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Water Requirements of Grafted Grape Vines under Desert Land Conditions

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Abstract: This investigation was conducted during three consecutive years (2009, 2010 and 2011) using Superior Seedless cv. grafted on Freedom rootstock on six - year old grown in a sandy soil and supported by the Gable system. Distances were 2 m between vines and 3 m between rows under drip irrigation system with two lateral lines per row and two 4 L/h emitter per vine and use valve regulates water amount to attain irrigation treatment. The vines were cane-pruned to 72 buds per vine (6 canes x 12 buds / cane). The study included four levels of irrigation water (0.6, 0.8, 1.0 and 1.2 of Et_0). General trend, indicate that bud burst percentage decreased gradually by increasing water discharge of irrigation treatment; the greatest values were resulted from 0.6 followed by 0.8 ET. Whereas, there was a gradual increase in fruitful buds percentage as the amount of applied water increased from 0.6 to 1.2 ET. Also, the results of the two seasons indicated that the total leaf area per vine was negatively affected with water stress. While, water amount exceeding the 1.0 ET did not result in further wood ripping increased, while water application amount less than 1.0 ET resulted in significant reduction in wood ripening. Fluctuation in the average monthly soil temperature at 20 cm depth of surface soil result indicated that, high irrigation rate (1.2 ET) resulted the lowest average soil, temperature followed by adequate irrigation 1.0 ET. Soil moisture decreased horizontally and vertically with decreasing irrigation rate. While root density increased where soil moisture accumulated Depth of the roots and their distribution in the soil profile under different water regimes 1.2 ET treatment recorded the highest values of roots being almost in the horizontal as well as in the vertical direction. In this area, the greatest amount of roots was observed within the 50 cm distance from the vine trunk and the 30 cm depth of soil surface. The highest values of number of cluster, yield, cluster weight, berry size, berry shattering and acidity were found with 1.2 ET treatment, while, berry firmness, berry adherence and TSS, TSS / acid were the highest with 0.6 ET. The concentrations of N, P, K, in the leaf tissues and total carbohydrate in the canes increased with increasing irrigation levels while decreasing irrigation levels increased content of proline during the two studied seasons. Regarding the effect of different irrigation levels on the physiological aspects, the obtained data showed that, under severe water stress the leaf relative turgidity decreased, whereas, hard leaf character was increased with increasing the soil water shortage. Connecting the previous results with water used efficiency it was found that 1.0 ET irrigation rate recorded the highest water efficiency which means less water and better yield. Moreover, data mention that, period from veraison to harvest berry development is very critical period of Superior Seedless cv. grafted on Freedom rootstock which recorded high consumed about 49.15% of the total water consumptive use. Concerning the effect of irrigation treatment on endogenous plant hormones in buds data indicated that, maximum increased in hormone content (IAA, GA_3 and Cytokinin) was obtained by increasing irrigation levels 1.0 ET to 1.2 ET. Absisic acid (ABA) recorded the reverse trend. Low irrigation markedly raised the concentration of ABA in buds. It is generally recommended that irrigation of Superior Seedless cv. grafted on Freedom rootstock should be maintained at 1.0 ET for economical yield and improved fruit quality under the same circumstances.

Key words: Irrigation · Grape · Grafting · Freedom · Superior seedless

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INTRODUCTION

The role of irrigation in viticulture is considered both controversial and essential to grape production. Water is a vital component to function of the vine with its presence or lack impacting photosynthesis. Moreover, the presence of water is essential for the survival of all plant life in grapevine, water acts as a universal solvent for many of the nutrients and minerals needed to carry out important physiological functions [1].

Rootstock utilization has been significantly increasing in the world. They vary in root distribution and affect scion responses in vigor, yield, fruit quality and other physiological parameters [2, 3].

In the last few years a vast acreage of superior Seedless cv. grafted on Freedom rootstock has been being cultivated in the newly reclaimed areas along the desert roads in North and Middle Egypt to stimulate its withstanding to unfavorable environmental conditions. This region depended on wells in the irrigated which may sometimes be insufficient to meet the need of the vines of irrigation water and grapevines may be suffering in these new areas from water stress that may prevail throughout the season. Despite these conditions, grape is still one or the major horticultural crops grown in the region. Although grapevine is traditionally non-irrigated crop grown in a range of natural environments, grape berry composition and vine development are highly dependent on water status [4]. Thus recently, vineyards have been irrigated with drip irrigation system in the region. However, there is a controversy about the positive and negative impacts of irrigation on grapevine quality. It is commonly stated that excessive water application induces vegetative growth that causes lower fruit quality including low sugar content and unbalanced acidity of berries [5, 6]. On the contrary, low amount of water supplement can improve grape quality due to reduction in vigor leading to an increase in slight interception in the cluster zone [7, 8]. Therefore a national use of water in irrigation in a given environment and cultivar is still unclear.

Water stress was effective in inducing early bud break, cluster formation and increasing fruitfulness compared to continuously well watered vines [9-11]. Moreover Nadal and Lampreave [12] reported that water stress decreased leaf area of grapevines. Drought is one of the most severe limitations on the yield of sugarcane. This stress induces various biochemical and physiological response in plants as a survival mechanism [13]. In this respect, Ferreyra *et al*. [14], disclosed that different irrigation water amounts were applied, between 40 and 100% Etc. They mentioned that the table grape yields decreased in comparison with applied water in the range of studied treatments. 60% Etc restriction decreased yield in 22%. The cluster and berry weight was reduced linearly with duration of water deficit [15]. Moreover, Messoudi and El-Fellan[16] in their study on four irrigation regimes (40, 60, 80 and 100 Etc) found that all treatments lower than 80% Etc was affecting negatively on cluster weight and berry diameter. Irrigation of grapevines has a significant effect on grape juice characteristics such as Brix and titratable acidity Liumi *et al*. [17] found that TSS and acidity were decreased by increasing irrigation level on Chardonnay grapes. Meanwhile Gurovich [18] indicated that a restriction equivalent to 75% Etc have a positive effect on soluble solids content compared with 50% Etc. Concerning grape behavior storage under room condition as (shelf life), Suriender *et al*. [19] reported that physiological weight loss and total soluble solids increased with storage duration. Meanwhile Adel *et al* . [20] and El - Shobaky *et al*. [21] found that shattering% of Thompson Seedless grape bunch held under room temperature gradually increased with the advance of storage period. As for the effect of irrigation level on coefficient of wood ripening Peacock [22] reported that mild to moderate water stress may be beneficial by stopping shoot growth and promoting wood maturity. Moreover, El Gendy [10] recorded that applied water amount exceeding the 1.0 ET treatment did not result in further increase for ripening wood while water application amount less than 1.0 ET gave significant reduction in wood ripening. Many investigators reported the accumulation of free proline as a result of water stress [23]. Moreover, leaf content of N, P, K increased by increasing soil moisture. In this regard Rodriguez and Garcia, [24] found that drought negatively affected the nutrient content of NPK.

Considering the impact of rates of irrigation on hormones, Ndung *et al.* [9] and Shawky *et al.* [23] indicated that increasing water stress significantly reduced leaf content of both IAA and GA while a considerable increment sin leaf ABA was found. Water stress caused an inhibition in the amount of water accumulated in leaf tissues and this reflects directly the efficiency of the biological processes in leaves. Rodrigues *et al.* [25] detected lower relative water content values as a result of water stressed plants of Rosaki grape.

Regarding the relationship between root growth and available soil water Magriso [26], found that reducing size of root had decreased the size of root system and leaf surface area which in turn caused a reduction in water consumption of four grape varieties grown under soil moisture regimes.

Therefore, the present study was conducted to determine water requirement for Superior Seedless cv. grafted on Freedom rootstock (which have spread in recent years in the desert land conditions) to increase the tolerance to unfavorable environmental conditions especially drought on growth parameters, yield, fruit quality and chemical analysis of leaf mineral content.

MATERIALS AND METHODS

This investigation was conducted during three consecutive years (2009, 2010 and 2011) in a private vineyard located at 84 kilometer of Cairo Alexandria Desert Road. Superior Seedless cv. grafted on Freedom rootstock of 6-year-old were grown in a sandy soil and supported by the Gable system. Distances were 2 m between vines and 3 m between rows under drip irrigation system with two lateral lines per row and two 4 L/h emitter per vine and use valve regulates water amount to attain irrigation treatment. The vines were cane-pruned to 72 buds per vine (6 canes x 12 buds / cane). The tested vines were nearly the same and subjected to the same horticultural practices. The work in the first year was considered as a preliminary trial and then the experiment proceeded with the same manner during the second and third seasons, respectively.

Representative soil samples were taken from the experimental field before initiating the experiment and subjected to the different soil analysis as well as the chemical analysis of well irrigation water are shown in Tables 1-3 according to analysis implemented and studies, soil, Water and Environment Research Institute according to Chapman and Pratt [27].

