Egypt. J. Soil Sci. 43, No. 4, pp. 577–588 (2003)

Nutrients Uptake and Water and Fertilizers Use Efficiency by Vine Grapes Grown on a Newly Reclaimed Sandy Area as Affected by Uniformity of Emission

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TWO SUCCESSIVE years (2000 – 2001) completely randomized field experiment with four replications on five years old Thompson seedless vines (Vitis spp.) was conducted in a drip irrigated newly reclaimed sandy area at El-Saff desert, Giza Governorate. Field emission uniformity and absolute field emission uniformity were determined for the area under study to be 88.64% for Eu and 89.80 % for Eua. The irrigation system at the studied area could be considered as good.

Although the uniformity of irrigation at the area under study has exceeded 85%, great differences were estimated between the discharge of the drippers that adversely affected the uniformity of growth , nutrients uptake, yield and both water and fertilizers use efficiency by the vines. With this respect, differences among the annual amounts of irrigation water received by the vines and consequently fertilizers dissolved in it have reached 31.6% . Accordingly, significant variations were calculated to be 32.4 % for leaf area , 51.6 % for the dry weight of the leaves and 60.2 % for obtained yield.

Content of nutrients in the leaves of vines that received the maximum amounts of irrigation water were higher than those of vines that received the minimum amounts by 33.3, 63.3, 45.5, 32.1, 18.2 and 48.6% for N, P, K , Fe, Zn and Mn, respectively. Consequently, relative uptake of these nutrients took the same trend. Positive differences in this parameter were 102.0 , 143.5, 120.1, 99.8 , 78.7 and 124.4 for the aforementioned nutrients, respectively . Values of water and fertilizers use efficiency by the vines were also greatly affected by the uniformity of irrigation . Differences among them have reached 21.6%.

Improving the uniformity of emission of the trickle irrigation system to be more than 90 % will lead to uniform fertigation and at the same time will raise either the uptake of nutrients or the efficiency of using water and fertilizers by the vines.

Keywords: Trickle irrigation, Field emission uniformity, Sandy soils, Vine grapes, Water use efficiency, Nutrients uptake, Fertilizer use efficiency.

For any irrigation system; the uniformity and efficiency of using both water and fertilizers by the growing plants are of major importance. Ideally, the application of water throughout the system should be absolutely uniform. With trickle irrigation, each dripper should deliver exactly a predetermined amount of water (Vermeiren and Jobling, 1980). Actually, drip irrigation system is not completely uniform. The variation or non -uniformity of emitter discharge in such irrigation system is the result of number of factors. The most important of these factors are the hydraulic variation and emitter discharge variation, (Bucks *et al.*, 1982). The hydraulic variation along the lateral line and sub main manifold is a function of land slope, length and diameter of the pipe and emitter discharge relationships. Emitter discharge variation at a given operating pressure is caused by manufacturing variability, and emitter plugging either complete or partial (Abou Khaled, 1982 & 1991; Bralts & Kesner, 1983 and Bralts *et al.*, 1985).

In Egypt, most of the newly reclaimed areas are planted with fruit trees under drip irrigation. Due to the variation in the amounts of irrigation water received by the growing trees in the same sub unit, growth, nutrients uptake, fruit yield and consequently both water and fertilizers use efficiency by the trees varied also from one tree to another (Ibrahim,1993; El-Sonbaty & El-Hady, 1993; El-Hady *et al.*, 1994 and El-Hady , 2002).

The present work aims at studying the effect of emission uniformity on grape vines grown in a newly reclaimed sandy area. In this study, the actual amounts of water and consequently fertilizers received by the vines through drip irrigation system were estimated. Nutrients uptake, fruit yield and both water and fertilizers use efficiency by the vines were evaluated.

Material and Methods

Two consecutive years (2000 and 2001) completely randomized field experiment with four replications for each treatment (Steel and Torrie, 1980) was conducted as follows:

Location

At a private vine yard (10fed) El-Saff , Giza governorate.

Indicator plant

Five years old grape vines (*Vitis spp.*), verity Thompson variety seedless "Banaty."

