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Promoting Irrigation Water Utilization Efficiency in Superior Vineyards

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ABSTRACT

The effect of different laterals and emitters frequency on growth, leaf content of N, P, K, Mg, S, Zn, Fe and Mn, berry setting, yield as well as physical and chemical characteristics of superior grapes were investigated during 2009 and 2010 seasons. Eight years old superior grape vines grown at 1.75×2.75 m apart in sandy loam soil in Qena Governorate under drip irrigation system with 4 L h^{-1} emitters were used in this study. One or two laterals and two to six emitters per vine were used. Results revealed that leaf area, main shoot length, leaf content of N, P, K, Mn, S, Zn, Fe and Mn, berry setting, yield, cluster weight as well as physical and chemical characteristics of the grapes markedly improved with increasing number of laterals from one to two and number of emitters from two to six. Increasing emitters' frequency from four to six on double laterals gave significant effect on the above mentioned characters. The best recommended treatment for increasing irrigation water utilization efficiency in Superior vineyards as well as improving yield quantitatively and qualitatively is double laterals and six emitters/ vine.

Key words: Promoting, water use efficiency, superior vineyards, double laterals, emitters

INTRODUCTION

Water management is a critical aspect of successful grape production in Egypt (Beaumont, 1993; Hassan *et al*., 1999). In new vineyards of reclaimed areas in Egypt and especially where irrigation water is scarce, trickle irrigation is increasingly being introduced. Water applied via trickle irrigation at the proper time and quantity can influence grape yields and fruit quality (El-Hady and Abd El-Kader, 2003). In addition, water can be a scarce resource in many areas and its efficient use must be a high priority (De Oliveira *et al*., 2009).

Thus, methods for scheduling irrigation are an important aspect of good vineyard management (De la Hera *et al*., 2007). One of the main advantages of drip irrigation is the opportunity to obtain high system uniformity. In general, drip irrigation systems often achieve over 90 % uniformity with proper design, installation and maintenance. This is in contrast to typical uniformities of 40-60 for gravity systems and 50-75% for sprinkler systems (Caswel and Zilbernian, 1985). Moreover (Zhang *et al*., 2004) noted that under China conditions and maize crop field, the drip Irrigation systems was more efficient than sprinkler irrigation and sprinkler irrigation was more efficient than border/furrow irrigation.

Wetting patterns are primarily dictated by soil texture, soil tilth, structure including soil compaction and chemistry. In general, water from an emitter exhibit more laterals, horizontal movement in heavier clay soils with more vertical, downward movement in lighter sandy soils (Gal *et al*., 2004).

The use of closely spaced emitters is rapidly gaining popularity thus, the ability to achieve superior wetting patterns more quickly than with wider spaced emitters (Gal *et al.*, 2004). In this respect, the wetting patterns of emitters spaced at 12 and 8 inches, so, "wetted corridor of moisture" achieved down and across the bed after 30 h of irrigation with the 8 inches spacing. Therefore, "blackening of the beds" is highly desirable by many growers under modern irrigation systems, especially when setting transplants or germinating seeds, it was possible to increase soil water availability to enhanced vegetative growth.

In general, irrigation management should focus in the adoption of practices that enhance the efficient use of water so that other sectors can have more water for economic use (CAWMA, 2007).

Previous studies showed that saving irrigation water, increasing water utilization efficiency as well as controlling irrigation was accompanied with enhancing growth and fruiting of grapevines and other fruit crops. (REF) Using modern methods of irrigation is considered an important target for achieving the benefits of water. Caswel and Zilbernian (1985), Hepner *et al.* (1985), Araujo *et al.* (1995), McCarthy *et al.* (1997) and Gal *et al.* (2004).

Weather parameters, crop characteristics, management and environmental aspects are factors affecting evaporation and transpiration (Allen *et al.*, 1998). At the same time a better management of water in irrigated agriculture it is necessary to enhance crop production and preserve soil and water quality (CAWMA, 2007).

The increment of water use from February until July may be attributed to the development of shoots, leaf area and clusters, as well as to the increase of evaporative demand. In addition the optimum water use of grapevine was 20, 35 and 23 L/vine/day from pruning to fruit set, fruit set to veraison and veraison to fruit maturation, respectively (Araujo *et al.*, 1995). On other hand, Serman *et al.* (2004) observed that under different irrigation rates 100, 80, 70 and 60% of ETo, the amounts of water applied were 1060, 877, 763 and 649 mm year^{-1}, respectively. On 3 year old Superior vines with trickle irrigation. At the same time, Ferreyra *et al.* (2004) studied the response of Cabernet Sauvignon grapes to four irrigation treatments. The first at 100% of crop evapotranspiration (ETc) throughout the second at 40% ETc throughout the season but the third with no irrigation until veraison and 100% ETc applied throughout the rest of the season and the fourth treatment at 100% ETc from bud burst until veraison and no irrigation throughout the rest of the season. The amount of water use were 4447, 1769, 1711 and 2700 m^3 ha^{-1}. for treatments numbers 1,2,3 and 4, respectively. Furthermore, Seif *et al.* (2007) noted that water consumptive use were 936.50, 749.16, 561.88 and 374.60 mm season^{-1}. Whereas crop coefficient were 0.75, 0.61, 0.50 and 0.43 when vines were irrigated at 125, 100, 75 and 50% ETpan, respectively.