Table 1: Chemical properties of the experimental soil (1: 2.5) soil extract

			Soluble anions (meg/1)			Soluble cations (meg/1)				Available						
Depth	PH	EC dS/m	HCO^-_3	Cr	$SO^=_4$	Na^+	K^+	Ca^{++}	Mg^{++}	N	P	K	Cu	Fe	Mn	Zn
0-10	7.56	0.16	1.2	1.1	0.16	0.55	0.11	1.1	0.7	26.6	1.5	255.0	2.6	3.2	8.2	2.4
10-20	7.78	0.22	0.9	1.5	0.50	0.67	0.13	1.2	0.9	31.5	1.2	204.0	2.8	4.2	5.6	17.2
20-30	7.62	0.15	1.0	1.0	0.20	0.52	0.09	1.0	0.6	24.5	3.3	153.0	1.2	3.0	4.2	2.8

Table 2: Physiological properties of the experimental soil (1 :2.5) soil extract

Depth	V.C.S%	C.S%	M.S%	F.S%	V.F.S%	Silt+ Clay%	Textural class
0-10	14.6	28.8	19.9	22.2	9.5	5.0	Sand
10-20	19.2	35.1	20.4	16.9	4.7	3.6	Sand
20-30	18.0	34.3	22.7	19.4	2.7	2.9	sand

F.C% = 13.7 W.P% = 6.45

Table 3: Some chemical properties of the experimental water (well water)

			Anions (meg/L)				Cations (meg/L)			
PH	EC mmhos/cm	EC (ppm)	CO^-_3	HCO^-_3	Cl^-	$SO^=_4$	Ca^{++}	Mg^{++}	Na^+	K^+
7.1	0.86	550.4	0.2	2.89	2.91	1.22	2.1	0.75	4.2	0.19

Table 4: Monthly crop coefficient (Kc) for grapevine, evapotranspiration (mm/day) values and ETc (mm/day) of different treatments

treatments	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
K_c	0.20	0.20	0.25	0.45	0.60	0.70	0.70	0.65	0.55	0.45	0.35	0.00
Et_o mm/day	2.1	2.5	4.6	5.2	5.8	6.5	7.1	7.8	5.3	4.5	2.5	2.0
Et_c mm/day	0.42	0.50	1.15	2.34	3.48	4.55	4.97	5.07	2.92	2.03	0.88	0.00

Table 4: Monthly crop coefficient (Kc) for grapevine, evapotranspiration (mm/day) values and ETc (mm/day) of different treatments

treatments	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
K_c	0.20	0.20	0.25	0.45	0.60	0.70	0.70	0.65	0.55	0.45	0.35	0.00
Et_o mm/day	2.1	2.5	4.6	5.2	5.8	6.5	7.1	7.8	5.3	4.5	2.5	2.0
Et_c mm/day	0.42	0.50	1.15	2.34	3.48	4.55	4.97	5.07	2.92	2.03	0.88	0.00

Table 5: Daily and monthly water requirements (m^3/fed) of different irrigation treatments for Superior Seedless cv. grafted on Freedom rootstock grapevine in new lands

	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Treat.	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M
0.6ET	6.04	1.06	14.4	1.26	49.68	2.90	126.38	5.90	375.95	8.77	491.4	11.47	268.33	12.52	547.49	12.77	157.37	7.34	109.67	5.11	25.37	2.21	0.00	0.00
0.8ET	8.05	1.41	19.2	1.68	66.24	3.86	168.51	7.86	501.26	11.70	655.2	15.29	357.77	16.70	729.98	17.03	209.83	9.79	146.23	6.80	33.83	2.94	0.00	0.00
1.0ET	10.06	1.76	24.0	2.10	82.8	4.83	210.64	9.83	626.57	14.62	819.0	19.11	447.21	20.87	912.48	21.29	262.29	12.24	182.79	8.53	42.29	3.70	0.00	0.00
1.2ET	12.07	2.11	28.8	2.52	99.36	5.80	252.77	11.80	751.88	17.54	982.8	22.93	536.65	25.04	1094.98	25.55	314.75	14.69	219.35	10.23	50.75	4.44	0.00	0.00

Table 6: Monthly water requirements (L/vine/day) of drip irrigation system of Superior Seedless cv. grafted on Freedom rootstock grapevine in new lands

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.2 ET	3.01	3.60	8.29	16.86	25.06	32.76	35.77	36.50	20.99	14.61	6.34	0.00
1.0 ET	2.39	3.00	6.94	14.04	20.89	27.30	29.81	30.41	17.49	12.19	5.29	0.00
0.8 ET	2.01	2.40	5.51	11.23	16.71	21.84	23.86	24.33	13.99	9.71	4.20	0.00
0.6 ET	1.51	1.80	4.14	8.43	12.53	16.39	17.89	18.24	10.49	7.30	3.16	0.00

Table 7: Seasonal crop water requirements (m^3/fed) and seasonal water consumptive use (m^3/fed) for Superior Seedless cv. grafted on Freedom rootstock in new land in Egypt

Treatments	Seasonal crop water requirements (m^3/fed)	Seasonal water consumptive use (m^3/fed)
0.6 ET	2172.08	1846.27
0.8 ET	2895.5	2461.18
1.0 ET	3620.13	3077.11
1.2 ET	4344.16	3692.53

The Experimental Design: Four treatments of irrigation were arranged in a complete randomized design with three replicates. The collected data confirmed the high efficiency of the irrigation system in this vineyard. Data related to macro climate of the vineyard way analyzed, mean night and day temperature, rate of evapotranspiration in the soil, humidity and wind-speed were obtained from Central laboratory for Agriculture climate (CLAC), El-Giza, Egypt.

Water requirements for grapevines were calculated by using equation as follows,

$$\text{(WR) Water Requirement} = \text{ETo} \times \text{Kc} \times \text{IE}$$

Eto: Daily reference evapotranspiration (mm / day) as shown in Table 4 can be calculated from the actual temperature, humidity, sunshine radiation and wind speed, data, according to the FAO penman-Monteith method [28].

Kc: Crop coefficient values were taken from FAO [28] as shown in Table 4.

IE: Irrigation efficiency or water consumptive use (85% of crop water requirements for drip irrigation system).

Irrigation levels were 0.6, 0.8, 1.0 and 1.2 times potential evapotranspiration as 1.0 ET is considered as on equivalent to 100% replacement of the exacted non stressed evapotranspiration for grapevines. Daily and monthly water requirements (m^3 / Fed) of different irrigation treatment recorded in Table 5.

While monthly water requirements (L / vine / day) of drip irrigation system of Superior Seedless cv. grafted on Freedom rootstock grapevine in new lands are given in Table 6.

Water consumptive use m^3 / Fed were estimated by dividing seasonal crop water requirements m^3 / Fed on IE presented in Table 7.

The considered treatments were evaluated through the following estimations:

Bud Behavior Measurements:

- Bud burst percentage was calculated according to the following equation:
  Bud burst%: calculated by dividing number of bursted buds by buds load per vine x 100
- Fruitful buds% : number of fruitful buds per vine / number of bursted buds per vine x 100

The Vegetative Growth: Five current season fruiting shoots per vine were labeled shortly after growth commencement to be measured at monthly intervals for determining growth rate (SGR) as well as the total surface area of the leaves per vine (m^2 / vine) which was determined as follows: The mean leaf area multiplied by the number of leaves / shoot by number of shoots per vine using leaf area meter, Model CI203, U.S.A.

Coefficient of wood ripening: was calculated by dividing length of the ripened part of the cane by the total length of the cane [29].

Yield and Berry Characteristics:

- Number of clusters per vine, yield per vine (kg) and average cluster weight (g).
- Average berry weight (g), berry size (cm^3), berry firmness (g / cm^2), berry adherence strength (g) by using Shatilan's instrument.
- Shattering percentage was determined on clusters stored for seven days at room temperature (28 to 30 °C) shattering percentage was calculated by dividing weight of shattered berries by the initial weight of the cluster.

Berry Juice Measurements:

- Total soluble solids percentage (TSS) using a hand refractometer.
- Titratable acidity percentage according to [30].
- Total soluble solids / acid ratio (TSS / Acid).

Chemical Analysis:

- Petioles samples in front of the cluster were taken from the fully matured leaves at full bloom, which for each growing season and washed with tap water followed by distilled water then oven dried at 70°C for 48 hours, dried samples were digested according to the method of Jackson [31].

Determinations of Some Nutrients:

- Nitrogen content (%) was determined by the modified micro Kjeldahl method as described by Naguib [32].
- Phosphorous content (%) was determined colorimetrically estimated according to the Official Methods of Analysis [30].
- Potassium content (%) was estimated by using flame photometer as described by Jackson [33].

