the time and amount of water to be applied and optimizing the timing and degree of plant stress, within the restriction of available water (Pereira *et al*., 2002; Fereres and Soriano, 2007; Geerts and Raes, 2009).

The tool to improve winegrape quality in irrigated vineyards is to apply an appropriate balance between vegetative and reproductive development, as an excess of shoot vigor may have undesirable consequences for fruit quality (McCarthy, 1997). A moderate water stress, maintained through deficit irrigation, may reduce vine growth and competition for carbohydrates by growing tips, as well as promoting a shift in the partition of photo-assimilates towards reproductive tissues and secondary metabolites. These changes in plant metabolism by moderate water stress may increase the quality of the fruit and produced wine (Matthews and Anderson, 1988, 1989).

Under Mediterranean conditions, it has been a common practice to manage the deficit irrigation during the end stage of grapevine development (Williams and Matthews, 1990). However, in Australia, for example, the most common practice is to apply less water early in the season (McCarthy *et al*., 2000). Both practices have shown to benefit wine, in one case reducing the grape size by limiting available water and in the other one by limiting the potential for grape growth. Flavor compounds, which determine wine quality, are located principally in the berry skin; therefore a smaller size in the grape berries improves fruit quality as the skin to flesh ratio increased (McCarthy, 1997).

Plant nutrition is another critical factor whose management should be adjusted to each specific cycle phase. The use of fertigation affects the fruit chemical characteristics as increasing the fruit soluble solids and pH and decreasing acidity (Busato *et al*., 2011). The fertilization and soil water availability can affect the quality of production. No restrictive level of soil water availability support excessive vegetative growth and competes with berries by assimilated. On the other hand, very several droughts can adversely affect the yield and quality of grape (Busato *et al*., 2011). Therefore, the main objectives of the study are to:

1. Determine water requirement for superior seedless under environmental conditions of Nubaria region, Egypt.
2. Evaluate the effect of different water regime and fertigation practices on growth, fruit yield, quality and water use-efficiency of grapevine.

MATERIALS AND METHODS

This study was conducted during the 2006, 2007 and 2008 growing seasons at a commercial private table grape vineyard, Nubaria region (30° 54′ N; 29° 52′ E; and 25 m a.s.l.), Egypt. This area is characterized by a semi-arid climate. Some climatological data of the experimental site were taken from Nubaria Weather Station and are given in Tables (1 and 2).

Table (1). Average daily climatic parameters for the experimental site during 2006 growing season

Growing Months	Average minimum daily temperature T_{min} (°C)	Average maximum daily temperature T_{max} (°C)	Average daily temperature T_m (°C)	Average daily wind speed U_2 (m/s)	Average relative humidity %	Average daily solar radiation ($MJ/m^2/day$)
January	8.7	17.6	13.2	2.72	76.87	16.07
February	8.3	19.4	13.8	4.04	65.50	20.44
March	9.2	22.1	15.6	4.40	64.68	26.56
April	13.0	24.9	19.0	5.39	63.07	32.13
May	14.3	25.9	20.1	4.43	61.35	35.85
June	19.4	29.4	24.4	5.15	63.20	37.37
July	20.6	30.5	25.5	4.83	67.39	36.60
August	22.1	31.4	26.7	4.45	69.55	33.44
September	20.8	30.3	25.6	4.43	66.53	28.37
October	17.0	27.9	22.4	3.72	64.26	22.52
November	12.2	22.1	17.2	3.63	64.77	17.51
December	9.5	18.9	14.2	3.51	74.61	15.07

Table (2). Average daily climatic parameters for the experimental site during 2007 growing season

Growing Months	Average minimum daily temperature T_{min} (°C)	Average maximum daily temperature T_{max} (°C)	Average daily temperature T_m (°C)	Average daily wind speed U_2 (m/s)	Average relative humidity %	Average daily solar radiation ($MJ/m^2/day$)
January	8.1	18.0	13.0	3.50	74.65	16.07
February	9.3	18.6	14.0	4.76	70.29	20.44
March	10.1	21.7	15.9	5.01	61.97	26.56
April	12.9	23.4	18.1	6.12	65.87	32.13
May	16.1	27.5	21.8	5.74	65.68	35.85
June	19.7	30.0	24.9	5.73	67.47	37.37
July	22.0	31.0	26.5	5.36	70.19	36.60
August	22.0	31.5	26.8	4.58	70.00	33.44
September	20.3	29.9	25.1	4.88	65.50	28.37
October	16.8	28.2	22.5	3.91	69.45	22.52
November	13.4	24.5	19.0	3.92	69.50	17.51
December	9.5	19.1	14.3	4.37	71.55	15.07

The experiments were conducted using Superior seedless grapevine irrigated by surface drip irrigation system. The grapevines with 7 years old were trained under Parron Trellising System (Chacon, 1998) spaced 1.5 m between vines × 3 m between rows (vines rows spacing) and the vines were cane pruning.

Throughout the growing season the vines were subjected to all various recommended table grape cultural practices performed by the grower.

Soil samples were collected randomly from representative areas of the experimental site (0-30, 30-60 and 60-90 cm depth). Some physical and chemical properties of experimental site are carried out by the methods outlined in Carter and Gregorich (2008) and shown in Table (3).

Table (3). Some physical and chemical analysis of the experimental soil

Parameters	0 – 30 cm	30 – 60 cm	60 – 90 cm	Unit
Mechanical Analysis				
Sand	88.12	84.32	84.85	%
Silt	2.20	2.00	2.50	%
Clay	9.68	13.68	12.65	%
Textural class	Loamy sand	Loamy sand	Loamy sand	
Soil Bulk Density	1.67	1.69	1.72	Mg/m^3
Field capacity	15.6	16.2	16.1	%
Permanent wilting point	7.4	7.8	7.6	%
Available water content	8.2	8.4	8.5	%
pH (1:1,water suspension)	8.31	8.42	8.45	-
EC(1:1, water extract)	6.49	5.25	4.92	dS/m
$CaCO_3$	28.2	31.6	32.9	%
Organic matter content	1.51	1.42	1.45	%
Soluble cations				
Ca^{2+}	30.8	21.1	22.8	meq/L
Mg^{2+}	6.5	11.6	8.0	meq/L
Na^+	17.3	14.8	15.1	meq/L
K^+	9.8	4.7	3.2	meq/L
Soluble anions				
HCO_3^-	2.2	2.0	1.8	meq/L
Cl^-	23.1	22.3	21.4	meq/L
SO_4^{2-}	39.5	28.1	26.3	meq/L
Available nutrients				
Nitrogen (N)	264	170	136	mg/kg
Phosphorus (P)	56	52	45	mg/kg
Potassium (K)	650	550	425	mg/kg

The grapevines were irrigated from El Naser canal using surface drip irrigation system. The water sample was taken from El Naser canal for chemical analysis as shown in Table 4 according to Carter and Gregorich (2008).