Soil

A sandy calcareous slightly saline soil (90.3 % sand and 12.0% $CaCO_3$). The main analytical data of the soil (Dewis and Freitas, 1970) are: Presented in Table 1.

Irrigation system

Trickle irrigation. Distance between laterals is 2.5 m. Distance between drippers is 2.0 m. Drippers discharge is ≈4 l/hr. Number of drippers / feddan are 800, *i.e.* one dripper for each vine.

Irrigation water

Two sources were alternatively used, *i.e.* El-Saff canal water and water of a well dug inside the yard. Regarding their quality, both were classified as no problem waters (Ayers and Westcot, 1976) (Table 2). Water requirements for the crop determined after Doorenbos and Pruit (1977) and Vermeiren and Jobling (1980) are ≈5000 m^3 / fed divided into 1585 hr begining from 15th of February till 15th of November (Table 3).

TABLE 1. Analytical properties of El-Saff sandy calcareous soil .

1- Mechanical analysis

Sand		Silt 20 – 2 μ %	Clay ‹2 μ %	Soil texture
Course 2000 - 200 μ %	Fine 200-20 μ %			
67.5	22.8	5.0	4.7	Sandy

2- Chemical analysis

pH 1:2.5	EC dSm^{-1}	$CaCO_3$ %	OM %	CEC Cmole Kg^{-1}	Macro – nutrients (ppm)					
					Total			Available		
					N	P	K	N	P	K
7.4	2.1	11.95	0.06	4.84	415	738	1015	32	6	56

3- Hydrophysical analysis

Bulk density kg m^{-3}	Total porosity %	Water holding capacity* %	Field capacity* %	Wilting percentage*	Hydraulic conductivity m day^{-1}	Mean diameter of soil pores μ
1.63	38.5	22.8	7.11	1.22	7.3	16.7

*On dry weight basis.

TABLE 2. Analysis of irrigation water used

Source	pH	EC dSm^{-1}	Soluble cations (meq/l)				Soluble anions(meq/l)			
			Na^+	K^+	Mg^{++}	Ca^{++}	CO^-_3	HCO^-_3	Cl-	$SO^=_4$
Canal	6.24	0.28	1.91	0.18	2.40	9.0	--	2.2	0.4	10.39
Well	6.77	0.95	6.0	0.15	6.0	5.2	0.02	2.6	0.4	14.33

*Adj. SAR =1.6 for the canal water and 5.06 for the well water
** Fe = traces (‹ 3ppm).

TABLE 3. Water requirements for trickle irrigated vine grapes grown on a sandy soil at El-Saff , Giza governorate.

Month	F	M	A	M	J	J	A	S	O	N
No. of days	15	31	30	31	30	31	31	30	31	15
E Pan mm day-1	4.5	6.4	8.5	11.2	12.8	11.1	9.7	8.9	6.9	4.5
Kp	0.7	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.7
ET* mm day^{-1}	3.15	4.16	5.53	7.28	8.32	7.22	6.31	5.79	4.49	3.15
Kc	0.3	0.3	0.45	0.6	0.7	0.7	0.7	0.55	0.45	0.35
Kr										
Ks	1.15 (87%)									
Eu	1.11 (90%)									
Lr	10%									
IRg mm day^{-1}	1.33	1.75	3.49	6.13	8.18	7.09	6.20	4.47	2.83	1.55
IR g l /day/plant	6.63	8.76	17.45	30.67	40.88	35.46	30.99	22.33	14.17	7.74
IR g m^3 / season/ plant	0.09	0.27	0.52	0.95	1.23	1.10	0.96	0.67	0.43	0.12
	6.34 m^3 / season / vine ≈5000 m^3 / fed.									

*ET. = reference crop evapotranspiration, Kc = crop coefficient , Kr = reduction factor for the influence of ground cover, Ks = a coefficient for the water storage efficiency of the soil, Eu = application uniformity; Lr = leaching requirements; IRg = goss irrigation requirements.