Determinations of Total Carbohydrates in the Canes: Total carbohydrates in the canes were determined using phenol sulphuric acid method described by Smith *et al*. [34].

Determinations of Proline Content: Proline content was colorimetrically estimated in fresh samples of the middle leaves according to Bates [35].

Physiological studies

Determinations of Leaf Relative Turgidity (L.R.T.): Equal leaf discs (1 cm) were cut from mature leaves, weighed to give the fresh weight, floated in water for 24 hours until they attained an equilibrium, reweighed (turgidity weight) and finally oven dried at 70°C for 24 hours to reach a constant weight (L.R.T.) and calculated using the following formula according to Ritche [36].

L.R.T. = turgid wt.-fresh wt. / turgid wt.-dry wt. x 100

Determinations of Hard Leaf Character (H.L.C.): Hard leaf character (H.L.C.) was determined according to Youssef [37] using the following formula:

H.L.C. = dry weight of leaf (g) / leaf area (cm^2)

Root Distribution: Soil samples were collected using an auger from four directions at 50 and 100 cm from the vine trunk and from depths of 0-30 and 30-60 cm. Root were classified into fine roots (less that 2 mm) in diameter, medium roots (2-6 mm) and large roots (more than 6 mm) length was recorded for each sample Bohm [38]. Moreover, soil temperature through the 30 cm below the soil surface (where most of the root system is located) was recorded daily by using 25 cm long sensor thermometer.

Soil Moisture Determination: The soil samples accompanied to roots at different distances and depths were immediately transferred in tightly closed aluminum cans to the laboratory where they were weighed, dried in oven at 105°C for 24 hours then reweighed and their moisture content were determined according to Garcia [39].

Acidic Hormones: Acidic hormones gibberellins (GA_3), Indole acetic acid (IAA), Cytokinin and Absisic acid (ABA) were determined in buds at the time of dormancy (1^{st} week of January) following the method outlined by Shindy and Smith [40].

Irrigation Measurement:

- *Consumptive use percentage for the different growth stages of vine*

After calculating the consumptive use of the whole season (from February till October), the grapevine growing seasons were divided to four separate stages. Stage 1: bud break to flowering, stage 2 covers the period from bloom to veraison, stage 3 is the ripening phase and covers the period of veraison to harvest and stage 4 covers post harvest to dormancy. Estimation of the consumptive use percentage separately for every stage was recorded for the growing seasons.

- *Water use efficiency (WUE)*

Water use efficiency was calculated according to Viets [41].

WUE = Y / WU
WUE: water use efficiency (Kg / m^3)
Y : yield (K / fed)
WU: consumptive use (m^3 / season).

Statistical Analysis: The obtained data were subjected to statistical analysis of variance according to Snedecor and Cochran [42] means were compared using the New LSD values at 5% level.

RESULTS AND DISCUSSION

Effect of Irrigation Treatments on Bud Behavior of Superior Seedless Cv. Grafted on Freedom Rootstock

Bud Burst Percentage: Concerning the effect of irrigation treatments on the bud burst percentage of Superior Seedless cv. grafted on Freedom rootstock cultivar during 2010 and 2011 seasons, it can be noticed from Table 8 that the highest recorded percentage were irrigation treatments at 0.6 ET and 0.8 ET and it were significantly higher when it compared to either 1.0 ET or 1.2 ET. However, applied water amount exceeding the full ET i.e 1.2 ET gave the least significant percentage especially during the 2nd season. In this regard previous studies [9, 11, 43, 44] reported that water stress was effective in inducing early bud break compared to continuously well watered vines.Data is hand indicated that bud burst percentage decreased gradually by increasing water discharge of irrigation treatments; the greatest values resulted from 0.6 ET followed by 0.8 ET, 1.0 ET and 1.2 ET, respectively.

Fruitful Buds: Data in Table 8 represent the percentage of fruitful buds in relation to the percentage of fruitful buds. In dealing with the differences between the irrigation treatments, it was found that irrigation treatment 1.2 ET produced the highest fruitful buds percentage followed by 1.0, ET respectively. It is clear from the same Table that the lowest percentages were attained by 0.6 ET and 0.8 ET, respectively. Therefore, it could by stated that, there was a gradual increase in fruitful buds percentage that could be maximized by application of amounts greater than full irrigation treatment (1.0 ET). This can be explained when rates increase irrigation efficiency rises of root system absorb elements from the soil during the growing season and composition of carbohydrates which have a role in fertility buds.

These results, as a general trend, are in agreement with found by prior studies [10, 11, 44]. They reported that, gradual increase in fruitful bud percentage of grapevine was in parallel with increasing the irrigation rate.

Effect of Irrigation Treatments on Canopy Measurements of Superior Seedless cv. Grafted Freedom Rootstock:

Shoot Growth Rate (SGR): It can be observed from data of Fig. 1 that the growth rate of current shoots (SGR) was extremely high through the first period of growth from March 10th up to April 10th during the two studied seasons, followed by a sharp decrease during the second period from April 10th up to May 10th. This decrease continued till it reached its minimal value at the final period from August 10th up to September 10th. It is

Table 8: Effect of different irrigation treatments on bud behavior of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011 seasons

	1st season		2nd season	
Treatments	Bud burst%	Fruitful bud%	Bud burst%	Fruitful bud%
0.6 ET	95.13	60.35	83.66	62.51
0.8 ET	80.15	61.95	81.58	64.80
1.0 ET	78.34	65.25	78.63	68.45
1.2 ET	76.85	68.34	69.89	72.38
New LSD	0.06	0.07	0.07	0.08

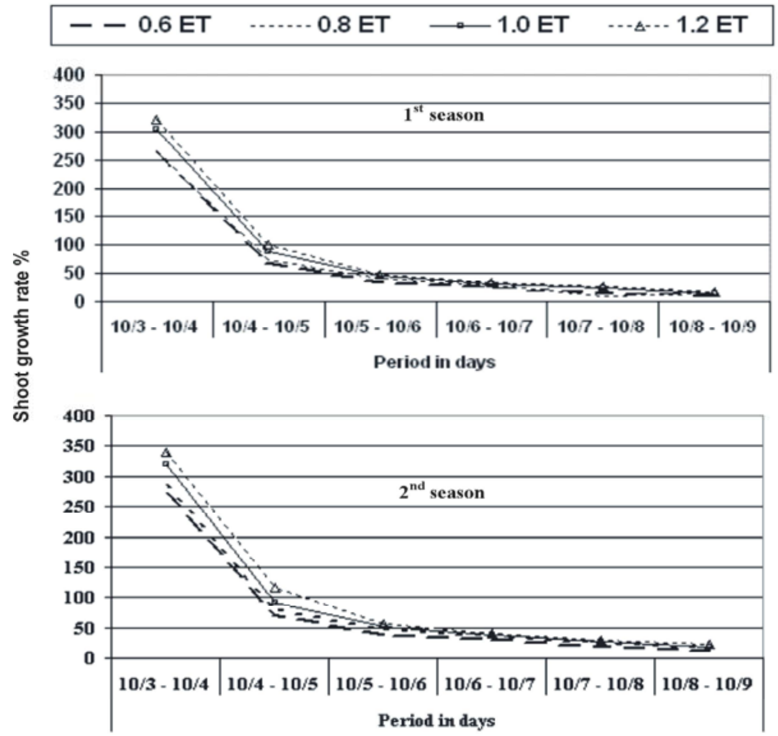

Fig. 1: Effect of irrigation treatments on shoot growth rate (%) (SGR) of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011 seasons

noteworthy that, the sharp decrease in shoot growth rate that was observed during the second period was coincided with the approach of blooming time and fruit set. The results are in accordance with those of Weaver [45] who mentioned that (SGR) begins to slow down by bloom time, while Kliewer [46] found that the decreased value of (SGR) was due to the cluster consumption of carbohydrate.

Concerning the effect of different irrigation treatments on shoot growth rate (SGR) the data disclosed that all irrigation treatments increased shoot growth rate of this cultivar There was a gradual increase in this parameter along the growing season (mid March up to mid September). In addition, the periodical increase in shoot growth rate was faster and greater by raising the amount of irrigation water from 0.6 ET to 1.2 ET, since the shoot growth rate (SGR) of vines subjected to the 1.2 ET and 1.0 ET irrigation treatment was enhanced than those obtained from vine irrigated with 0.6 ET and 0.8 ET. In other words, the reduction in shoot growth rate resulting from irrigation at 0.6 ET and 0.8 ET compared to 1.0 ET and 1.2 ET in 1st and 2nd seasons. Therefore, these results indicated that water application at amounts lower than 1.0 ET exhibited an inhibitory effect on shoot growth rate (SGR).