Table (4). The chemical analysis of irrigation water used in the present study

Parameters	Value	Unit
pH	7.92	-
EC	1.81	dS/m
Soluble cations		
Calcium (Ca^{+2})	2.2	me/l
Magnesium (Mg^{+2})	8.7	me/l
Sodium (Na^{+})	6.8	me/l
Potassium(K^{+})	0.2	me/l
Soluble anions		
Carbonates($CO_3^{=}$)	4.3	me/l
Chloride (Cl^{-})	7.3	me/l
Sulfate ($SO_4^{=}$)	6.3	me/l
Soluble Nutrients		
N	0.08	mg/l
P	0.14	mg/l
B	Trace	mg/l
Fe	0.07	mg/l
Mn	0.02	mg/l
Cu	0.01	mg/l
Zn	0.10	mg/l

The experiment was arranged in Randomized Complete Block Design (RCBD) with three replicates. Three irrigation treatments were applied i.e. 60, 80 and 100% of reference evapotranspiration (ET_0) as calculated using Class A pan evaporation data (Allen *et al.*, 1998) and two fertigation programs (F1 and F2) in addition to farm irrigation (according to farm experience) and fertigation practices (IF1) as control. The grapevine was fertigated using two fertigation programs as follows:

1) Traditional farm fertigation program (F1)

through the drip irrigation which depends on applying the nutrients in its individual form with giving only attention for the macro-nutrients without the micro-nutrients which the vines also needs in its different growth stages (Table 5).

2) New proposed fertigation program (F2)

The new proposed fertigation program depends on applying the nutrients in its individual form with giving attention on the macro- and micro-nutrients which the vines also needs in its different growth stages (Table 6). The proposed fertigation program (F2) which applying the nutrients and study its effect on the vines and these new strategies could be summarized as follows:

- Applying the nutrients materials which the vines needs combined in a form of nutrient solution,

- Applying these nutrients with different doses based on the different requirements of the vines on its growth stages,
- Applying all the required nutrients to the vines including the micro nutrients,
- Applying the right form of micro nutrients in the calcareous soil which is chelated form for decreasing its loss, and
- Applying the right balance between the nutrients and decrease the excess of using the nitrates.

Table (5). The farm fertigation program for grapevine (F1), concentrated solution (200 times)

Salts	Composition of Concentrated solution (200 times)	unit
Calcium nitrate	141.6	g/l
Ammonium nitrate	46.9	g/l
Phosphoric acid	58.8	ml/l
Potassium sulfate	111.4	g/l
Magnesium sulfate	49.5	g/l
Boric acid	0.45	g/l
Ammonium molybdate	0.011	g/l

Table (6). The new proposed fertigation program for grapevine (F2), concentrated solution (200 times)

Salts	Initial stage	Development stage	Flowering and fruit set stage	Filling stage	unit
Calcium nitrate	141.6	165.2	165.2	118.0	g/l
Ammonium nitrate	46.3	31.1	10.7	8.9	g/l
Phosphoric acid	29.9	59.8	89.7	59.8	ml/l
Potassium sulfate	89.1	133.6	178.2	133.6	g/l
Magnesium sulfate	49.5	49.5	49.5	49.5	g/l
Boric acid	0.28	0.56	0.68	0.45	g/l
Ammonium molybdate tetrahydrate	0.008	0.015	0.018	0.015	g/l
EDTA	10	10	10	10	g/l
Fe-chelate (10%)	3.1	6.15	6.15	4.61	g/l
Mn-chelate (10%)	0.8	1.54	1.54	0.76	g/l
Cu-chelate (10%)	0.08	0.15	0.23	0.15	g/l
Zn-chelate (10%)	0.08	0.15	0.23	0.15	g/l

Systematic determination of several water parameters was carried out to provide basic information for the interpretation of experimental results. The following parameters were determined:

- The values of ET_o were calculated using the Class A pan evaporation method (Doorenbos and Kassam, 1986; Allen *et al.*, 1998) according to the following equation:

$$ET_0 = K_{pan} \times E_{pan} \qquad (1)$$

Where: ET_0 is the reference evapotranspiration (mm d^{-1}), E_{pan} is the daily measured pan evaporation rate (mm d^{-1}) and K_{pan} is the pan coefficient that depends on the relative humidity, wind speed, and the site conditions (bare or cultivated). A value of 0.75 was used for the experimental site according to local climatic condition (FAO, 1970).

- The crop coefficient (Kc) values for different growth stages of grape vine (FAO, 1975) were illustrated in Table (7).

Table (7). Crop coefficient of grapevine according to the growth stages

Growing stage	Kc value
Initial stage	0.35
Development stage	0.85
Flowering and fruit set stage	0.85
Filing stage	0.65

- The amount of applied irrigation water was calculated according to the following equation (Vermeiren and Jopling, 1984; Cuenca, 1989).

$$AIW = \frac{K_c \times K_r \times ET_0}{(1-LR) \times E_i} \qquad (2)$$

Where: AIW= depth of applied irrigation water (mm), ET_o= reference evapotranspiration (mm d^{-1}) obtained from class A pan data, K_c= crop coefficient, K_r= reduction factor that depends on the crop cover, E_i= irrigation efficiency of the drip system (assumed as 0.9) and LR is the leaching requirements used for salt leaching in the root zone depth (assumed as 0.15).

- Irrigation time was calculated before an irrigation event by collecting the actual emitter discharges according to the following equation:

$$t(hr) = \frac{AIW \times A}{1000 \times q} \qquad (3)$$

Where: t = irrigation time (hr), A= wetted area by an emitter (m^2) and q= emitter discharge (m^3/hr).

- Plant water consumptive use (crop evapotranspiration, ET_c) was calculated by the following formula

$$CU(mm) = K_c \times K_r \times ET_0 \qquad (4)$$

Where: CU or ETc is the grapevine water consumptive use (mm/day).