The objective of this study was therefore, to maximize water use efficiency through elucidating the effect of trickle irrigation system treatments on enhancing growth, yield and water utilization efficiency in Superior vineyard orchards under Qena conditions.

MATERIALS AND METHODS

Experimental site description: This investigation was carried out during 2009 and 2010 seasons on 75 vigor of uniforms eight year's old Superior grapevines in vineyard located at a private orchard in ELQenwia Qena Governorate. The selected vines were trained according to cane pruning system (66 eyes for each vine at 6 fruiting canes×9 eyes+6 renewal spurs×2 eyes) using shape supporting gable system. The vines were planted at 1.75×2.75 meters apart which gave (831 vines fed.$^{-1}$) Irrigation source was Nile water and its salinity was 0.36 (dS m^{-1}) pH = 7.4 where, the soil is saline and Loamy sand. Mechanical, Physical and chemical characters of the tested soil were determined according to Richards (1954).

The successful production of grapes depended on irrigation management and irrigation water utilization efficiency (Kang and Zhang, 2004; Loveys *et al.*, 2005; Stevens *et al.*, 2008). Until now there is no recommended water requirement and irrigation scheduling in the new reclaimed land under drip irrigation system. Therefore, a preliminary study was conducted during 2006 to 2008 seasons to calculate the average irrigation requirement for grape vines grown in this area. So this study was designed to determine the best system of increasing water efficiency under drip irrigation system in the grape vine. The ability to estimate crop water use is important in semiarid areas such as Qena region where the production of crops are dependent upon the availability of irrigation water. In the present study it was favorably that to implement this work should be definite amount of water use through the average of the three previous study years from 2006 to 2008.

Crop water requirements: Applied water per vine and per feddan was calculated from ETo avg, according to equation of Doorenbos and Pruitt (1984) as:

$$Etc = \frac{ETo \times Kc \times GC\% \times Plant\ area}{Ea - pe}$$

Where:

ETc = Applied irrigation water (liter/tree/day)

ETo = Potential evapotranspiration (mm/day)

Kc = Crop coefficient from FAO56. and AgriMet Crop Coefficients (http://www.usbr.gov/pn/agrimet/cropcurves/WGRPcc.html) The crop coefficient is dependent upon stage of crop growth, canopy height, cover and architecture (Allen *et al.*, 1998)

GC = Canopy cover represented by the shadow area average which ranged between 0.32 in Feb. to 0.70 from May till Sept

Canopy size measured by the amount of shade cast on the ground beneath grapevines growing areas (Walker and Stevens, 2004):

Plant area = 2.75×1.75. Ea = Irrigation system efficiency (%) = 85 % for drip irrigation

Pe = Effective rainfall (mm) = 0.30 rainfall

Leaching requirement (LR) = 0.36/2×12 = 0.015

The crop coefficient (Kc) values were 0.15 (Feb.), 0.45, 0.75, 0.45 and 0.35 in April, July and Oct. Nov., respectively under Qena conditions eight year old Superior grapevines and gable system supporting the results indicated that total applied water during the growing period was 10428.3 L/vine/year, while in unit of m it was 10.5 m^3/vine per year. When using unit of area as Feddan (4200 m^2) the one feddan contains 831 vine and crop water requirements was 8665.7 m^3 fed^{-1}.

Experimental treatments and design: Irrigation was done by drip system. All the selected vines received the usual horticultural practices that normally applies in vineyards except those dealing with irrigation.

The present experiment included the following five treatments:

T_1: One lateral and two emitters/vine
T_2: One lateral and three emitters/vine
T_3: Double laterals and two emitters/vine
T_4: Double laterals and four emitters/vine
T_5: Double laterals and six emitters/vine

Each treatment was replaced three times, five vines per each. All the selected vines received the same irrigation water amount namely 10. 5 m^3/vine/year. The distance between laterals and vines were 2.75 and 1.75 meters, respectively. Emitters discharge was four L h^{-1}. Operating times (hrs) in the present five treatments are shown in Table 1.

Emitter discharge was 4 L h^{-1}. Irrigation water amount was 9.4 m^3/year/vine for all treatments. Complete randomized block design was adopted for statistical analysis of the present results. Main shoot length (cm.) was measured at the middle of May in the two of the eight main shoots in all directions of the vines.

Leaf area (cm^2) was estimated in twenty leaves per vine from those leaves opposite to the first clusters on each shoot (middle of May) and leaf area (cm^2) was recorded according to the following equations reported by Ahmed and Morsy (1999):

$$\text{Leaf area (cm}^2\text{)} = 0.45\ (0.79\times W^2) + 17.77$$

Where, W is the maximum diameter (cm^2).