These results, as a general trend, are in agreement with the conclusion given by Pire and Ojeda [47] who found that vegetative growth was restricted by the lowest level of water application particularly with drip irrigation on grapevine. On this way, Vallone *et al*. [48] from their studies for (*Vitis vinifera*, L), indicated that, shoot growth rate was reduced by water deficit by 20% and 30% during fruit set to veraison and from veraison to harvest.

Total Leaf Surface Area per Vine (m^2): Data in Table 9 illustrate the effect of the different irrigation treatments on the total leaf surface area per vine of Superior Seedless cv. grafted on Freedom rootstock. The statistical analysis appeared that increasing irrigation water through the two seasons of the study results in an obvious increase in the total leaf surface area per vine. The ameliorative effect of the highest rate irrigation (1.2 ET and 1.0 ET) on this parameter could be attributed to high efficiency of the root system in absorbing and transporting the water and mineral via to the leaves. However, it was found that irrigation treatment at 1.2 ET produced the highest value of this parameter in both seasons under study. Reversely, the least value of the total leaf surface area per vine was for the lowest irrigation treatment 0.6 ET

Table 9: Effect of irrigation treatments on total leaf surface area / vine (m^2) and wood ripening coefficient of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011

	1st season		2nd season	
Treatments	Leaf surface area / vine (m^2)	Wood ripening coefficient	Leaf surface area / vine (m^2)	Wood ripening coefficient
0.6 ET	12.56	0.89	14.88	0.93
0.8 ET	16.89	0.87	19.76	0.90
1.0 ET	21.70	0.82	25.52	0.85
1.2 ET	24.65	0.81	29.48	0.83
New LSD	0.08	0.07	0.07	0.08

followed by 0.8 ET. Also, the differences between 1.0 ET and 0.8 ET were statistically confirmed as the farmer was more effective than the later.

Likewise, Shishkanu *et al*. [49] reported that the decrease in soil moisture level from 70% to 35% of the field capacity generally resulted in a marked decrease in leaf area on Pina Noir and Sauvignon grapevines. Merino *et al*. [50] reported that increasing irrigation increased total leaf area of Chardonnay vines. Moreover, Nadal and Lampereave[12] and Behairy [44] reported that water stress decreased leaf area on grapevine.

Wood Ripening Coefficient: Concerning the influence of irrigation rate on wood ripening coefficient of Superior Seedless scion, the obtained results in Table 9 show that, wood ripening coefficient decreased by increasing irrigation water and there was a significant difference between highest irrigation rate 1.2 ET and lowest irrigation rate 0.6 ET, this holds true in both growing seasons. Nevertheless, both 1.0 ET and 1.2 ET treatments reflected nearly the same effect on wood ripening. In other words, it can be conclude that applied water amount exceeding the 1.0 ET treatments (full ET) did not result in further ripening increased, while water application amount less than 1.0 ET resulted in significant reduction in wood ripening for both seasons, under this study. This finding reflect the importance of water, management in adequate manner as one of the major factors affecting the development of wood ripening which reflect directly on producing good ripened canes or spurs which in turn will keep the productively and fruit quality advantages.

The results obtained by Peacock [22] who reported that mild to moderate water stress may be beneficial by stopping shoot growth and promoting maturity. Moreover, El-Gendy [10] and Behairy [44] mentioned that coefficient of wood ripening in Thompson Seedless and Flame Seedless grapevines decreased by increasing irrigation water.

Effect of Irrigation Treatments on Root Growth Measurements of Superior Seedless cv. Grafted on Freedom Rootstock

Fine Roots (Root less than 2 mm in Diameter): The effect of irrigation treatments (1.2, 1.0, 0.8 and 0.6 ET) on the average length of fine roots (< 2mm) assessed at two distance from the vine trunk (50 and 100 cm) and at two depths through the soil profile (0-30 and 30-60 cm) are presented in Figs. 2 and 3. In general, irrigation increased root growth expressed as roots length. The increase in root length was proportional to the increase in the amount of applied water. Thus maximum increase in the fine roots length was obtained from irrigation at 1.2 ET. It was also remarkable that length of fine roots was higher for vines irrigated at full ET (1.0 ET) than those subjected to irrigation at 0.8 ET or 0.6 ET as the later produced the shortest roots.

Moreover, the horizontal extension of fine roots was more concentrated at the distance of 50 cm from the vine trunk than those extended to the distance of 100 cm from vine trunk. Furthermore, the effect of irrigation at 1.2 ET followed by 1.0 ET was superior in producing higher fine roots density at the distance of 50 cm while the effect of 0.6 ET had the lowest density either at 50 cm or 100 cm from vine trunk.

In addition, the obtained data disclosed that fine roots extension through the vertical direction was also affected by irrigation treatments. Regardless of irrigation treatments, it was found that density expressed as the length of fine roots was higher at 0-30 cm depth than those found at 30-60 cm depth in the soil profile. Taking the effect of irrigation treatments into consideration, it is quite clear that low irrigation treatments (0.8 ET and 0.6 ET) depressed fine roots formation and produced the shorter fine roots especially irrigation at 0.6 ET, while irrigation either at 1.0 ET or 1.2 ET stimulated the formation of fine roots. These results held true during both seasons of this study.

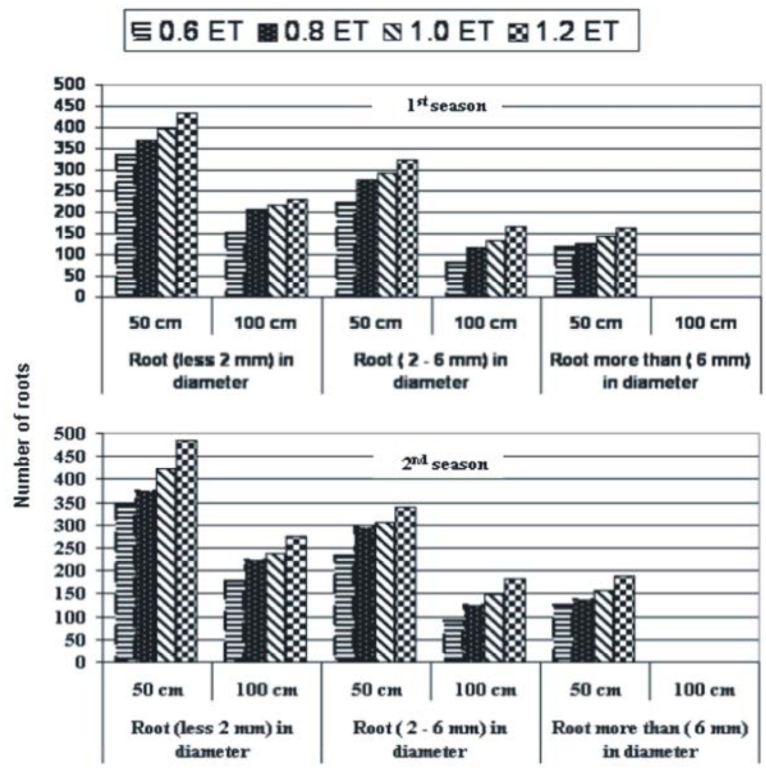

Fig. 2: Effect of irrigation treatments on average length of roots at different distances of vine trunk of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011 seasons.

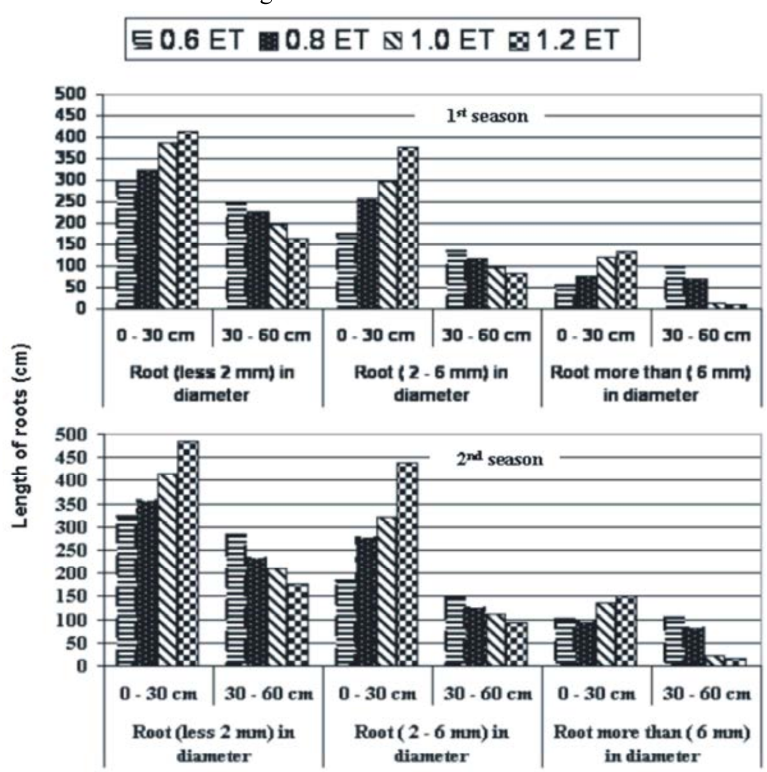

Fig 3: Effect of irrigation treatments on average length (cm) of roots at different depths of soil of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011 seasons