- Irrigation water use efficiency (IWUE) was calculated according to the following equation (Barrett and Skogerboe, 1980).

$$IWUE(kg/m^3) = \frac{\text{Grapevine Yield (kg/fed)}}{\text{Applied Irrigation Water}(m^3/fed)} \quad (5)$$

- Consumptive water use efficiency (CWUE) was calculated according to the following equation:

$$CWUE(kg/mm) = \frac{\text{Grapevine Yield (kg/fed)}}{\text{ConsumptiveWater(mm/fed)}} \quad (6)$$

The following growth and yield parameters were studied:

- **Vegetative measurements**

In 2007 and 2008 vine bud behavior is usually expressed as the percentages of bud burst, bud fertility and fruiting buds (fruitfulness), to realize these relations dormant buds per the studied vines were watched at weekly intervals all along the bursting period and number of busted buds were counted up to the end of the bursting period. In addition, the number of fertile buds buds which gave at least one cluster per vine was also recorded, and then the following formulas were used to estimate:

Bud Burst % = (No of bursted buds/Total number of buds per vine) × 100 (7)

Fruitful buds % = (No of fruitful buds per vine/Total No of buds per vine) × 100 (8)

Coefficient of bud fruitfulness % = (Total no of clusters per vine / Total number of fertile buds) × 100 (9)

- **Yield Measurements**

At harvest time clusters per vine for each irrigation and fertigation treatments were counted, weighted and average yield per vine in kilograms was estimated subsequently yield, tons per feddan was calculated.

Representative random samples of 15 clusters per each treatment 5 cluster for each replicate were taken to determine the following quality measurements:

a) Average cluster weight (g)
b) Average No. of berries per cluster
c) Average berries diameter, mm
d) Average TSS (%) was measured in juice using hand refractometer according to Chen and Mellenthin (1981).
e) Average weight of 100 berries (g)
f) Average volume of 100 berries (cm^3)
g) Average Juice volume of 100 berries (cm^3): 100 berries were squeezed and the obtained juice was analyzed for berries quality.
h) Average content of vitamin C (mg/100 ml juice): The ascorbic acid content of the juice was determined by titration with 2, 6-dichloro phenol-indo-phenol (AOAC, 2016) and calculated as milligrams per 100 ml of juice.
i) Average content of juice total acidity (%) was determined in fruit juice according to Chen and Mellenthin (1981). Five milliliters from the obtained juice were used to determine the titratable acidity. The titratable acidity was expressed as mg malic acid / 100 milliliters fruit juice

j) Total sugars were determined in fresh fruit samples according to Malik and Singh (1980). Sugars were extracted from 5 grams fresh weight and determined by phenol sulfuric and Nelson arsenate –molybadate colorimetric methods for total and reducing sugars, respectively. The non-reducing sugars were calculated by difference between total sugars and reducing sugars.

k) Sugar purity was calculated according to the following equation:

Sugar purity (%) = (total sugar/TSS) x100 (10)

l) Juice ratio was calculated as follows:

Juice ratio = (volume of 100 berries juice/volume of 100 berries) X 100 (11)

- **Chemical composition**

Leaf petioles samples were taken at harvesting from each treatment for macro- and micro-nutrients content determination. The leaf samples were dried at 75°C for 48 hours. After dryness, the petioles were milled and stored for analysis as reported. A 0.5g of the petioles powder was wet-digested with H_2SO_4–H_2O_2 mixture according to (Lowther, 1980) for the determinations of nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) and boron (B) contents according to Jackson (1973).

- **Statistical analysis**

The experiment was arranged in Randomized Complete Block Design (RCBD). The obtained data throughout the two seasons were subjected to analysis of variance according to Senedecor and Cochran (1991) using Statistix software (Statistix, 2003) and means were separated by the LSD test at 5% probability level.

RESULTS AND DISCUSSION

Vegetative growth

The vegetative growth of grapevine is presented in Table (8) as average of the two seasons (2007 and 2008). The results are significantly affected by irrigation and fertigation treatments except for spure no. and bud break characters. Cane No. was increased with increasing irrigation level. The same trend was noticed with other parameters i.e. spure No., buds No., shoot No. and branch No. The bud break (%) behaves the same trend. The irrigation treatment (80% of ET_0) gave the maximum value of all vegetative parameters in which increased by 53.76, 29.85, 59.97, 57.17, 62.50, 12.45 and 19.53% for Cane No, Spure No, Buds No, Shoots No, Bunch No., Bud Break and Fertility, respectively (Table 1). The results in Table (8) also indicated that the vegetative parameters significantly affected by fertigation program. The proposed fertigation program (F2) was more effective on growth parameters than the fertigation program (F1). The proposed fertigation program (F2) was superior over the farm fertigation program (F1) by 3.85, 3.96, 3.78, 8.02, 6.36, 0.94 and 5.30% for the average of all irrigation regimes, respectively.

The results indicated that I_2F2 treatment (80% irrigation and proposed fertigation program) was the best treatment which increased most growth characters of grapevine. The results showed that shoot growth is very sensitive to water stress. Some authors have shown that if water is not restricted more shoots could be obtained (Kliewer *et al.*, 1983; Matthews *et al.*, 1987), since irrigation increases the rate of shoot growth during the phase of linear growth (Bravdo and Hepner, 1986). Kliewer *et al.* (1983) stated that reduction in the rate of shoot growth in irrigated vines can be detected even before any significant differences in predawn leaf water potential occurs, suggesting that the shoot growth rate is a very sensitive indicator of water stress. Water stress also reduced bud break and fertility, this phenomena attributed to the lower activity of the terminal meristem (Kliewer *et al.*, 1983).

Table (8). The vegetative growth characters of grapevine of two seasons as affected by irrigation and fertigation treatments

Irrigation and fertigation treatments	Cane No	Spure No	Buds No	Shoots No	Bunch No	Bud Break (%)	Fertility %
Farm(IF1)	9.3	6.7	60.2	49.5	20.8	74.7	37.9
I_1 F1	10.7	6.7	72.0	58.7	23.5	80.0	38.1
I_2 F1	13.7	8.5	93.3	76.8	30.5	83.4	46.3
I_3 F1	12.0	7.5	83.7	62.7	26.2	81.6	44.0
I_1 F2	11.2	7.2	73.8	62.5	24.5	81.3	39.5
I_2 F2	14.3	8.7	96.3	77.8	33.8	84.0	45.3
I_3 F2	12.3	7.7	88.3	73.8	27.0	82.0	50.4
LSD	2.4*	ns	22.0*	19.8*	9.9*	ns	13.9*

The present results show the potential to utilize deficit irrigation to control the redistribution of photo-assimilates through a reduction in vigor with a positive effect on light interception in the cluster zone and in the berry composition. The manner of physiological responses to water deficits was identical in both seasons, but most of the effects of deficit irrigation (low irrigation) are more pronounced in all character. This can be explained by the low sensitivity to water stress (Regina and Carbonneau, 1996). By irrigating grapevine with 80% of ET_0 we imposed a mild water deficit that led to leaf predawn water potential at the end of the season.

Also, the fertigation strategies significantly affected the vegetative growth. The fertigation program (F1) resulted in less growth than proposed fertigation program (F2). The lower vegetative growth may be caused by less efficient of nutrients uptake compared to the F2 grapevine. Simillar results were observed by Myburgh and Howell (2012) and Howell and Conradie (2013).