Petioles of these leaves were saved, oven dried and grounded then 0.5 g weight of each sample was digested using H_2SO_4 and H_2O until clear solution was obtained. The digested solution was quantitatively transferred to 100 mL volumetric flask and completed to 100 mL by distilled water. Therefore, leaf content of N, P, K, Mg and S (as percentages) and Zn, Fe and Mn (as ppm) in the samples were determined according to the methods that outlined in Wilde *et al.* (1985).

Berry set % was calculated by dividing the number of attached berries in the caged clusters by the total number of flowers/ cluster and multiplying the product by 100.

Harvesting was conducted (middle June) when TSS/acid reached at least 24-26 (Weaver, 1976). The yield per vine was recorded in terms of weight (kg) and the number of clusters per vine. Five clusters were taken at random from the yield of each vine for the determination of cluster weight (g) as well as the following physical and chemical characteristics of the grapes.

Table 1: Operating times (h) in the five trickle irrigation system during the period 2009 and 2010

	Month										
Treatment	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
T_1	0.0	0.29	1.38	3.44	6.21	8.10	7.05	6.41	4.52	2.84	1.40
T_2	0.0	0.19	0.90	2.29	4.14	5.40	4.70	4.27	3.00	1.89	0.93
T_3	0.0	0.29	1.38	3.44	6.21	8.10	7.05	6.41	4.52	2.84	1.40
T_4	0.0	0.14	0.70	1.72	3.12	4.05	3.53	3.20	2.26	1.42	0.70
T_5	0.0	0.10	0.46	1.15	2.10	2.70	2.35	2.14	1.50	0.95	0.47

- Percentage of shot berries by dividing number of small berries by total number of berries per cluster and multiplying the product×100
- Percentage of total soluble solids in the juice
- Percentage of total acidity (expressed as g. of tartaric acid/100 mL of juice) by titration against 0.1 N NaOH using phenolphthalein as indicator (AOAC, 1995)
- Total soluble solids/acid
- Percentage of total sugars in the juice (AOAC, 1995)

Water utilization efficiency (WUE) yield kg m^{-3} water was estimated by dividing total yield per vine by applied water (m^3/vine/year).

Statistical analysis: All the obtained data were tabulated and subjected to the proper statistical analysis according to Mead *et al*. (1993) using new LSD test at 5% for comparing between means of all treatments.

RESULTS AND DISCUSSION

Meteorological data: Qena Governorate located in South Egypt (Longitude 32.44, latitude 26.11 and 74.2 meter above sea level). Meteorological data were collected for a period of three years (2006-2008) of the studied area in order to detect the effect of different laterals and emitters frequencies on growth "or yield", leaf contents of representative macro and micro nutrients, berry setting % and phonological characteristics of Superior vineyards'. The soil of the studied area has loamy texture, some other physicochemical properties of studied area are given in Table 2 and 3.

Table 4 shows the average three years of climatic data from 2006 to 2008 belonged to Qena area which collected from the meteorological station of South Valley Uni., reference evapotranspiration (ETO).

Data in Table 5 indicated that in Qena region the Mean of three years ETo (mm $month^{-1}$) registered highest ETo of 636 mm in June, but the lowest in December, 186 mm, while the total mean for the three years (2006 to 2008) recorded 4969.4 mm $year^{-1}$. In the 2009 and 2010 seasons this average for the three years of ETo was used as a basis for water use during the

Table 2: Some initial physical properties of the studied soil

	Particle size distribution					Soil moisture content (g g^{-1})		
Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	Bulk density g cm^{-3}	FC	WP	AW
0-30	76.8	19.61	3.6	Loamy sand	1.65	0.15	0.06	0.09
30-60	44.8	51.55	3.6	Silt loam	1.65	0.24	0.08	0.16
60-90	60.7	34.50	4.8	Sandy loam	1.71	0.20	0.07	0.12

Table 3: Some initial chemical properties of the studied soil

							Available macro nutrients (ppm)		
Layer depth (cm)	pH (1:2.5)	EC (dS m^{-1})	$CaCO_3$ (%)	OM (%)	CEC (meq/100 g soil)	ESP (%)	N	P	K
0-30	7.4	2.3	4.9	0.92	16.7	9.3	30	8	47
30-60	7.6	2.6	4.7	0.65	11.9	9.7	39	5	42
60-90	7.9	1.9	3.6	0.35	11.1	5.8	22	4	28

Table 4: Meteorological data of Qena region average of three years (2006 to 2008)

Parameters	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Average
Max. Temperature (°C)	23.1	24.9	31.3	35.2	39.3	42.2	42.1	42.1	40.2	35.4	29.4	26.7	34.3
Min. Temperature (°C)	7.4	8.9	14.6	17.8	22.5	24.7	26.5	26.1	23.4	19.9	14.0	8.7	17.9
Relative humidity (%)	49.0	41.0	35.0	26.0	23.0	25.0	28.0	28.0	30.0	38.0	46.0	51.0	35.0
Wind speed (m sec^{-1})	4.5	5.2	6.0	6.1	6.7	6.7	6.7	7.3	6.7	5.7	4.6	4.8	5.9
Sunshine hours (h)	10.6	11.3	12.0	12.7	13.4	13.8	13.6	13	12.3	11.6	10.8	10.5	12.1
Total Rain (mm)	0.2	0.6	0.1	0.2	0.3	0.0	0.0	0.0	0.0	0.4	1.1	0.6	0.3
Rad (MJ m^2 day^{-1})	17.7	21	24.9	28.1	30	30.7	30.3	28.7	25.9	22.1	18.4	16.8	24.6
Evapotranspiration (mm day^{-1})	6.2	8.3	12	16.2	19.1	21.2	18.2	18.3	16.4	12.6	8.0	6.0	13.59