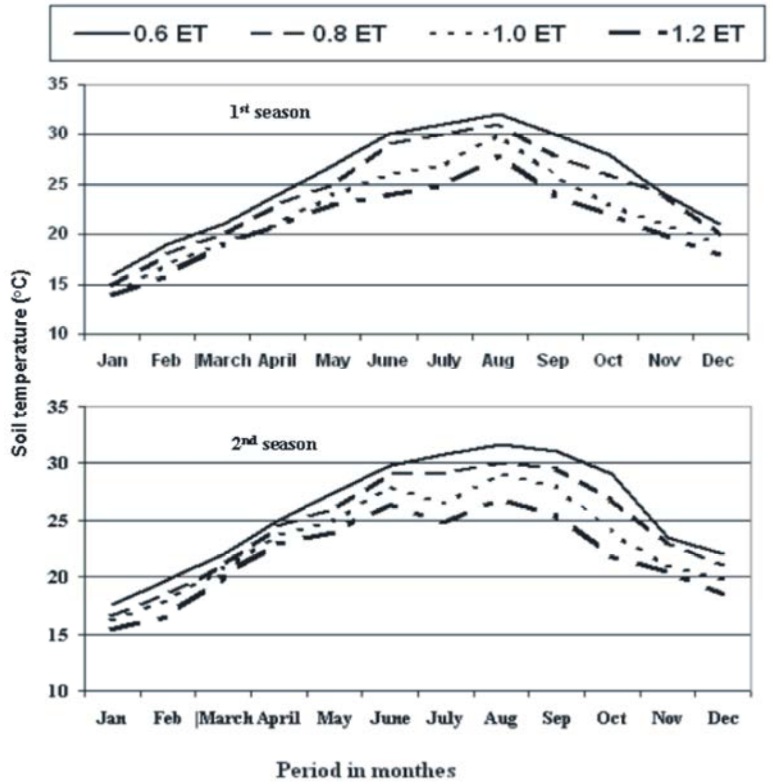

Fig. 4: Effect of irrigation treatments on average monthly soil temperature at 30 cm depth of surface soil during 2010 and 2011 seasons

Medium Roots (Roots 2-6 mm in Diameter): Data in Figs. 2 and 3 showed a gradual increment was found as irrigation amount which increased from 0.6 ET to 1.0 ET. The highest values were resulted from irrigation at 1.2 ET and the lowest ones obtained from 0.6 ET, while full irrigation (1.0 ET) and 0.8 ET treatments rated in-between. Also, it is noticeable that the positive effect due to irrigation treatments was considerably higher when the effect of distance from vine trunk or the depth in soil profile was considered. Moreover, the data showed an obvious increase in medium roots either at 50 cm distance or at 0-30 cm soil depth. The growth of medium was roots reduced by increasing the distance more than 50 cm from vine trunk or the depth more than 30 cm from the soil surface.

Large Roots (Roots More than 6 mm in Diameter): The horizontal and vertical extension of large roots as affected by irrigation treatments are presented in Figs. 2 and 3. Generally, results of large roots had a trend similar to that previously mentioned with fine and medium roots. Since the distribution of large roots was linearly increased by increasing irrigation water as well as decreasing the distances from vine trunk or soil surface. These findings were previously supported by some researchers [10, 11, 51]. They recorded that, the bulk of the roots are usually concentrated in the upper soil layer and irrigation improved roots system development. Adequately watered grapevines exhibited the highest values of roots being almost in the horizontal, as well as in the vertical direction. In this concern, the greatest amount of roots was observed within the 0.5 m distance from the vine trunk and the 0.3 m depth of soil surface.

Effect of Irrigation Treatments on Soil Temperature: Fig. 4 presents fluctuations in the average monthly soil temperature at 20 cm depth of surface soil. Results indicated that the highest average soil temperature occurred in the period from May to September in the first and second season. The lowest temperature was recorded from December to March in the first and from December to February in the second season. Concerning the effect of irrigation treatments, results showed that, high irrigation rate (1.2 ET) resulted in the lowest average soil temperature followed by adequate irrigation (1.0 ET) than other irrigation treatments. Nevertheless the highest average of soil temperature was attributed to reducing water application at (0.6 ET) or (0.8 ET). These results are

Table 10: Effect of irrigation treatments on soil moisture distribution at different distances and depths of soil during 2011 seasons

	Distances (cm)of vine trunk		Depth (cm)	
Treatments	(0-50 cm)	(50-100 cm)	(0-30 cm)	(30-60 cm)
0.6 ET	4.18	3.25	6.81	4.25
0.8 ET	5.58	4.80	8.35	5.95
1.0 ET	7.76	5.63	10.95	7.36
1.2 ET	8.47	5.95	12.48	10.25
New LSD	0.07	0.08	0.08	0.07

in agreement with the findings of Tamasi [52] who stated that the rate of growth roots depended mostly on environmental conditions due to soil water depletion and rising soil temperature. However, the root temperature of Thompson Seedless most favorable for maximum growth was about 86 °F [53]. In this respect, Fukui *et al*. [54] recorded that, the optimum soil temperature for development of root system on apple trees was 20-24°C. On the contrary, when the temperature of the soil exceeds 32 °C root growth stops [52]. Therefore, one can say that when irrigation rate was increased from 1.0 ET to 1.2 ET it led to a reduction in temperature of the soil, which resulted in the creation of root growth and this is properly illustrated Figs.2 and 3.

Effect of Irrigation Treatment on Soil Moisture: Data presented in Table 10 showed a significant decrease in soil moisture parallel to the decrease in irrigation rate at different distances (50 and 100 cm) from the vine trunk as well as at different depths (0 and 30), (30 and 60 cm) from the soil surface. At distance from the vine trunk induced the highest soil moisture distribution horizontally and vertically especially at optimum and moderate irrigation rates (1.2 ET and 1.0 ET) respectively. While under low rate irrigation (0.6 ET and 0.8 ET) resulted in an obvious depression in soil moisture. Moreover, the horizontal extension of soil moisture was more concentrated at the distance of 50 cm from the vine trunk than those extended to the distance of 100 cm from the trunk.

In addition the obtained data disclosed that soil moisture extension through the vertical direction was also affected by irrigation treatments. Regardless irrigation treatment, it was found that density expressed as the soil moisture was significantly higher at 0-30 cm depth than those found at 30-60 cm depth in soil profile. Therefore it could be concluded that soil moisture concentrated at the soil surface layer (0-30 cm) and around the trunk (50 cm) especially at 1.2 ET and 1.0 ET, respectively.

Generally, these results clearly illustrated that, root system distribution decreased with increasing the distance from the trunk and with the depth from the soil surface. In other words, root density increase where soil moisture accumulated.

However, many other investigators revealed that, soil moisture distribution was uniform under drip irrigation and decreased as by increasing the depth and distance emitter. Kulinich [55] found that, in grapevines root mass and root penetration were always greater on irrigated than on non-irrigated plots. The best results being on plots maintained at 70-80% of field capacity by drip irrigation delivered at a depth of 20-25 cm by vertical filter tubes. On those plots, the main root mass was found at a depth of 20-40 cm. furthermore, Magriso [26] found that, reducing size of the root had decreased the size of root system and caused a reduction in water consumption [56].

Effect of Irrigation Treatments on Yield / Vine and Fruit Quality of Superior Seedless cv. Grafted on Freedom Rootstock

Number of Cluster / Vine, Cluster Weight, Yield / Vine and Yield / Feddan (kg): Data shown in Fig. 5 indicate that average number of cluster / vine increased linearly with increasing the rate of irrigation water and the highest number was recorded for vines subjected to 1.2 ET irrigation treatments, but the lowest one was for those treated with 0.6 ET, while full ET and 0.8 ET rated in-between. Given schedule 8 fruitful buds, it can be said that, there was a positive linear relationship between irrigation treatments and their effect on fruitful buds whereas increasing treatment of applied water from 0.6 ET up to 1.2 ET and thus led to the increase in the number of clusters.