Grapevine yield and yield characters

Table (9) shows the grapevine yield as affected by irrigation regime and fertigation practices. Both irrigation regime and fertigation practices affected the no. of cluster per tree. The no. of cluster ranged between 24 and 39 cluster per tree, in which the highest number (39) was recorded for I_2 (80% of ET_0) and F2 (proposed fertigation practice) and the lowest one (24) was recorded with farm irrigation and fertigation practices (farm practices). Also, the same trend was noticed with average cluster weight, in which the values of 469.5g for I_2F2 and 315.1 g for I_2F1 were recorded.

The results in Table (9) indicated that irrigation regime significantly affected the vine production and gross yield. Increasing irrigation up to 80% of the potential evapotranspiration (ET_0) increased the cluster weight by about 20.28% with the fertigation program (F1) and by about 49.00% with proposed fertigation program (F2) as compared to the farm irrigation and fertigation practices. Also, applying the proposed fertigation program (F2) significantly increased the gross yield by 70.40 and 117.29% over the farm practices, respectively.

Table (9). The grapevine yield of two seasons as affected by irrigation and fertigation treatments

Irrigation and fertigation treatments	Cluster No.	Cluster Weight (g)	Vine production (kg/vine)	Gross yield Ton/fed
Farm (IF1)	26	315.1	7.562	7.033
I_1 F1	24	366.2	9.521	8.855
I_2 F1	39	379.0	12.886	11.984
I_3 F1	25	454.8	11.370	10.574
I_1 F2	27	356.1	9.615	8.942
I_2 F2	34	469.5	16.433	15.282
I_3 F2	28	448.4	12.555	11.676
LSD	9.29*	58.5***	4.305*	4.003*

The yield characters significantly affected by irrigation and fertigation treatments (Table 10). As general, irrigation at 100% ET_0 has the high values for both fertigation programs. The increases were 5.18, 11.83, 21.49, 11.04, 8.18 and 13.12% for TSS, total sugar, reducing sugar, weight of 100 berries, volume of 100 berried and volume of juice, respectively for farm fertigation program (F1). The increases for proposed fertigation program (F2) were 12.05, 28.26, 67.30, 20.04, 17.78 and 20.80%, respectively over the farm practices. The proposed fertigation program (F2) was superior over the fertigation program (F1) by 6.53, 14.69, 37.71, 8.11, 8.88 and 14.75 %, respectively (Table 10).

The sugar purity and juice ratio were significantly affected by irrigation and fertigation treatments. The highest values were attained with 60% of ET_0 for farm fertigation program (F1) and at 100% of ET_0 for proposed fertigation program (F2). The increases were 6.54 and 7.07% for F1 and 14.46 and 10.20% for F2, respectively. In the same time, F2 was superior over F1 by 7.43 and 2.92% respectively. The highest value of non-reducing sugar was attained at 60% of ET_0 for both F1 and F2 fertigation programs. The non-reducing sugar was decreased by 0.92, 4.37% for F1 and F2, respectively over the farm practices (Table 10).

The juice percentage of grapevine barriers was affected by irrigation and fertigation treatments in which the highest value was attained at I2 (80% of ET0) and F2 (proposed fertigation practice. The increase was about 10.44% over farm irrigation and fertigation treatments.

The yield of grapevine depends strongly on the soil water regime, and that maximum yield is obtained when near field capacity soil condition are maintained from bud break to veraison (Van Rooyen *et al.*, 1980). Grapevine irrigated at 80% of ET_0 produced more yield than grapevine irrigated with 60% of ET_0. A wet soil regime (80% of ET_0) during berry ripening had a positive impact on juice TSS of grapevine. The grapevines experienced severe post-veraison water deficit had higher TSS in comparison with a well one (El-Ansary *et al.*, 2005).

Acidity was significantly affected by fertilization treatments. F2 fertigation program had significantly higher than F1 fertigation program. Acidity and pH were slightly affected by irrigation; acidity was higher in most irrigated grapes at the end of ripening, mainly due to higher malic acid content. Also, the results of both seasons indicated that vitamin c was not significantly affected by irrigation and fertigation treatments (Table 10).

Because of the high dependence of fruit quality on various environmental and endogenous factors (Jackson and Lombard, 1993), the overall effect of irrigation might change according to other cultural practices, particularly those affecting the crop level (Bravdo *et al.*, 1984; Poni *et al.*, 1994b). Vines with higher crop level seem to benefit more of a higher amount of irrigation both in terms of yield (Lakso *et al.*, 1999) and of fruit composition (Hepner and Bravdo, 1985).

This is normally because under high yield a source limitation for carbohydrates derived from water stress might be more detrimental to proper fruit ripening, hence negatively affecting fruit and wine quality.

Grapevine Evapotranspiration

The average value of reference evapotranspiration (ET_o) at the experimental site using class A pan for the two growing seasons (vegetative stage to harvest) was 439.67 mm Table (11). The average daily ET_0 was 5.22 and 3.89 mm d^{-1} and seasonal ET_o values were 459.35, 393.47 mm of the two seasons, respectively. The fluctuation of ET_o during the different growth stages attributed to the changes of weather conditions and crop water requirements as reported by Allen *et al.* (1998) in which the evapotranspiration rate was affected by the changes of radiation, air temperature, humidity, wind speed and light intensity.

Daily crop evapotranspiration (ET_c) values of grapevine during the two growing seasons were estimated by multiplying ET_o and crop coefficient (K_c). This data showed that the mean ET_c values in the 1st and 2nd seasons were 3.25 and 2.53, respectively. The average values of ET_c for the two growing seasons during (bud break to setting, setting to verasion and verasion to harvest) were 429.4, 283.2, 322.4 and 351.8 mm for Farm, I_1, I_2 and I_3 irrigation treatments, respectively, Table (11).

The data could indicate also that grapevine ET_c values varied properly due to the change in both climatic conditions (ET_o change) and plant growth (K_c values). The ET_c values gradually increased with proceeding plant age till the berries growth stage then the rate decreased till the end of the growth season. This trend is in agreement with the finding of Doorenbos and Pruitt (1977) in which the ET_c values increased with the progress in plant growth and reached a peak during some part of the plant growth period, depending on the plant type, growth characteristics and environmental conditions, then tapered off by harvest time.

Applied Irrigation Water (AIW)

The amounts of applied irrigation water to grapevine at different growth stages as average of the two growing seasons under different irrigation treatments are presented in Table (12). The irrigation treatments were applied at vegetative growth stage till the harvest then in post-harvest. All the experimental plots received equal amount of irrigation water to ensure good management of grapevine in this stage. The amount of irrigation water applied at I_1, I_2 and I_3 were 1554.8, 1770.0, and 1986.3 m^3/season. As in case of ET_c, the amounts of AIW increased with the development of growth stages to reach the peak at mid-season stage and then decreased at late season stage (Table 12).