Table 5: Average evapotranspiration ETo for Qena region during 2006 to 2008 seasons

	Reference evapotranspiration ETo (mm/month)												
Year	Jan.	Feb.	March	April	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
2006	191.4	230.5	371.4	484.5	592.0	635.8	582.7	567.6	491.8	390.8	239.5	185.9	4963.9
2007	192.2	234.7	374.6	488.5	593.1	636.5	582.6	567.1	492.0	391.5	241.0	187.3	4981.1
2008	193.1	232.1	373.0	485.0	591.2	635.7	582.5	567.2	492.2	389.5	239.5	184.8	4965.8
Average	192.2	232.4	372.0	486.0	592.1	636.0	582.8	567.3	492.0	390.6	240.0	186.0	4969.4

two seasons. The data (Table 6) represented the average water consumptive recorded 10.5 m^3/year/vine under Qena conditions in 2009 and 2010 seasons, the mean of evapotranspiration of the three years prior to this study were used. Data in Table 3 showed that the highest value of evapotranspiration in June was 21.2 mm day^{-1} which resulted in water consumptive of 64.8 L/day/vine, the lowest values of evapotranspiration were recorded in Jan, and Dec (6.2 and 6.0 mm day^{-1}, respectively) without irrigation. Meanwhile, water consumptive recorded 11.1, 27.48, 49.7, 56.42, 51.24, 36.1, 22.7 and 11.2 L day^{-1} in Mar., Apr., May, Jul., Aug., Sep., Oct. and Nov., respectively. As a result, Grapevine water use and Kc started from Feb. to Nov. This findings were in agreement with that of http://www.usbr.gov/pn/agrimet/cropcurves/WGRPcc.html and Seif *et al*. (2007) who noted that the amount of irrigation water of 5, 11, 19, 33, 37, 34, 30, 26, 18 and 13 L/day/vine can be applied during February up to November, respectively. So the previous results were in agreed with Serman *et al*. (2004), Ferreyra *et al*. (2004) and Teixeira *et al*. (2007).

In general, under arid climates evapotranspiration is above 200 mm year$^-$1, so the total amount of water required for irrigation varies from climate to climate (De Oliveira *et al*., 2009). furthermore, crop growth and second yield are not possible without irrigation after the final grape product (Martin and Gilley, 1993; Williams and Matthews, 1990). Meanwhile Saayman and Lambrechts (1995) observed that WUE can be improved by drip irrigation system which was more effective than sprinkler irrigation. Moreover, saving of WUE of about 25% may be due to a reduced wetted soil volume under sandy soil. The optimum response was obtained when irrigation of about 90 mm at veraison in Barlinka grapes. Also Caswel and Zilbernian (1985), Zhang *et al*. (2004) and De la Hera *et al*. (2007) noted that drip irrigation systems often achieve over 90% uniformity with proper design, installation and maintenance. This is in contrast to typical uniformities of 40-60 for gravity systems and 50-75% for sprinkler systems. In this respect Teixeira *et al*. (2007) they revealed that the accumulated actual Evapotranspiration (ET) from pruning to harvest in wine grape was 438 and 517 mm for the first and second Growing cycles, respectively. In addition, table grape consumed less water than wine grape (393 and 352 mm) for the first and second growing seasons, respectively. This result was due to the shorter crop stages. On the other hand, these

Table 6: Average vineyard evapotranspiration ETo and water use for Qena region from 2006 to 2008

Months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
ETo (mm/day) average of 3 years	192.2	232.4	372	486.0	592.1	636.0	582.8	567.3	492.3	390.6	240.0	186.0
Crop coefficient Kc (FAO)	0.0	0.15	0.25	0.45	0.65	0.75	0.75	0.7	0.55	0.45	0.35	0.0
Ground covers Redu. Fact. of	0.0	0.32	0.65	0.66	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0
ETc loc mm/month	0.0	11.15	60.45	144.3	269.4	333.9	305.97	277.97	189.53	123.04	58.8	0.0
Eu application emission uniformity	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17	1.17
IRg mm/month gross irrigation	0.0	13.04	70.7	168.8	315.2	397.7	358.0	325.2	221.8	144.0	68.8	0.0
IRg 1 L/vine/month	0.0	62.76	340.2	812.3	1517.0	1914.0	1723.0	1565.0	1067.4	693.0	331.1	0.0
LR (0.015)	0.0	63.61	345.3	824.5	1540.0	1943.0	1749.0	1588.5	1083.4	703.4	336.1	0.0
IRg 3 L/vine/day	0.0	2.3	11.1	27.48	49.7	64.8	56.42	51.24	36.1	22.7	11.2	0.0
	L/vine/year					m^3/year/vine					m^3/year/feddan	
Total applied water	10428.3					10.5					8665.7	

results were not in agreement with those obtained by Cuevas *et al.* (2007) which observed that flowering was advancement under low water irrigation. This result may be due to modifications in the plant hormonal balance due to root signal which eventually led to earlier flower induction.