Concerning the influence of irrigation rate on average cluster weight, yield / vine and yield / feddan of Superior Seedless cv. Grafted on Freedom rootstock throughout the two studied seasons. Data in Fig. 5 declare that cluster weight, yield / vine and yield / feddan increased by increasing irrigation rate. A progressive increase in

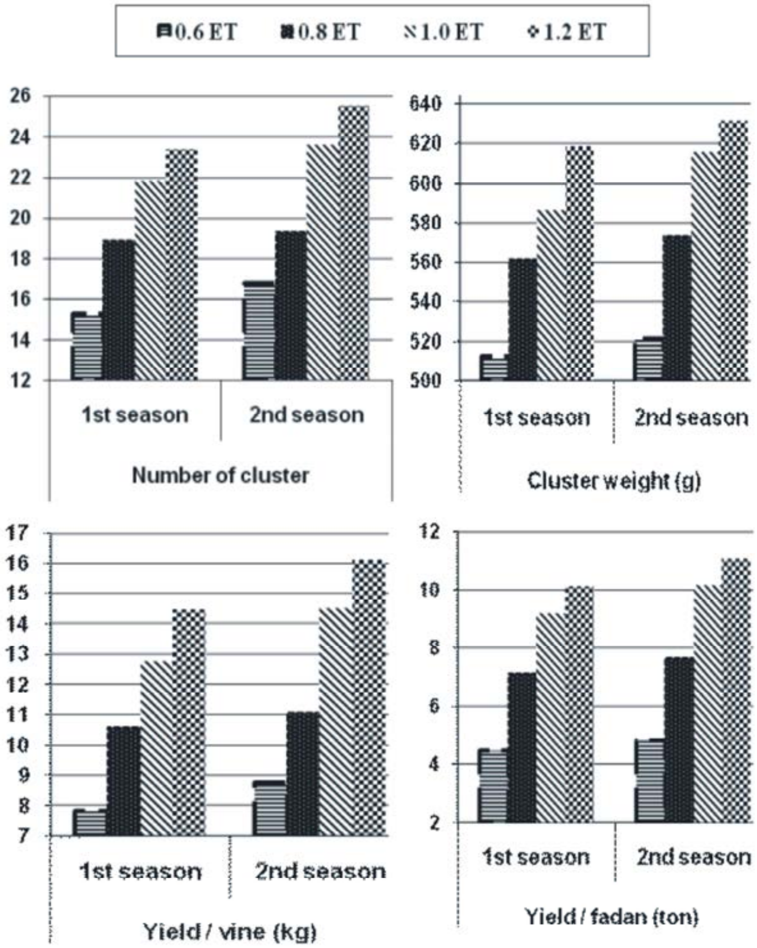

Fig. 5: Effect of irrigation treatments on number of cluster, cluster weight, yield / vine and yield / feddan / ton of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011 seasons

cluster weight, yield / vine and per feddan was found when amount of irrigation water increased reaching the greatest with irrigation at 1.2 ET. On the contrary, cluster weight and yield was remarkably reduced at the lowest irrigation rate (0.6 ET). Anyhow, it can be concluded that, the cluster weight and yield for vine received 1.2 ET and 1.0 ET irrigation water were heavier compared to vines subjected to 0.8 ET or 0.6 ET, respectively.

These results are in conformity with the findings of Gurovich [18] on irrigation scheduling of table grapes under drip irrigation. He mentioned that for 75% Et_c treatment, cluster weight was larger than that produced on the 50% Et_c treatment and it was a positive effect on berry weight and diameter. Moreover, Ferreyra *et al*. [14] disclosed that different irrigation water amounts were applied, between 40 and 100% crop evapotranspiration (Et_c). They found that grapevine yield was increased as the irrigation water rates increased.

The increase of cluster weight and yield observed in irrigation treatments can be interpreted in view of the fact that these treatments led to the increase in photosynthetic activity for leaves. As a consequently, of that, immigration of assimilates from leaves towards cluster is enhanced. Moreover, irrigation increased root distribution in the horizontal, as well as in the vertical direction and increase roots length and the wetted root zone was the largest. At this status capability of the vine to uptake soil water as fast. Hence, rate of uptake nutrient increased.

Effect of Irrigation Treatments on Physical and Chemical Characteristics of Berries of Superior Seedless cv. Grafted on Freedom Rootstock

Berry Characteristics: Data shown in Table 11 for 2010 and 2011 seasons indicate that vines had significantly greater fresh weight of berry when they were irrigated at 1.2 ET in the 1st and 2nd seasons followed by those

Table 11: Effect of irrigation treatments on physical and chemical characteristics of berries of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011 seasons

Treatments		Berry weight (g)	Berry size (cm^3)	Berry firmness (g/cm^2)	Berry adherence (g/cm^3)	Berry shattering (%)	TSS (%)	Acidity (%)	TSS/ acid ratio
		---------------1st season---------------							
0.6 ET		3.23	3.01	432	515	17.95	19.1	0.50	38.2
0.8 ET		4.12	3.98	421	506	19.80	18.9	0.54	35.0
1.0 ET		5.50	5.22	403	435	21.45	18.2	0.63	28.89
1.2 ET		6.15	6.01	385	410	25.36	17.8	0.65	27.38
		---------------2nd season---------------							
0.6 ET		4.15	4.08	445	538	19.55	19.5	0.46	42.39
0.8 ET		5.43	5.11	430	519	21.63	19.2	0.48	41.74
1.0 ET		6.18	5.98	412	466	24.15	18.6	0.59	31.53
1.2 ET		7.05	6.80	301	428	29.32	18.3	0.61	30.00
New LSD	1st season	0.020	0.028	1.153	0.035	0.040	0.109	0.045	0.089
	2nd season	0.049	0.053	1.153	0.998	0.057	0.109	0.060	0.020

irrigated by 1.0 ET. While vines subjected to 0.6 ET induced the least significant values for the two studied seasons. This result is in harmony with that mentioned by Gurovich [18] who indicated that the weight of berry was influenced in a positive correlation when 0.75 Et_c was applied by trickle irrigation particularly when compared with 50% Et_c.

Also, similar trend could be noticed on the effect of irrigation treatments on berry size of Superior Seedless cv. grafted on Freedom rootstock. Whereas raising the amount of irrigation water from 0.6 ET to 1.2 ET progressively increased water accumulation in berry tissues which in turn produced large berries. However, it reflect bad effect of limited water application, especially when lower than full ET, on berry weight and size, consequently cluster weight as well as total yield. In this respect, El- Gendy [10] and Behairy [44] revealed that, increasing irrigation rate resulted in an obvious increase in berry size, especially with higher rate.

Concerning the effect of irrigation treatment on berry firmness (gm / cm^3) data indicated statistically significant decrease in berry firmness associated with increase irrigation water during both seasons. The highest increase in this parameter was obtained from the lowest irrigation rate (0.6 ET) followed by (0.8 ET) then the highest irrigation treatment 1.2 ET. In other words, there was a general decrease in berry firmness as applied water amount increased from 0.6 ET to 1.2 ET.

As for berry adherence strength, it was negatively affected by increasing the irrigation water. Statistically irrigation at low rate 0.6 ET showed highest significant values in this parameter than the other irrigation treatments in two seasons.

These results seemed to be in harmony with results mentioned by other researchers [10, 11, 44] who found that reducing water application increased berry firmness and berry adherence strength.

Berry Shattering: The effect of irrigation treatments on berry shattering percentage after seven days from harvest of Superior Seedless cv. grafted on Freedom rootstock are shown in Table 11. Irrigation treatments as compared with each other's showed that the treatment lower than 1.0 ET resulted in the lowest berry shattering percentage during 1st and 2nd seasons while treatment higher than 1.0 ET produced highest percentage. The treatment of 1.0 ET had the intermediate effect.

The current results agreed with those reported by Berry and Aked [57] who reported that after storage Thompson Seedless grape for 6 days at room temperature loss dehydration and berry shatter were the main causes of quality loss at this stage.

Chemical Characteristics of Berries

Total Soluble Solids (TSS): The effect of irrigation on soluble solids content of berry juice of Superior Seedless cv. grafted on Freedom rootstock is shown in Table 11. Generally, it can be observed that there were significant differences between all treatments in this respect. However, TSS increased significantly with decreasing the irrigation rate. In other words, results revealed that vines treated with the low irrigation level (0.6 ET) had the highest TSS content followed by those treated with 0.8 ET. It can be also noticed that there were no significant differences between the two treatments received low irrigation rate (0.6 ET and 0.8 ET) compared with the other treatments. Meanwhile, the lowest berry TSS was obtained with irrigation at the high level irrigation (1.2 ET) while 1.0 ET treatments rated in-between in their effects. This holds true in both seasons under study. Therefore we can say that when was reduced the irrigation rates before the harvest they can cause an increase total soluble solids of berries. Similar results were observed by Liumi *et al*. [17] who investigated the effect of different levels of irrigation on chardonnay grapes. They found that TSS was decreased by increasing irrigation level. Moreover, Volachavic [58] reported that irrigation decreased the sugar production.