But for the farm irrigation practice (I), the AIW was 2357.6 m^3/fed. The applied water of I_1 (60%) during the growing stages were 118.8, 284.8, 209.9 and 941.4 m^3/fed for vegetative to flowering, berries growth, berries ripening and post-harvest, respectively. The values for I_2 (80%) were 159.8, 383.1, 282.2 and 944.9 m^3/fed and the values for I_3 (100%) were 199.5, 476.8, 352.9 and 957.2 m^3/fed, respectively. The corresponding values for farm irrigation practice were 106.4, 829.0, 515.0 and 907.2 m^3/fed.

These results showed that the saved applied irrigation water (AIW) for I_1, I_2 and I_3 treatments were 34.05%, 24.92%, and 15.75% as average of the two growing seasons, respectively over the farm irrigation practice.

Water-Use Efficiency (WUE)

The effect of irrigation and fertigation treatments on WUE of grapevine is presented in Table (13). It is clear that WUE has increased in case of water deficit compared with farm irrigation practice, and it is increased significantly with 80% of ET_0 in comparison with non-stressed treatment (100% of ET_0).

The data also showed that there were no significant differences between I_2F_1 and I_3F_1 and between I_1F2, I_2F2 and I_3F2 treatments in the two growing seasons. The 80% of ET_0 irrigation treatment (I_2) gave optimum yield under different two fertilizer programs (F_1 and F_2). The results indicated that crop water-use efficiency (CWUE) has the highest value with 80% of ET_o treatment for both fertigation programs. It is account as 42.24 and 46.12 kg/mm of water with increases of 132.49 and 151.47% over the farm practices (Table 13). The proposed fertigation program (F2) was superior to the farm fertigation program (F1) by 8.16%. Also, the irrigation water-use efficiency (IWUE) behaved the same trend in which the values were 7.77 and 8.40 kg/m^3.

Table (10). The yield characters of grapevine of two seasons as affected by irrigation and fertigation treatments

Irrigation and fertigation treatments	TSS %	Total sugar %	Reducing sugar %	Non Reducing sugar %	weight of 100 berries g	volume of 100 berries cm^3	volume of juice cm^3	Purity %	Juice ratio %	VC mg/100 ml juice	AC (%)
Farm(IF1)	16.02	11.75	7.40	4.35	452.0	433.0	365.1	73.35	84.32	0.416	0.462
I_1 F1	16.20	12.66	8.35	4.31	486.9	446.7	403.3	78.15	90.28	0.555	0.414
I_2 F1	16.78	13.04	8.91	4.13	501.0	462.8	410.0	77.71	88.59	0.555	0.442
I_3 F1	16.85	13.14	8.99	4.15	501.9	468.4	413.0	77.98	88.17	0.555	0.408
I_1 F2	17.18	13.17	9.01	4.16	526.0	500.0	417.1	76.66	83.42	0.555	0.489
I_2 F2	17.53	14.60	10.94	3.66	541.3	508.9	433.3	83.29	93.12	0.555	0.489
I_3 F2	17.95	15.07	12.38	2.69	542.6	510.0	473.9	83.96	84.96	0.624	0.428
LSD	**1.38^***	**1.18^***	**1.83^***	**1.68^{ns}**	**58.9^***	**53.8^***	**61.1^***	**7.56^***	**7.78^***	**ns**	**ns**

Table (11). Average grapevine evapotranspiration and applied irrigation water (mm/season)

Irrigation treatments	ET_0 (mm/season)	ETc (mm/season)	Applied water (m^3/fed)	Water saving %
Farm (I)	374.4	429.42	2357.6	-
I_1	374.4	283.2	1554.8	34.05
I_2	374.4	322.4	1770.0	24.92
I_3	374.4	351.8	1986.3	15.75

Table (12). The applied Irrigation water (m^3/fed) to grapevine during growth stages of two seasons

Growth stages	Irrigation regime			Farm irrigation
	I_1	I_2	I_3	I
Vegetative to Flowering (Bud Break to Setting)	118.8	159.8	199.5	106.4
Berries Growth (Setting to Verasion)	284.8	383.1	476.8	829.0
Berries Ripening(Verasion To Harvest)	209.9	282.2	352.9	515.0
Post-Harvest (Harvest to Dormancy)	941.4	944.9	957.2	907.2
Total (m^3/fed)	1554.8	1770.0	1986.3	2357.6
Saving water over farm irrigation (%)	34.05	24.92	15.75	0.00

Table (13). Average grapevine water–use efficiency of two seasons as affected by irrigation and fertigation treatments

Irrigation and fertigation treatments	Y	ET_c	AIW	CWUE	IWUE
	ton/fed	mm/fed	m^3/fed	kg/mm	kg/m^3
Farm (IF1)	7.87	429.42	2357.60	18.34	3.34
I_1 F1	8.28	283.20	1554.82	29.22	5.32
I_2 F1	13.75	322.40	1770.04	42.64	7.77
I_3 F1	10.55	351.80	1986.30	30.00	5.31
I_1 F2	9.10	283.20	1554.82	32.13	5.85
I_2 F2	14.87	322.40	1770.04	46.12	8.40
I_3 F2	11.67	351.80	1986.30	33.17	5.87

Deficit irrigation is based on the fact that crop sensitivity to water stress varies along the growth cycle and because discontinuous water deficits during specific periods may benefit WUE, increase water savings and improve berry quality (McCarthy *et al*., 2002; Loveys *et al*., 2004; Cameron *et al*., 2006). On the other hand, over-irrigation results in higher costs of water, energy and nutrients lixiviation, while less irrigation can cause major losses in yield and quality. In grapevines, deficit irrigation strategy is generally implemented in post-veraison phase, i.e. at the onset maturation, because reductions in water before this stage can significantly decrease berry size and yield (Faci *et al.,* 2014; Conesa *et al*., 2015). By using the water deficit strategy, plant water status can be maintained within certain limits of water deficit (with respect to maximum water potential) at specific phases of the crop cycle, normally when fruit growth is least sensitive to water deficit (Marsal *et al*., 2002; Kang and Zhang 2004).

Also, Serman *et al*. (2004) reported for the cv. "Superior Seedless" grown under a Mediterranean climate type that 70 and 100 % of ETc irrigation treatments resulted in similar yield and in a reduction of 3000 m^3 ha^{-1} of irrigation water and an increase of WUE from 2.4 to 3.1 kg m^{-3} .