**Initial leaves : late Feb – early March.

***Harvest: late half of July.

****ground cover : 30-35 % at mid season.

*****Cultivation: clean cultivated (weeds free).

Uniformity of emission

Irrigation uniformity was determined after Vermeirn and Jobling (1980). The lowest and the highest rate of discharge were 3.736 ± 0.05 and 4.917 ± 0.053 l/h, respectively with an average of 4.215 ± 0.311 l/h (Fig. 1). Calculated field emission uniformity (Eu) and absolute field emission uniformity (Eua) using Keller and Karmeli (1975) method were 88.84 % and 89.80 % , respectively.

Fertilization

1. Basal dose

Farmyard manure; superphosphate 15.5 % P_2O_5 , agricultural sulphur and potassium sulphate 48-52 % K_2O at the rates of 20 m^3 , 100 kg , 100 kg and 50 kg / fed, respectively during January.

2. Fertigation

Ammonium sulphate 20.5 % N at the rate of 300 kg / fed for the 1st season (2000) and 350 kg/ fed for the 2nd one (2001); phosphoric acid 50% P_2O_5 at the rate of 30 kg/ fed. and potassium sulphate 48-52 % K_2O at the rate of 100 kg/fed distributed along the growing season begining from 15th of February.

Location of laterals on sub- main

Location of distribution points on the lateral

		1/3 down	2/3 down	for end
Inlet end from the main →	4.917 ± 0.053	4.493± 0.068	4.333 ± 0.064	4.285 ± 0.048
1/3 down	4.598 ± 0.093	4.371 ± 0.036	4.248 ± 0.035	4.208± 0.036
2/3 down	4.396± 0.069	4.216 ± 0.033	4.167± 0.034	4.028 ± 0.055
for end	3.919 ± 0.05	3.815 ± 0.025	3.781 ± 0.038	3.736 ± 0.054

Fig. 1. Discharge from selected distribution points (l/hr) in the submain unit.

Field emission uniformity (Eu) = Minimum rate of discharge (l/hr) x100 /Average rate of discharge (l/hr)

Absolute field emission uniformity (Eua) =

1/2 [Average of lowest 1/4 of the field data emitter discharge (l/hr) /Average of all the field data emitter discharge (l/hr) +

Average of all the field data emitter discharge (l/hr) / Average of the highest 1/8 of the field data emitter discharge (l/hr)] x 100

3.Foliar

Micro nutrients were sprayed thrice as chelates at the rate of 100, 100 and 200 g/fed of respectively, Mn (EDTA) 13 % Mn, Zn (EDTA) 14 % Zn and Fe (EDTHA) 6% Fe just before flowering , after fruit setting and one month later, respectively.

Other agricultural practices

The normal ones for vines.

Choice of experimental units and treatments: Three sets of vines were chosen according to the amounts of irrigation water received by the vines, *i.e.* 3.736 ± 0.05, 4.215 ± 0.311 and 4.917 ± 0.053 l/hr for sets no. 1, 2 and 3 , respectively. These values correspond to the lowest, the average and the highest discharge of the emitters, in sequence. Each set consists of 24 vines divided into 4 replications. Accordingly, the annual amount of irrigation water received by each vine were 5.922 , 6.681 and 7.793 m^3 for the three sets of vines, respectively.

Studied parameters

a) Some growth parameters that include :
1) Leaf area. 2) Average dry weight of leaves
b) Content of N, P , K , Fe ,Zn and Mn in the leaves (Cottenie *et al* ., 1982) and relative uptake of such nutrients. Leaf area and dry weight as well as leaf analyses were estimated for 6 month old leaves randomly sampled from each vine.
c) Number of bunches / vine , average weight of bunch and obtained yield / vine.
d) Water use efficiency by vines expressed as kg of the fruit yield produced by each m^3 of irrigation water used (Hillel, 1971).
e) Fertilizers use efficiency by vines expressed as kg of the fruit yield produced by each unit of fertilizer nutrient used.

Experimental design and statistical analysis

The field experiment was designed in a completely randomized system . Results were statistically analyzed according to Snedecor and Cochran, (1980).