Total Acidity: Data of the two studied seasons Table 11 proved that the total titratable acidity was significantly affected by irrigation treatment. On the contrary of TSS content, total acidity% expressed as tartaric acid was high in cluster received high irrigation rate (1.2 ET) compared to full ET (1.0 ET) or low irrigation rate (0.6 ET and 0.8 ET). It means that the accumulation of tartaric acid in berry juice was associated with increasing irrigation water. It is clear that the highest significant value was for the high irrigation rate (1.2 ET), whereas 0.6 ET or 0.8 ET irrigation treatment had the least significant value but the differences were not significant. In this respect full ET (1.0 ET) the data showed more pronounced in this parameter over the treatment low rate irrigation in both seasons of investigation. This result seemed to be in harmony with those mentioned by Messaoudi and El-Fellah [16] who found that water deficit had a negative effect on titratable acidity decrease while soluble solids content (SSC) increased. Moreover, Shellie [59] mentioned that fruit harvested from high water stress plots had lower titratable acidity than vines from low water stress plots.

Total Soluble Solids / Acid Ratio: Response of TSS / acid ratio to the different irrigation treatments as represented in Table 11 show almost similar trend to that obtained with TSS where the highest values were attributed to the lowest irrigation (0.6 ET and 0.8 ET) compared to 1.2 ET irrigation level. While full ET irrigation treatment rated in-between averaging in both seasons.

Regarding these characters may be ascribed to activity of shoot growth, leaf area and root distribution under high irrigation level explain by the previously which might lead to acceleration in translocation of nutrients and assimilates from different parts of the vine towards berries. Consequently, stimulate of berries development and maturity. These finding agreed with those reported by previous studies [10, 11]. They mentioned the negative effect of applied water amounts on TSS / acid ratio of grapevines.

Effect of Irrigation Treatments on Some Physical Properties of Leaves of Superior Seedless cv. Grafted on Freedom Rootstock

Leaf Relative Turgidity (LRT): Data concerning leaf relative turgidity as affected by irrigation treatments are presented in Fig. 6. Leaf relative turgidity decreased as irrigation rate were decreased. In this respect, reducing the amount of applied water from 1.2 ET to 0.6 ET the turgidity in leaves reduced during in both seasons. In other words, leaf relative turgidity was increased when irrigation water was raised from 0.6 ET, 0.8 ET, 1.0 ET and 1.2 ET, respectively.

Thus, it could be postulated that water stress caused an inhibition effect on the amount of water accumulated in leaf tissues and this reflects directly the efficiency of the biological processes in leaves which in turn reduce leaf expansion as well as leaf dry matter. These results are nearly in the same line with those obtained by El Gendy [10] and Ali and Abd-El Monien [11]. They revealed lower relative water content (turgidity) values as a result of water stress.

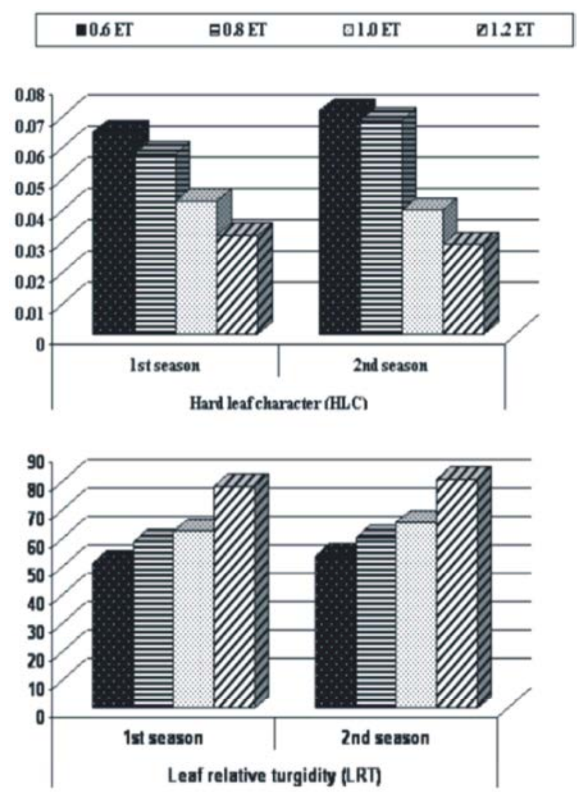

Fig. 6: Effect of irrigation treatments on some Physiological properties of leaves of Superior Seedless cv. grafted on Freedom rootstock in 2010 and 2011 seasons

Table 12: Effect of irrigation treatment on total carbohydrates (%), leaf prolin content% and leaf mineral content (N, P, K)% on petiole of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011seasons

	Total carbohydrates%		Leaf proline content%		Nitrogen%		Phosphor%		Potassium%	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
0.6 ET	35.56	37.20	0.22	0.24	2.53	2.58	0.53	0.56	2.19	2.25
0.8 ET	37.80	39.35	0.19	0.23	2.61	2.65	0.58	0.63	2.26	2.31
1.0 ET	42.64	44.68	0.17	0.18	2.68	2.72	0.66	0.71	2.34	2.38
1.2 ET	43.40	46.18	0.15	0.16	2.75	2.79	0.72	0.78	2.39	2.43
New LSD	0.021	0.022	0.023	0.022	0.024	0.025	0.028	0.029	0.028	0.032

Hard Leaf Character (HLC): Data in Fig. 6 represent the effect of irrigation treatments on hard leaf character throughout the two studied seasons. Generally, the lower irrigation rate (0.6 ET) yielded in the highest values of hard leaf followed by 0.8 ET.

Meanwhile the vine subjected to higher irrigation to the 1.0 ET or 1.2 ET cause lower values in this parameter. Such increment may be attributed to the low area of leaves in vines under higher water stress condition.

This fact could be explained in view of the table leaf area. This result confirmed previous data by Mohamed [60] and El Gendy *et al.*[61] who reported that hard leaf character was affected with the low irrigation rate.

Effect of Irrigation Treatment on Chemical Characteristics of Superior Seedless cv. On Grafted Freedom Rootstock

Total Carbohydrate Content of Canes (g/100g D.W.): Data tabulated in Table 12 represent the effect of irrigation treatments on total carbohydrates of canes throughout the two studied seasons. Generally, irrigation treatments have positively affected cane carbohydrate content, increased significantly with increasing the amount of irrigation water, whereas the canes accumulated that least amount of carbohydrates under irrigation at the lower rate (0.6 ET). While the higher irrigation rate (1.2 ET) yielded in the highest percentage of carbohydrates in cane tissue followed by full ET (1.0 ET) in this respect, irrigation at 0.8 ET gave the intermediate values of this parameter were statistically confirmed during both seasons. This results lead to the conclusion that thick and medium cane could produce from irrigation at 1.2 ET and 1.0 ET, respectively while deficit irrigation (0.6 ET and 0.8 ET) gives thin canes which, consequently, may reflects poor bud opening and fertility.

Concentration of the various carbohydrates in the canes has affected the metabolic activity of the vines which was reflected on the growth and yield. The canes are the main storage organs of various food materials needed to promote the various growth activities of the vine at early stage during the season.

Furthermore, some researchers investigated the effect of irrigation water on total carbohydrate content of canes. For instance El Gendy [10]; Ali and Abd-El Moniem [11] and Lavin [62] found that irrigation generally increased canes content of total carbohydrates.

Proline Content (%): It is obvious from the data presented in Table 12 that the proline content gradually and significantly increased as the amount of irrigation water decreased. In other words, the petioles could accumulate much more proline with decreasing the irrigation quantity from 1.2 ET to 0.6 ET. In this respect, irrigation at 0.6 ET resulted in the highest proline content followed by irrigation at 0.8 ET. While vine under 1.2 ET irrigation treatment contained the lowest values of these parameters. The treatment of 1.0 ET had the intermediate effect. However, the primary effects of water stress which led to accumulation of proline were decreasing proline synthesis and increasing proline formation. Therefore, it can be said that, the role of proline in drought injury is still a metter of controversy, it had been suggested that the accumulation of proline may be used as a basis for water stress. Similarly, El Gendy [10] ; Shewky *et al*. [23] and Abd El-Moteleb [63] reported that, the content of free proline with an optimum supply of water is usually very low. In reverse, the accumulation of proline was raised with water stress.

Leaf mineral N, P and K content (%): Data concerning nitrogen, phosphorus and potassium content of leaves as affected by different irrigation treatments are presented in Table 12, it can be pointed out that, nitrogen, phosphorus and potassium content in the leaves was positively affected by irrigation rate. It is obvious from the given data that N and P uptake increased in vines which received irrigation water at 1.2 ET while the least uptake and accumulation of N and P in petioles tissues was observed when vine was subjected to irrigation at low level (0.6 ET) followed by 0.8 ET level. However, the N, P and K concentration in vines irrigated at full ET rated in-between. This is true for both seasons of this study.