WUE was significantly decreased as water stress treatments increased but increased significantly with proposed fertigation program (F2). Similar results were found by Palliotti *et al*. (2001) and Sepaskhah and Ghahraman (2004), in which the highest WUTE was observed under I_2 irrigation treatment (I_2) (80% of ET_c) and proposed fertigation program (F2).

Petiole Nutrients content

Date presented in Table (14) illustrated that irrigation and fertigation treatments significantly affected the grapevine petioles nutrients content except for sodium content. All nutrients content were found to be adequate for plant and grapevine and not suffer from nutrients deficiency according to the standard value illustrated in Tables (15 and 16). Results from tissue analyses compared with standards (guidelines) which place each nutrient into a particular classification (e.g. deficient, marginal, adequate, high or toxic) allows semi-quantitative conclusions to be made regarding vine nutrient status and vineyard fertilizer requirements. Various nutrients affect the quality of fruit produced by the grapevine which, in turn, has an influence on wine quality. These effects can either be direct through the effect on berry composition which determines the taste and aroma profile of the wine, or indirectly through the influence on vegetative growth.

The petiole standards shown in Table (15) are the best available at the present time. These are generally regarded as being appropriate for commercial, high yielding, irrigated vineyards and are aimed at maintaining 'adequate' levels. They are not necessarily appropriate for lower yielding, irrigated or dry-grown vineyards (Table 16).

Nutrients involved in development of grapevines, photosynthetic functioning and metabolic pathways are required in certain quantities to ensure healthy growth and performance. Essential elements are classified and macro- or micronutrients dependent on the quantity of that element required by the plant. Macronutrients include nitrogen, phosphorous, potassium, calcium, magnesium and sulfur occurs at high levels in plant tissue, 0.2 to 3% of dry weight. Micronutrients occur at lower levels in plant tissue; iron and manganese at 50 to 150 ppm dry weight and molybdenum, copper, zinc and boron at 0.5 to 40 ppm dry weight. If an element is not available in adequate amounts then vine performance is limited by the supply of that one element. In the case of micronutrients, the availability, rather than element concentration that is often the limit when deficiencies are recorded. Deficiencies or toxicity of individual essential elements can result in characteristic foliar symptoms and restricted growth habit.

In this study, fertigated grapevines were found to have higher levels of N in the petioles at fruit set than conventionally fertilized grapevines (Conradie and Myburgh, 2000). However, less Mg was found in both the leaf blades and petioles of the fertigated grapevines. Neither fertigation nor conventional fertilization influenced the mineral ions in the grape juice.

Many important observations were made from the present study:
I) it is possible to control the canopy development of grapevines by irrigation and fertigation management. It was found that for this particular soil (Calcareous soil) and site (Nubaria region), the irrigation regime at 80% of the reference evapotranspiration and fertilized with the proposed fertigation program imposed until harvest, provided the best balanced vines with good canopy size, good yields, and excellent fruit and grapevine quality, II) cold hardiness of buds and canes was not affected by the imposed irrigation treatments. This implies that irrigation strategies could be used in vineyards for fruit quality control without compromising cold hardiness and III) sugars and carbohydrate reserves in berries were not affected by irrigation treatments. Therefore, reducing irrigation would not compromise sugars and carbohydrate storage or accumulation. Other advantages of reduced irrigation treatments and proposed fertigation program are savings in cost of labor and materials associated with trellis modification and vineyard management practices such as irrigation, fertigation, pesticide application, shoot and leaf removal, hedging, pruning, etc. As general, the proper irrigation (80% of ET_0) and fertigation (proposed program) management practices proposed in the present study can improved the growth of the Thompson seedless grapevines and resulted in good yield and quality.

Table (14). Average nutrients content in grapevine petioles of two seasons as affected by irrigation and fertigation treatments

Irrigation and fertigation treatments	N	P	K	Ca	Mg	Na	S	Fe	Mn	Cu	Zn	B
			%							mg/kg		
Farm (IF1)	0.86	0.26	1.37	1.21	0.26	0.16	0.16	56.3	32.6	5.5	28.5	26.2
I_1 F1	0.91	0.28	1.43	1.24	0.29	0.13	0.18	59.4	33.4	6.5	28.8	28.1
I_2 F1	0.97	0.33	1.50	1.29	0.31	0.13	0.21	65.6	36.3	7.8	32.0	30.2
I_3 F1	1.06	0.37	1.57	1.34	0.32	0.16	0.23	70.2	40.4	9.5	37.2	32.6
I_1 F2	1.03	0.34	1.86	1.27	0.34	0.12	0.22	66.5	36.5	8.1	33.0	27.9
I_2 F2	1.13	0.41	2.03	1.42	0.42	0.13	0.26	86.6	41.1	9.8	36.2	31.3
I_3 F2	1.21	0.46	2.12	1.57	0.47	0.14	0.30	93.3	46.0	11.9	41.1	36.2
LSD	0.06**	0.06**	0.32**	0.08**	0.06**	NS	0.05**	5.03**	4.86**	1.79**	4.04**	3.18**

Table (15). Plant tissue analysis guidelines for testing nutrients content in grapevine optimum norms

Nutrients	Thompson	Full Bloom	Veraison
N (%)	0.87-1.61	1.6 – 1.8	0.9 – 1.3
P (%)	0.29-0.65	0.20 – 0.60	0.16 – 0.29
K (%)	2.0-3.0	1.50 – 5.00	1.50 - 2.50
Ca (%)	0.98-1.36	0.40 – 2.50	1.20 – 1.80
Mg (%)	0.63-1.10	0.13 – 0.40	0.26 – 0.45
Fe (mg/kg)	54-80	40 – 180	31 – 50
Mn (mg/kg)	42-209	18 - 100	31 – 150
Zn (mg/kg)	30-88	20 – 100	30 - 50
Cu (mg/kg)	5-10	5 – 10	5 – 15
B (ppm)	31 - 70	25 – 50	25 – 50

Table (16). Grapevine petiole nutrients content interpretation from the present study

Nutrient	range	Interpretation
N (%)	0.86 – 1.21	Normal
P (%)	0.26 – 0.46	Normal
K (%)	1.37 – 2.12	Normal
Ca (%)	1.21 – 1.57	Normal
Mg (%)	0.26 – 0.47	Normal
Fe (mg/kg)	56.3 – 93.3	Normal
Mn (mg/kg)	32.6 – 46.0	Normal
Zn (mg/kg)	28.5 – 41.1	Normal
Cu (mg/kg)	5.5 – 11.9	Normal
B (ppm)	26.2 – 36.2	Normal

REFERENCES

Allen, R. G., L. S. Pereira, D. Raes and M. Smith (1998). Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. FAO, Rome. Italy, 300: 6541.

AOAC (2016). Official Methods of Analysis. Association of Official Analytical Chemists International. Washington, D.C.