According to these results, using drip irrigation system were studied using amount of water of 8665.7 m^3 $year^{-1}$ on eight year's old Superior grapevines grown at 1.75×2.75 m apart in sandy loam soil under Qena conditions. The number of laterals and emitters per vine ranged from one to two and from two to six/vine, respectively. The merit was enhancing irrigation water utilization efficiency in Superior vineyards.

Leaf area and its content from N, P, K, Mg, S, Zn, Fe and Mn in the leaves: Data in Table 7 clearly show that leaf area significant differs with respect to number of laterals and emitters per vine and its content of N, P, K, Mg, S, Zn, Fe and Mn. Increasing frequencies of laterals from one to two and at the same time number of emitters from two to four significantly affect the leaf area. In this respect, the highest value was observed in (T_5) using irrigation treatment, double laterals and six emitters/vine with 87.0 and 79.5 cm^2 in the first and second seasons, respectively. At the same time (T_4) of Double laterals and four emitters/vine were less effective but not significantly different from (T_5) during the successive seasons. Meanwhile the lowest values in leaf area were obtained in (T_1) with One lateral and two emitters/vine which recorded 71.1 and 72.2 cm^2 in the first and second seasons, respectively. However, T3 recorded the intermediate value of 74.5 and 77.5 cm^2 under drip irrigation with Double laterals and two emitters/vine it recorded during the first and second seasons, respectively.

From the above mentioned results it could be concluded that the optimum release of water under wetted area that saved their surely reflected on supplying the vines with their requirements from water and nutrients at different stages of growth and grape development and these explain the present effects of increasing number of laterals and emitters for each vine (Caswel and Zilbernian, 1985). These results are in agreement with those obtained by Hepner *et al.* (1985), McCarthy *et al.* (1997), Zhang *et al.* (2004), El-Hady and Abd El-Kader (2003), De la Hera *et al.* (2007), Teixeira *et al.* (2007), Stevens *et al.* (2008) and De Oliveira *et al.* (2009).

Also the data in Table 7 shows considerable differences in main shoot length as well as leaf content of N, P, K, Mg, S, Zn, Fe and Mn. Considering the number of laterals and emitters per vine. The results reveal that main shoot length gradually increased by increasing the laterals and

Table 7: Influence of laterals and emitters frequency on the leaf area, main shoot length and mineral content of Superior grapevines during 2009 and 2010 seasons

	Leaf area (cm^2)		length (cm.)		N (%)		P (%)		K (%)	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
T_1: One lateral and two emitters/vine	71.1	72.2	96.0	98.0	1.92	1.94	0.16	0.18	1.81	1.89
T_2: One lateral and three emitters/vine	73.3	75.0	99.5	101.1	1.99	2.01	0.18	0.21	1.91	1.96
T_3: Double laterals and two emitters/vine	74.5	77.5	103.3	104.0	2.10	2.09	0.21	0.25	2.01	2.11
T_4: Double laterals and four emitters/vine	77.8	79.3	107.1	108.0	2.16	2.17	0.24	0.28	2.12	2.22
T_5: Double laterals and six emitters/vine	78.0	79.5	107.2	108.1	2.17	2.18	0.25	0.29	2.14	2.23
New LSD at 5%	1.1	1.2	1.7	1.9	0.06	0.05	0.02	0.02	0.07	0.06
	Mg (%)		S (%)		Zn (ppm)		Fe (ppm)		Mn(ppm)	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
T_1: One lateral and two emitters/vine	0.30	0.33	0.41	0.42	51.0	52.0	29.2	30.0	29.0	30.0
T_2: One lateral and three emitters/vine	0.39	0.41	0.45	0.46	55.0	57.0	33.0	34.0	35.0	33.0
T_3: Double laterals and two emitters/vine	0.42	0.44	0.50	0.50	60.0	61.9	36.0	38.0	40.0	39.9
T_4: Double laterals and four emitters/vine	0.44	0.48	0.55	0.56	66.0	66.6	40.0	41.5	45.0	46.3
T_5: Double laterals and six emitters/vine	0.45	0.49	0.56	0.57	67.5	68.0	41.0	42.0	46.0	47.0
New LSD at 5%	0.02	0.02	0.02	0.02	2.2	2.3	2.4	2.5	2.5	2.5

emitters per vine. Therefore, the best result was observed when Superior vineyards irrigated by using Double laterals and six emitters/vine (T_5) the values are 107.2 and 108.1 cm during the first and second seasons respectively. Under these conditions main shoot length was less than (T_5) and no significant under drip irrigation by using (T_4) Double laterals and four emitters/vine. Meanwhile the lowest value of main shoot length was observed with (T_1) were 69.0 and 98.0 (cm) as well as (T_2) which gives 99.5 and 101.1 (cm) in the first and second seasons. Intermediate main shoot length 103.3 and 104 (cm) was recorded in the Double laterals and two emitters/ vine (T_3) during both seasons.