Results and Discussion

Although the basal doses of fertilizers are the same for all the vines of the studied area, variations in the amounts of irrigation water – and consequently dissolved fertilizers received by vines greatly affect the nutrients uptake yield and both water and fertilizers use efficiency by the vines.Table 4 presents the annual amounts of fertilizers received by vines through fertigation as affected by emission uniformity.

TABLE 4. Effect of irrigation uniformity on the amount of fertilizers received by the vines through fertigation.

Set No.	N (g/vine)		P2O5 (g/vine)	K2O (g/vine)
	2000	2001		
Set.1	68.111	72.377	16.613	55.375
Set.2	76.875	81.690	18.750	62.500
Set.3	89.636	95.250	21.865	72.875

A. Emission uniformity and the nutrients uptake by the vines

Content of macro – nutrients (N, P and K) and micro ones (Fe, Zn and Mn) in the leaves as affected by the uniformity of irrigation are presented in Table 5. Data show that the content of nutrients in the leaves of the vines of set 1 (that receive the minimum amounts of irrigation water) are lower than those of trees of set 2 (that receive the average amounts of irrigation water) by 12.4% for N, 26.8 % for P, 16.% for K; 12.4 % for Fe , 8.0 % for Zn and 24.4 %for Mn. On the other hand, the content of nutrients in the leaves of vines of set 3 (that receive maximum amounts of irrigation water) are higher than those which receive the average amounts of irrigation water (vines of set 2) by 17.6, 19.5, 21.8, 15.7, 8.8 and 12.3 % for the aforementioned nutrients, respectively.

TABLE 5. Effect of irrigation uniformity on the relative uptake of nutrients by vines.

Treatment	Average weight of leaf		Leaf area cm^2	Macro nutrients						Micronutrients					
				Content %			Relative uptake			Content ppm			Relative uptake		
	fresh weight (g)*	dry weight (g)**		N	P	K	N	P	K	Fe	Zn	Mn	Fe	Zn	Mn
Set1															
2000	3.74	1.27	175.6	0.77	0.31	1.11	0.978	0.394	1.410	510	68.2	25.5	647.7	86.6	32.4
2001	3.66	1.25	174.1	0.72	0.29	1.35	0.900	0.363	1.688	550	74.8	29.7	687.5	93.5	37.1
meam	3.70	1.26	174.9	0.75	0.30	1.23	0.939	0.379	1.549	530	71.5	27.6	667.6	90.1	34.8
Set2															
2000	4.44	1.43	205.2	0.81	0.42	1.43	1.158	0.601	2.045	590	76.4	34.0	843.7	109.2	48.6
2001	4.58	1.49	209.6	0.90	0.39	1.50	1.341	0.581	2.235	620	77.0	38.9	923.8	117.8	58.0
mean	4.51	1.46	207.4	0.85	0.41	1.47	1.250	0.591	2.140	605	77.7	36.5	883.8	113.5	53.3
Set 3															
2000	5.32	1.88	234.9	0.98	0.55	1.83	1.842	1.034	3.440	690	82.6	39.4	1297.2	155.3	74.1
2001	5.52	1.93	227.3	1.01	0.42	1.75	1.949	0.811	3.378	710	86.4	42.5	1370.3	166.8	82.0
mean	5.42	1.91	231.6	1.00	0.49	1.79	1.896	0.923	3.409	700	84.5	41.0	1333.8	161.0	78.1

* L.S.D. 0.05 = 0.39 and 0.31 for the growing seasons 2000 and 2001, respectively.

** L.S.D. 0.05 = 0.15 and 0.17 for the growing seasons 2000 and 2001, respectively.

Taking the leaf area and the average of the dry weight of leaves as growth parameters , data in Table 5 indicate that, amounts of water delivered to the vines markedly affect such parameters. The higher the amounts of irrigation water received by the vines are, the higher is the leaf area or the average dry weight of the leaf. Presented data show that the differences between the leaf area or the average dry weight of the leaves of vines of set 1 and those of set 3 reached 32.4 or 51.6 %.