Barrett, J.W.H., and G. W. Skogerboe (1980). Crop production functions and the allocation and use of irrigation water. Agricultural Water Management, 3: 53-64

Bravdo, B., and Y. Hepner (1986). Irrigation management and fertigation to optimize grape composition and vine performance. Hort. Science, 21(3):328 (1600).

Busato, C. C. M., A. A. Soares, A. A., G. C. Sediyama, S. Y. Motoike, and E. F. Reis (2011). Manejo da irrigação e fertirrigação com nitrogênio sobre as características químicas da videira 'Niágara Rosada'. Ciência Rural, v.41, n.7, p.1183-1188

Cameron, K. D., M. A. Teece, and L. B. Smart (2006). Increased accumulation of cuticular wax and expression of lipid transfer protein in response to periodic drying events in leaves of tree tobacco. Plant Physiol., 140:176–183.

Carter, M. R. and E. G. Gregorich (2008). Soil Sampling and Methods of Analysis, Second Edition. Canadian Society of Soil Science; Boca Raton, FL: CRC Press, 1264 pages.

Chacon, A. (1998). Spanish Parron Manual. Technical report . Agric. Tech. Utilization and Transfer Project. Giza, Egypt.

Chen, B.M. and W.M. Mellenthin (1981). Effect of harvest date on ripening capacity and post – harvest life of Anjou pears. J. Amer. Soc. Hort. Sci., 106: 38-42.

Conesa, M. R., J. M. de la Rosa and F. Arte´s-Herna´ndez (2015). Long-term impact of deficit irrigation on the physical quality of berries in ‘‘Crimson Seedless’’ table grapes. J. Sci. Food Agric., 95:2510–2520.

Cuenca, R. H. (1989). Irrigation System Design: An engineering approach. Prentice Hall, Inc., Englewood Cliffs, New Jersy, USA.

Doorenbos, J and A. H. Kassam (1986). Yield response to water (un-modified reprint of 1979 edition). FAO, Irrigation and Drainage Paper No. 33.FAO, Rome.

Doorenbos, J., and W. O. Pruitt (1977). Crop water requirements. FAO Irrigation and Drainage paper 24. Food and Agriculture Organization of United Nations. Rome, Italy.

El-Ansary, D. O., S. Nakayama, K. Hirano and G. Okamoto (2005). Response of Muscat Alexandria table grapes to post-veraison regulated deficit irrigation in Japan. Vitis,, 35: 45-46.

Faci, J.M., O. Blanco, E. T. Medina and A. Martınez-Cob (2014). Effect of post veraison regulated deficit irrigation in production and berry quality of Autumn Royal and Crimson table grape cultivars. Agric. Water Manag., 134:73–83.

FAO (1970). Physical and Chemical Methods of Soil and Water Analysis. Soils Bull. No. 10, FAO, Rome, Italy.

FAO (1975). Crop water requirements. Irrigation and Drainage Paper. No. 24. FAO, Rome, Italy

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

Geerts, S. and D. Raes (2009). Deficit irrigation as an on-farm strategy to maximize crop water productivity in dry areas. Agric. Water Manag., 96:1275-1284.

Hepner, Y., and B. Bravdo (1985). Effect of crop level and drip irrigation scheduling on the potassium status of Cabernet Sauvignon and Carignane vines and its influence on must and wine composition and quality. Am. J. Enol. Vitic. 36:140–147

Howell, C. L. and W. J. Conradie (2013). Comparison of three different fertigation strategies for drip irrigated table grapes - Part II. Soil and grapevine nutrient status. S. Afr. J. Ecol. Vitic., 34: 10-20.

Jackson, M.L. (1973). Soil Chemical Analysis.Prentice-Hall, Inc. India.

Jackson. D. I., and P. B. Lombard (1993). Environmental and management practices affecting grape composition and wine quality-A review. Am. J. Enol. Vitic, 44:409–430

Kang, S. and J. Zhang (2004). Controlled alternate partial root-zone irrigation: its physiological consequences and impact onwater use efficiency. J. Exp. Bot., 55:2437–2446.

Kliewer, W. M., B. M. Freeman, and C. Hossom (1983). Effect of irrigation, crop level and potassium fertilization on Carignane vines. I. Degree of water stress and effect on growth and yield. Am. J. Enol. Vitic. 34:186-196

Lakso, A. N., R. M. Dunst, and A. Fendinger (1999). Responses to drought of balance-pruned and minimally-pruned 'Concord' grapevines. Acta Hortic., 493:103–107

Leib B.G., H. W. Caspari, C. A. Redulla, P. K. Andrews, and J. J. Jabro (2006). Partial rootzone drying and deficit irrigation of 'Fuji' apples in a semi-arid climate. Irrigation Science, 24: 85–99.

Lowther, J. R. (1980). Use of single sulfuric acid–hydrogen peroxide digest for the analysis of *Pinus radiata* needles. Common. Soil Sic. Plant Anal., 11:175–188.

Loveys, B., M. Stoll and W. Davies (2004). Physiological approaches to enhance water use efficiency in agriculture: exploiting plant signalling in novel irrigation practice. In: Bacon MA (ed) Water use efficiency in plant biology. University of Lancaster, Lancaster, pp 113–141.

Malik, C.P. and M.B. Singh (1980). Plant enzymology and histoenzymology. A text manual, kalyani publishers, New Delhi.

Matthews, M. A., M. M. Anderson and H.R. Schultz (1987). Phenological and growth responses to early and latee season deficits in Cabernet franc. Vitis, 26: 147-160.

Marsal J, M. Mata and A. Arbones (2002). Regulated deficit irrigation and rectification of irrigation scheduling in young pear trees: an evaluation based on vegetative and productive response. Eur. J. Agron., 17:111–122.

Matthews M. A., and M. M. Anderson (1988). Fruit ripening in grapes (*Vitis vinifera* L.) : responses to seasonal water deficits. American Journal of Enology and Viticulture, 39, 313–320.

Matthews M.A., and M. M. Anderson (1989). Reproductive development in grape (*Vitis vinifera* L.): responses to seasonal water deficits. American Journal of Enology and Viticulture, 40, 52–60.

McCarthy M.G. (1997). The effect of transient water deficit on berry development of cv Shiraz (*Vitis vinifera* L.). Australian Journal of Grape and Wine Research, 3, 102–108.

McCarthy M.G., Loveys B.R., Dry P.R. (2000). Regulated Deficit Irrigation and Partial Rootzone Drying as Irrigation Practices – Water Reports 22. Rome: FAO.