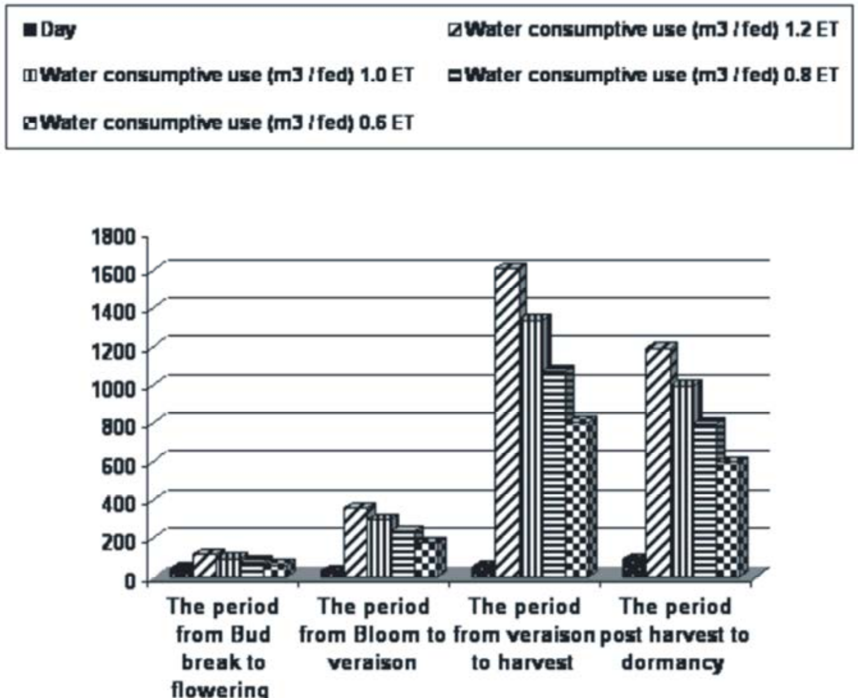

Fig. 7: Growth stage and water consumptive use of Superior Seedless cv. grafted on Freedom rootstock during 2011

Generally leaf mineral content (N, P and K) gradually and significantly decreased as the amount of irrigation water decreased. Such finding was also confirmed by Rodriguez and Gorica [24] who found that drought negatively affected in N, P and K in grafted Merenzao and Godllo vines. In leaf petioles of Thompson Seedless grapevines Shehata *et al.* [64] recorded an increase in N, P and K concentration with increasing water table levels. Also, Ali and Abd-El Moniem [11] and El- Gendy *et al*. [61] mentioned that NPK concentration in grapevine leaves increased with increasing soil moisture.

The relative increase accumulate much which more NPK with increasing the irrigation quantity from 0.6 ET to 1.2 ET might be mainly due to the consistent moisture content of the soil in the root zone together with adequate and greater distribution of the roots which may favor NPK uptake when vines subjected to irrigation at high level 1.2 ET and 1.0 ET as compared to the conditions prevailing under at low irrigation level 0.6 ET and 0.8 ET. The latter irrigation rates which had sharp fluctuations in moisture content of the soil which is inversely in the root zoon and declined uptake this leaf mineral content. This view is supported appreciably with those suggested by data previous such as increased water distribution as well as root distribution under high irrigation rate to absorb water and nutrients and consequently stimulating the growth and production of the vineyard.

Consumptive Use Estimated from Bud Break till Dormancy of Superior Seedless cv. Grafted on Freedom Rootstock: The effect of irrigation on vine growth and fruit development is best understood by dividing the season into four separate stages. Peacock [22] reported that, the water use by grapevines begging with bud break. He divided the season into four stages. These stages are applicable to established vines.

The First Stage: It covers the period from bud break to flowering where vegetative growth sets the pattern of the vineyard canopy for the whole growing season. To start the growing season with low levels of soil moisture will retard the potential of the vines. Therefore it is very important declare the consumptive use for the different stages of Superior Seedless cv. grafted on Freedom rootstock to criticize the critical and non critical periods to face the irrigation water shortage. Fig. 7 declares the different growth stages and its consumptive use for every stage. It is noticeable from this Fig, in the first stage the Superior Seedless cv. grafted on Freedom rootstock consumed about 3.5% of the total water consumptive during 45 days.

The Second Stage: It covers the period from bloom to veraison. Veraison is the point berries begins to soften. Rapid cell division occurs during this stage and water stress can reduce the berry size and potentially the yield.

Table 13: Effect of irrigation treatment on water use efficiency (WUE) of Superior Seedless cv. grafted on Freedom rootstock during 2010 and 2011 seasons

Treatments	1st season	2nd season
0.6 ET	2.43	2.60
0.8 ET	2.89	3.11
1.0 ET	2.98	3.31
1.2 ET	2.75	2.99
LSD at 5%	0.035	0.037

It is therefore of high importance to ensure proper water management during this critical stage. The percentage reached about 10. 82% of the total water consumptive during 30 days of the season.

The Third Stage: It is the ripening phase and covers the period of veraison to harvest. Irrigation during this period should maintain canopy health and avoid any vine stress, while, excessive irrigation can delay berry maturity, encourage cluster rot and berry cracking and delay or reduce wood maturity. Owing this stage high consumptive use was detected; the percentage reached about 49.15% during 50 day of the season.

The Fourth Stage: This period covers post harvest to dormancy. Water should be applied during this period to maintain the canopy but not encourage growth. The aim during this period is to maintain as many functional leaves as possible. This will allow the carbohydrates as the energy source for the vine in the bud burst stage of growth for the following season. The results declared that in this stage the vine consumed about 36.50% of the total water consumptive during 90 days of the season.

Accordingly and it is worth to mention that the third stage is very critical period which recorded high water consumption that reached 49.15% of the total water consumptive use followed by the post harvest to dormancy stage. On the contrary, the two other stages bud break to flowering and from bloom to veraison came in a descending percentages compared with them it.

Water use Efficiency (WUE): Data presented in Table 13 show the effect of irrigation on water used efficiency of Superior Seedless cv. grafted on Freedom rootstock throughout 2010 and 2011 seasons. It was found that irrigation rate at 1.0 ET recorded the highest water efficiency, followed by rates at 0.8 ET and 1.2 ET respectively. Moreover, the lowest (WUE) was found irrigation at 0.6 ET in both seasons under study. Soil can be safely irrigated with 1.0 ET to attain the highest water efficiency. These findings are in agreement with Hussein [65] on apple and Ali [66] on peach they found that 100% or 80% crop water requirement has nearly equal effect on vegetative growth and fruiting.

Effect of Irrigation Treatments of Superior Seedless Cv. Grafted on Freedom Rootstock on Endogenous Plant Hormones: Data concerning the effect of irrigation treatments on gibberellins (GA_3), Indole acetic acid (IAA), Cytokinin and Absisic acid (ABA) content in buds of Superior Seedless cv. grafted on Freedom rootstock are tabulated in Fig. 8. Generally, it is quite clear that the concentration of GA_3, IAA and Cytokinin proportional to the increase in the amount of applied water. Thus the maximum increased in hormone content was obtained by increasing irrigation levels 1.0 ET to 1.2 ET, while decreasing irrigation levels gradually decreased of this parameter. However, lowering the irrigation level up to 0.8 ET to 0.6 ET resulted in a noticeable reduction of GA_3, IAA and cytokinin. In this respect, absisic acid (ABA) recorded the reverse trend. Low irrigation markedly raised the concentrations of ABA in buds of Superior Seedless cv. grafted on Freedom rootstock under investigation. On the other hand, increasing the irrigation levels especially to 1.2 ET decreased concentration of ABA in buds followed by irrigation with 1.0 ET.

The obtained results are in line with the findings of Ndung *et al.* [9] and Shawkey *et al.* [23] who indicated that increasing water stress significantly reduced content of both IAA and GA_3 while a considerable increments in ABA concentration. From the foregoing results, one can conclude that there was a negative correlation between the content of IAA, GA_3 and cytokinin in buds and water stress levels. On the contrary, a positive correlation was existed between ABA content and water stress treatments.

The foregoing results obviously indicate that the increase in irrigation rates led to high hormone content is reflected on bud fertility, vegetative growth and the spread of the roots and thus can cause increased yield when compared to low rates of irrigation.

Overall, according to results in hand, grape growers are advised to follow irrigation program based on the available meteorological data. In addition, Superior Seedless cv. grafted on Freedom rootstock appeared to exhibit more susceptibility to increasing water application more than full ET (1.0 ET), whereas vines grown under 1.2 ET produced cluster with higher shattering and acidity percentage as well as lower berry adherence and total soluble content. Therefore, irrigation at 1.2 ET or 1.0 ET is nearly equal, so the latter could be beneficial to save water. Giving great attention avoidance by decreasing irrigation up to 0.6 ET as such rate reflects drastic effects on different growth, yield and fruit quality.

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