According to the previous presentation of the data , relative uptake of nutrients are also shown in Table 5 . It is obvious that high quantities of irrigation water delivered to the vines coincide with high relative uptake of the nutrients under study. In other words, while the relative uptake of nutrients of set 1, was lower than those of set 2 by 24.9 % for N ; 35.9 % for P ; 27.6 for K; 24.5 % for Fe; 20.6 for Zn; and 34.7 % for Mn, the relative uptake of the nutrients by vines of set 3 that grown at the same sub – main unit was higher than those of vines of set 2 by 51.7 ; 56.9; 59.3; 50.9; 41.9 and 46.5 % for the aforementioned nutrients , in sequence.

B. Emission uniformity and yield of vines

Data of the fruit yield of vine grapes as affected by the uniformity of emission are presented in Table 6. It is obvious that uniformity of emission markedly affected the number of bunches per vine and the average weight of the bunch, Consequently, the obtained fruit yields are significantly affected. The positive differences between the yield of the vines which receive the maximum amounts of irrigation water and that which receive the minimum amounts were 4.0, 53.8 and 60.2 % for the number of bunches per vine, the average weight of the bunch and the fruit yield of the vine in kilograms, respectively.

TABLE 6. Effect of emission uniformity on the fruit yield and water use efficiency by vines.

	Set 1			Set 2			Set 3			L.S.D 0.05	
	Season										
	2000	2001	mean	2000	2001	mean	2000	2001	mean	2000	2001
N	11.93	13.44	12.69	13.14	13.30	13.22	13.07	13.32	13.20	0.7	0.7
A	378.5	356.1	367.3	468.2	440.3	454.3	589.9	539.6	564.8	57.6	65.3
F	4.516	4.786	4.651	6.152	5.856	6.004	7.710	7.187	7.449	0.712	0.812
WUE	0.763	0.808	0.786	0.921	0.877	0.899	0.989	0.922	0.956	---	---

N : Number of bunches /vine

A : Average weight of bunch (g)

F : Fruit yield (kg/vine)

WUE : Water use efficiency by the vines (kg m^{-3}).

C. Emission uniformity and water use efficiency by the vines

Values of water use efficiency by the vines – expressed as kg of yield produced by each cubic meter of irrigation water used – as affected by uniformity of emission are presented in Table 6. Data show that the efficiency of water use by vines of set 1 (that received the minimum amounts of irrigation water) were the lowest, values of water use efficiency by vines of set 1 are lower than those which receive the average amounts of irrigation water, *i.e.* vines of set 2 by 17.2 and 7.9 % for 2000 and 2001 seasons , respectively. With an average of 12.6% on the other hand , values of water use efficiency by vines of set 3 (that received the maximum amounts of irrigation water) are the highest. The increase in values of water use efficiency by vines of this group (set 3) over those of vines of set 2 reached 7.4 %.

D. Emission uniformity and fertilizers use efficiency by the vines

Fertilizers use efficiency by the vines expressed as kg of yield produced by each one unit of N , P_2O_5 and K_2O added through fertigation are presented in Table 7. It is obvious that the amounts of water delivered to the vines and consequently fertilizers dissolved in it markedly affect the efficiency of using such fertilizers by the vines. The higher the amounts of irrigation water received by vines are, the higher are the efficiency of using added fertilizers. Presented data (means of two subsequent seasons, (2000 and 2001) show that the negative differences between the values of N , P_2O_5 and K_2O use efficiency by vines of set 1 and those by vines of set 3 were ≈18%.

Presented data indicate that uniformity of emission and consequently fertilizers application through trickle irrigation system greatly affect either the productivity or the nutritional status of the area. Although the uniformity of irrigation at the vineyard under study has reached about 88 % , great differences were estimated between the discharge of the drippers, that adversely affect the uniformity of growth , uptake of nutrients, obtained yield and water and fertilizers use efficiency by vines.

TABLE 7. Effect of emission uniformity on fertilizers use efficiency by vines.