The leaf content of N, P, K, Mg, S, Zn, Fe and Mn. Table 7 Gave the same trend as in the leaf area and main shoot length. Thus, the use of double laterals with two emitters significantly enhance these parameters when compared to the application of one lateral with two emitter. Increasing the number of emitters from four to six on double laterals did not show significant effect on growth characters and the nutrients. The least values were recorded on the vines that received water as one lateral with two emitters/vine (T_1). It gives the lowest macro nutrients (N%, P% and K%) in leaf (1.92 and 1.94% N), (0.16 and 0.18% P) and (1.81 and 1.89% K) during the first and second seasons, respectively, was also observed under this treatment. However, using double laterals and six emitters/vine(T_6) gave the highest values of leaf mineral content which were 2.17 and 2.18% N, 0.25 and 0.29% P) and (2.14 and 2.23% K), for the two seasons, respectively. On the other hand, the immediate values were recorded in the same trend was also observed in the (Mg, S, Zn, Fe and Mn).

The differences between treatments may be attributed to increasing the number of laterals and emitters per vine which increased the wetted area, that helps on supplying the vines with their requirements from water and different nutrients elements by rooting system consequently, increased macro and micro elements and plant hormone accumulation during growth and grape development (Caswel and Zilbernian, 1985).

Table 8: Influence of laterals and emitters' frequency on berry setting, yield, cluster weight, shoot berries as well as some physical and chemical characteristics of berries of Superior grapevines during 2009 and 2010 seasons

	Berry setting (%)		No. of clusters/vine		Yield/vine (kg)		Cluster weight (g)		Shoot berries (%)	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
T_1: One lateral and two emitters/vine	11.0	11.5	22.0	21.0	6.9	6.9	313.6	328.6	8.1	8.3
T_2: One lateral and three emitters/vine	12.1	12.8	22.0	23.0	7.8	8.0	354.5	347.8	6.1	6.0
T_3: Double laterals and two emitters/vine	13.9	14.1	22.0	24.0	8.9	9.1	404.5	397.2	5.0	4.9
T_4: Double laterals and four emitters/vine	14.2	15.3	23.0	24.0	10.0	10.5	434.8	437.5	3.9	3.7
T_5: Double laterals and six emitters/vine	14.3	15.5	23.0	24.0	10.6	10.6	460.9	441.7	3.9	3.5
New LSD at 5%	1.0	1.0	NS	1.0	0.7	0.9	30.1	31.0	0.9	0.8
	Berry weight (g)		TSS (%)		Total acidity (%)		TSS/acid		Total sugars (%)	
Treatments	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
T_1: One lateral and two emitters/vine	2.81	2.82	18.0	18.0	0.711	0.712	25.3	25.3	16.0	16.1
T_2: One lateral and three emitters/vine	2.95	2.96	18.5	18.7	0.681	0.671	27.2	27.9	16.8	16.9
T_3: Double laterals and two emitters/vine	3.05	3.10	19.0	19.5	0.651	0.641	29.2	30.4	17.3	17.5
T_4: Double laterals and four emitters/vine	3.15	3.25	19.7	20.9	0.628	0.600	31.4	34.8	17.8	18.2
T_5: Double laterals and six emitters/vine	3.16	3.27	19.0	20.0	0.661	0.631	28.7	31.7	16.5	17.1
New LSD at 5%	0.09	0.08	0.5	0.5	0.021	0.022	1.9	2.0	0.4	0.4

The present results agree with those of (Peacock *et al.*, 1977; Hepner *et al.*, 1985; McCarthy *et al.*, 1997; Teixeira *et al.*, 2007; Stevens *et al.*, 2008).

Berry setting: The percentage berry settings is presented in Table 8. which showed that there was a gradual and significant increase in berry setting (%) of Superior grapevines with increase in number of laterals from one to two as well as increase in the frequency of emitters per vine from two to six. Berry setting (%) was significantly maximized with the use of two emitters per vine on double laterals as compared with using the same number of emitters with one lateral. The results varied significantly (LEVEL OF PROBABILITY) among treatments except the last two (Table 8) (four or six emitters situated on double laterals). In this study, the maximum values were recorded on vines that were irrigated drip using double laterals with six emitters (T_5) conversely, using one lateral and two emitters/vine (T_1) gave the lowest values of 11.0% and 11.5%) berry setting during the first and second seasons respectively, while the treatment T_3 gave intermediate berry setting of Superior grapevines under Double laterals and two emitters/vine (13.9 and 14.1).

The beneficial effect of adjusting drip irrigation (selecting two laterals and four to six emitters/vine) on berry setting might be attributed to its positive effect on stimulating growth and vine nutritional status in favour of producing more berry on each cluster. Similar results were recorded by Hepner *et al.* (1985), Martin and Gilley (1993), Williams and Matthews (1990) and Stevens *et al.* (2008).