McCarthy, M.G., B. R. Loveys, P.R. Dry and M. Stoll (2002). Regulated deficit irrigation and partial rootzone drying as irrigation management techniques for grapevines. In: Deficit irrigation practices, 22nd edn. FAO Water Reports, Rome, pp 79–87

Medrano, H., M. Tomas, and S. Martorell (2015). Improving water use efficiency of vineyards in semi-arid regions—a review. Agron. Sustain Dev., 35:499–517.

Myburgh, P. A. and C. I. Howell(2012). Comparison of three different fertigation strategies for drip irrigated table grapes.Part I. Soil water status. , root system characteristics and plant water status. S. Afr. J. Enol., 33:264-274.

Palliotti, A., A. Cartechini and L. Nasini (2001). Grapevine adaptation to continuous water limitation during the season. Advances in Horticultural Science, 15(1/4): 39-45.

Pereira, L. S., T. Oweis, and A. Zairi (2002). Irrigation management under water scarcity. Agricultural Water Management, 57:175-206.

Regina, M. de A. and A. Carbonneau (1996). Trocas gasosas em Vitis vinifera sob regime de estresse hídrico: I. caracterização do comportamento varietal. Pesquisa Agropecuária Brasileira, Brasília, 31(12):869-876.

Poni, S., A. N. Lakso, J. R. Turner, and R. E. Melious (1994a). The effects of pre and post-veraison water stress on growth and physiology of potted Pinot Noir grapevines at varying crop levels. Vitis, 32:207–214.

Sepaskhah, A.R., and B. Ghahraman (2004). The effects of irrigation efficiency and uniformity coefficient on relative yield and profit for deficit irrigation, Biosystems Engineering, 87(4): 495- 507.

Serman, F.V., M. Liotta and C. Parera (2004). Effects of irrigation deficit on table grape cv. Superior Seedless production. Acta Hortic., 646:183–186.

Snedecor, G.W. and W.G. Cochran (1991). Statistical Methods. 8th edition. Iowa State Univ. Press, Ames. 503pp

Statistix (2003). Statistix 8.2, Analytical Software for Window. Tallahassee, FL.

Van Rooyen, F. C., H. W. Weber and I. Levin (1980). The response of grapes to a manipulation of the soil-plant-atmosphere continuum. I. Growth, yield and quality responses. Agrochemophysica, 12: 59-68.

Vermeiren, L., and G. A. Jopling (1984). Localized irrigation. FAO Irrigation and Drainage paper No. 36, Rome, Italy.

Williams, L.E. and M.A. Matthews (1990). Grapevine. In Irrigation of Agricultural Crops. B.J. Stewart and D.R. Nielsen, Ed. Agronomy Monograph No. 30. Am. Soc. Agron. Madison, WI. pp1019-1055.

الملخص العربي

تاثير الرى وإستراتيجيات التسميد على النمو، المحصول، الجودة وكفاءة إستعمال المياه للعنب المروى بالتنقيط

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٢ قسم الانتاج النباتي – كلية الزراعة سابا باشا – جامعة الاسكندرية

٣ قسم الاراضى والمياه – كلية الزراعة – جامعة الاسكندرية

أصبح الري والتسميد في كروم العنب من الممارسات الهامة لضمان محصول العنب وجودة الانتاج في المناطق التى تعانى من نقص مياه الرى. لذلك فإن الدراسة الحالية تهدف الى تحديد الاحتياجات المائية لكروم العنب صنف سوبريور في ظل الظروف البيئية لمنطقة النوبارية وتحديد تأثير الرجيم المائى وممارسات التسميد مع الرى على نمو العنب ومحصول وجودة العنب وكفاءة استخدام المياه. تم تطبيق ثلاث معاملات لنقص الرى هى ٦٠ و ٨٠ و ١٠٠ % من البخر – نتح المرجعي، وكذلك معاملتى تسميد مع الرى هما برنامج التسميد الشائع بالمزرعة وبرنامج تسميد مقترح . تم تطبيق الري من خلال الري بالتنقيط السطحي وتم إضافة التسميد مع مياه الرى فى صورة محلول مغذى . تأثرت نتائج النمو الخضري بشكل معنوى بالري وممارسات التسميد مع الرى . اعطت معاملة الرى (٨٠٪ من البخر– نتح المرجعى) اعلى قيم لصفات النمو الخضري حيث زادت بنسبة ٥٣.٧٦، ٢٩.٨٥، ٥٩.٩٧، ٥٧.١٧، ٦٢.٥٠، ١٢.٤٥، ١٩.٥٣٪ لعدد القصبات، عدد الافرع الرئيسية، عدد البراعم ، عدد النموات الخضرية، عدد الافرع، نسبة العقد ونسبة الخصوبة. وقد تفوق برنامج التسميد مع الرى المقترح على برنامج التسميد الشائع بالمزرعة. الرى عند ٨٠٪ من البخر – نتح المرجعى أدى الى زيادة وزن العنقود بنحو ٢٠.٢٨٪ مع برنامج التسميد الشائع بالمزرعة وبنحو ٤٩.٠٠٪ مع برنامج التسميد مع الرى المقترح بالمقارنة مع الري وممارسات التسميد الشائعة بالمزرعة. النتائج الحالية توصى برى كروم العنب عند ٨٠٪ من البخر– نتح المرجعى والتسميد بتطبيق برنامج التسميد مع الرى المقترح للحصول على اعلى محصول لكروم العنب. وقد كان برنامج التسميد مع الرى المقترح متفوقا على برنامج التسميد الشائع بالمزرعة بنسبة ٦.٥٣، ١٤.٦٩، ٣٧.٧١، ٨.١١، ٨.٨٨، ١٤.٧٥٪ للمواد الصلبة الكلية، السكريات الكلية، السكريات المختزلة، وزن ١٠٠ حبة، حجم ١٠٠ حبة وحجم العصير من ١٠٠ حبة، على التوالي. ومن الواضح أن كفاء استخدام المياه قد زادت في حالة نقص مياه الرى مقارنة مع ممارسة الري الشائع بالمزرعة، وأنه يزداد بشكل ملحوظ مع ٨٠٪ من البخر– نتح المرجعى مقارنة مع الرى الكامل (١٠٠٪ من من البخر – نتح المرجعى).

وقد أوضحت النتائج أن الري وممارسات التسميد مع الرى أثرت بشكل معنوى على محتوى أعناق الاوراق من العناصر الغذائية باستثناء الصوديوم. محتوى العناصر الغذائية كان كافيا لكرمة العنب حيث لم تكن تعاني من نقص العناصر الغذائية وفقا للقيم القياسية. توصى نتائج الدراسة الحالية بري العنب عند ٨٠٪ من البخر– نتح المرجعي لتوفير حوالي ٢٤٪ من مياه الري. كما توصي بتسميد العنب ببرنامج التسميد مع الرى المقترح للحصول على زيادة في المحصول بنحو ٤٦.٨٩٪.