Fertilizer Nutrient	Season	Set 1	Set 2	Set 3
Nitrogen	2000	66.3	80.0	86.0
(g fruit yield / g N)	2001	66.1	71.7	75.5
	mean	66.2	75.9	80.8
Phosphorus	2000	271.8	328.1	352.6
(g fruit yield / g P2O5)	2001	288.1	312.3	328.7
	mean	280.0	320.2	340.7
Potassium	2000	81.6	98.4	105.8
(g fruit yield / g K2O)	2001	86.4	93.7	98.6
	mean	84.0	96.1	102.2

Various investigators have recommended that values of Eu of 94 % or more are desirable and in no case should be below 90% (Aboukhaled, 1991; Vermeiren & Jobling, 1980; El-Sonbaty & El-Hady , 1993; El-Hady *et al.*, 1994 and El-Hady, 2000). Therefore, care of irrigation system for raising the uniformity of emission to the aforementioned percentage is a must. This will lead to an uniform growth and uptake of nutrients during the growing season and at the same time will raise either the yield or both water and fertilizers use efficiency by growing vines.

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(*Received* 8 / 2002)

تأثير انتظامية توزيع مياة الرى بالتنقيط على امتصاص العناصر المغذية و كفاءة استخدام المياة و الاسمدة لكرمات العنب النامية فى ارض رملية حديثة الاستصلاح

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أقيمت تجربة حقلية لعامين متتالين (٢٠٠٠ و ٢٠٠١) بنظام تام العشوائية ذو اربعة مكررات على كرمات عنب بناتى عمرها ٥ سنوات نامية فى ارض رملية بمنطقة الصف بمحافظة الجيزة تروى بنظام الرى بالتنقيط.

قدرت انتظامية التوزيع وانتظامية التوزيع المطلقة لمياة الرى فبلغت ٨٨,٦٤% و ٨٩,٨٠% على التوالى تعتبر انتظامية مياة الرى جيدة.

بالرغم من ان انتظامية توزيع مياة الرى بالموقع تحت الدراسة تعدت ٨٥% الا ان الاختلافات الكبيرة نسبيا فى تصرفات النقاطات فى المواقع المختلفة من البستان ادت الى حدوث اختلافات فى كميات الرى الواصلة للاشجار و بالتالى كميات الاسمدة الذائبة فيها. قدرت هذة الاختلافات ب ٣١,٦% .

نتيجة اختلاف انتظامية توزيع المياة بالموقع تحت الدراسة قدرت الاختلافات في مقاييس النمــو ب ٣٢,٤% لمســاحات الاوراق و ٥١,٦% للــوزن الجــاف للاوراق و ٦٠,٢% للمحصول الناتج من الكرمات.

ادت الاختلافات في كميات مياة الرى المضافة للاشجار ايضا الــى حــدوث فروق في كل من محتوى الاوراق من العناصر المغذيــة مقــدارها ٣٣,٣% و ٦٣,٣% و ٤٥,٥% و ٣٢,١ % و ١٨,٢ % و ٤٨,٦ % لعناصر النتروجين و الفوسفور و البوتاسوم و الحديد و الزنك و المنجنيز على التوالي . و تبعا لــذلك حدثت اختلافات في امتصاص هذة العناصر قــدرت ب ١٠٢,٠% و ١٤٣,٥ % و ١٢٠,١% و ٩٩,٨ % و ٧٨,٨% و ١٢٤,٤ % لنفس العناصر سابقة الــذكر على التوالي.

اثرت انتظامية توزيع مياة الرى و بالتالي توزيع الاسمدة على كل من كفــاءة استخدام المياة (المحصول الناتج من استخدام متر مكعب من مياة الرى) و كفاءة استخدام الاسمدة (المحصول الناتج من استخدام وحدة العنصر السمادى) بلغــت الاختلافات بين الكرمات في هذين العاملين ٢١,٦%.

من الدراسة يتضح انه يجب الاهتمام بنظام الرى بالتنقيط و العمل على زيادة انتظامية توزيع مياة الرى لتتعدى ٩٠% و هذا سوف يؤدى الى انتظــام توزيــع الاسمدة الذائبة في مياة الرى و انتظام النمو و امتصاص العناصر المغذية طوال موسم النمو و في نفس الوقت الى زيادة المحصول (كما ونوعا) و ارتفاع كفاءة استخدام الكرمات لكل من مياة الرى و الاسمدة المضافة.