Number of clusters/vine: Response of the number of clusters/vine to the number of laterals and emitters per vine ranged from one to two and from two to six/vine, respectively. In Table 8 no significant differences on number of cluster/vine were observed among the five drip irrigation treatments during the first seasons. However, the two treatments (T_4) and (T_5) (four or six emitters situated on double laterals) recorded the highest values in this respect (23 and 23) clusters/vine in the first seasons. While the same comparison in the second season the significant clearly showed between laterals. The positive effective response was recorded in (T_5), (T_4) and (T_3) they recorded (24 cluster/vine) per each treatments. On the other hand the lowest response was observed on in (T_1) One lateral and two emitters/vine (21 cluster/vine). It would appear that the positive effect of increasing laterals and emitters per vine was more effective in increasing the supplying vines with their requirements from water and different nutrients elements observation lead to increased macro and micro elements and plant hormone accumulation during growth and grape development (Caswel and Zilbernian, 1985).

These results corroborated the findings of Hepner *et al.* (1985), Martin and Gilley (1993), Williams and Matthews (1990) and Stevens *et al.* (2008).

Yield and cluster weight: Varying the number of laterals and emitters per vine in drip irrigation system had significant effect on yield as expressed in yield/vine and cluster weight (Table 8). Increasing the number of laterals (from one to two) and emitters per vine (from two to six) had a significant and gradual increase on yield and cluster weight. Thus, the best results were observed in (T_5) with double laterals and six emitters (10.6 kg vine^{-1}) in both seasons. This was followed but (not significantly different) by (T_4) with double laterals with four emitters (10.0 and 10.5 kg vine^{-1}) during the first and second seasons, respectively. In this respect, the intermediate effect on yield and significant differences were noticed with (T_3) double laterals with two emitters per vine (8.9 and 9.1 kg vine^{-1}) during the first and second seasons, respectively. So, using double laterals/vine was preferable than using one lateral which recorded (6.9 and 6.9 kg vine^{-1}) and (7.8 and 8.0 kg vine^{-1}) under two and three emitters per vine during the first and second seasons, respectively. Increasing the number of emitters per vine from four to six on double laterals did not give appreciable increase in yield and cluster weight.

Cluster weight (g) in Table 8 presented that the application of double laterals with four emitters/vine (T_4) reached (434.8 and 437.5 g cluster^{-1}) during the two studied seasons, respectively. However, the best results was noticed in (T_5) double laterals with six emitters reached (460.9 and 441.7 g cluster^{-1}). In this respect, vines subjected to drip irrigation through one lateral and two emitters/vine (T_1) gave significantly minimum cluster weight (g) of 313.6 and 328.6 during the two studied seasons, respectively intermediate values of 404.5 and 397.2 were recorded in T_3 while T_2 and three emitters/vine gave the highest values of 354.5 and 347.8 and significantly cluster weight (g) was noticed in (T_3) Double laterals and two emitters/vine ()followed by (T_2) One lateral and three emitters/vine (354.5 and 347.8) during the first and second seasons, respectively.

These results can be attributed to the positive action of adjusting drip irrigation system on berry setting, cluster weight and cluster number previously mentioned. This is supported by many earlier research findings Peacock *et al.* (1977), Hepner *et al.* (1985), Martin and Gilley (1993), Williams and Matthews (1990), Teixeira *et al.* (2007), Donaire *et al.* (1977), Stevens *et al.* (2008) and McCarthy *et al.* (1997). Also Glenn (2000) reported that when only a portion of the root zone is wetted, the water absorption by the wetted roots increases relative to the amount absorbed by the portion when the whole root systems is wetted thereby increasing the efficiency of water uptake. Conversely, these results are not in agreement with those obtained by Cuevas *et al.* (2007) which stated that flowering was advanced under low water irrigation. The result may be due to modifications in the plant.

Percent shoot berries: Percentage shoot berries gradually reduced with increasing laterals and emitters frequency. Using double laterals with six emitters per vine (T_5) gave the lowest values in Shoot berries (3.9 and 3.5) while there was no significant reduction in %shoot berries when the number of emitters per vine increased from four (T_4) to six (T_5) on Table 8. These results were consistent in both seasons. In this respect, the highest values in shoot berries were recorded in one lateral and two emitters/vine (T_1) with 8.1 and 8.3 during the first and second studied seasons, respectively. The enhancement in %shoot berries had a moderate but non-significant reduction in (T_3) with double laterals and two emitters/vine. This was followed by (T_2) (one lateral and three emitters/vine) during the two seasons.

The benefit of selecting the best system of drip irrigation on the availability of water to all plant organs at specific stage of berries development surely reflected on the reduction of shoot berries phenomenon. The findings of Weaver (1976), Williams and Matthews (1990), McCarthy *et al.* (1997), Glenn (2000) and Stevens *et al.* (2008) supported these results.

Physical and chemical characteristics of the berries: It is clear from the data in Table 8 that carrying out drip irrigation by increasing number of laterals from one to two as well as number of emitters from two to six per vine was significantly accompanied by higher quality of berries in terms of increase in berry weight (g). However, there was no significant response to influence of emitters frequency on the berry weight on (T_5) and (T_4) in descending order they recorded (3.16 and 3.26) and (3.15 and 3.25 g) in both treatments during the first and second seasons, respectively. In contrast statistical significant response was found in single lateral (T_1 and T_2) in ascending order which recorded (2.81 and 2.82 g) and (2.95 and 2.96 g) in both treatments during the tow studied seasons, respectively. On the other hand, a moderate effect was noticed in (T_3) which registered (3.05 and 3/1 g) during the two studied seasons.

A look at total soluble solids, TSS/acid, total sugars and decreasing total acidity shows a slight insignificant promotion of both physical and chemical characteristics of the grapes with increasing number of emitters from four to six at double laterals. Thus, the carrying out of drip irrigation by using (T_4) double laterals and four emitters per vine was the best treatments for total soluble solids. Furthermore, intermediate values in total soluble solids was recorded in (T_5) and (T_3) with (19.0 and 20.0) and (19.7 and 20.0) during the first and second seasons, respectively. In all the treatments, (T_2) and (T_1) recorded the lowest values in descending order both for 2009 and 2010 seasons.

The TSS/acid, total sugars and decreasing total acidity data are presented in Table 7. The best results of the TSS/acid and total sugars and decreasing total acidity, in Superior grapevines obtained by using drip irrigation with four emitters per vine on double laterals (T_4) comparing with using any other treatments. At the same time, the total acidity was higher under (T_1) followed by (T_2) in descending order. Medium effects on total acidity were observed in (T_3) and (T_5) in ascending order. Similar trend was also observed in TSS/acid. On the other hand, total sugars recorded the average effects using (T_3) and (T_5) in descending order. In this regard, the lowest value was obtained in T_1 followed by T_2 in decreasing order. The results may be due to the beneficial effect of adjusting the method of drip irrigation by enhancing the availability of water especially during critical levels of plant development thereby enhancing the biosynthesis of carbohydrates and encouraging cell division (Winkler *et al.*, 1974).

The results were in agreement with those by Weaver (1976), Williams and Matthews (1990), McCarthy *et al.* (1997), Glenn (2000) and Stevens *et al.* (2008).

Table 9: Effects of laterals and emitters' frequency on water utilization efficiency (WUE) in Superior vineyards during 2009 and 2010 growing seasons

Treatments	2009 Yield/vine (kg)	2009 Applied water (m^3/vine/year)	2009 Yield (kg m^{-3})	2010 Yield/vine (kg)	2010 Applied water (m^3/vine/year)	2010 Yield (kg m^{-3})
T_1: One lateral and two emitters/vine	6.9	10. 5	0.66	6.9	10. 5	0.66
T_2: One lateral and three emitters/vine	7.8	10. 5	0.74	8.0	10. 5	0.76
T_3: Double laterals and two emitters/vine	8.9	10. 5	0.85	9.1	10. 5	0.87
T_4: Double laterals and four emitters/vine	10.0	10. 5	0.95	10.5	10. 5	1.00
T_5: Double laterals and six emitters/vine	10.6	10. 5	1.01	10.6	10. 5	1.01

Water utilization efficiency (WUE) on yield (kg m^{-3}) water: Table 9 shows that WUE significantly increased with the increase of laterals from one to two and emitters from two to six per vine. Using (T_2) which is one lateral with three emitters/vine significantly improved WUE over using (T_1), one lateral with two emitters per vine. No significant promotion on WUE was observed when number of emitters was increased from four to six or double laterals. Therefore, the application of two laterals with six emitters/vine (T_5) gave optimum results where WUE reached 1.01 kg yield m^{-3}. The lowest WUE was observed by using (T_1) one lateral with two emitters which registered only 0.66 kg yield m^{-3}. Similar results were observed in the two seasons.

The great promotion on the yield and the same time for the reduction of water consumption obtained by (T_5) followed by (T_4) they leading to the enhance of WUE.

Similar results were reported by Araujo *et al.* (1995), McCarthy *et al.* (1997), El-Hady and Abd El-Kader (2003), Gal *et al.* (2004), De la Hera *et al.* (2007) and Stevens *et al.* (2008). In this respect Teixeira *et al.* (2007) observed that the accumulated actual evapotranspiration (ET) from pruning to harvest in wine grape was 438 and 517 mm for the first and second growing cycles, respectively. In addition, table grape consumed less water than wine grape with 393 and 352 mm for the first and second growing seasons, respectively. These results were however not in agreement with that obtained by Cuevas *et al.* (2007) which observed that flowering was advanced under low water irrigation. This result may be due to the modifications in the plant hormonal balance due to root signal which eventually led to earlier flower induction.

In conclusion, for the promotion of irrigation water utilization efficiency in Superior vineyards and at the same time improve yield quantitatively and qualitatively, it is suggested to use drip irrigation of double laterals and four or six emitters/vine.

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