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Alternative Irrigation Method as an Effective Technique for Rationalization of Irrigation with Foliar Fertilizer on Henna (*Lawsonia alba* Lam) Plant

Nahed M. Rashed* **and E.A. Moursi****

* *Vegetable and Ornamental Department*, *Faculty of Agriculture*. Damietta *University*, *Damietta, Egypt.* ** *Water Requirements and Field Irrigation Department, Soils, Water and Environment Research Institute*, *Agricultural Research Center, Cairo, Egypt.*

WATER SHORTAGE problem in Egypt is continuously increasing and it is prospected to reach the threshold level of less than 500 m^3/year/capita which so-called water scarcity limit. Therefore, the present study was carried out to use alternative irrigation technique I_1 (traditional irrigation like to practice by local farmers in the studied area), I_2 (irrigation furrow and left furrow with a fixed shape during the growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the growing season) on *Lawsonia alba* Lam plants and were applied foliar sprayed by potassium, micronutrients and humic liquid fertilizer. Despite, all growth was enhanced under I_1, chemical characteristics of henna plants were significantly increased by using I_3. The lowest values of applied irrigation water (AW) and water consumptive use (CU) were recorded under irrigation treatment I_3 (3397.09 and 3410.32 m^3/fed) and (2001.95 and 2020.49 m^3/fed) in the two seasons, respectively. Spraying plants with micronutrients only and micronutrients combined with potassium and humic observed highly growth characters, chemical criteria and the main component in most cases which increasing the leaves yield /fed for about 35.16%, lawsone yield/plant 43.37% and tannins yield/plant 35.64%, respectively when compared to non-sprayed plants. The deficit irrigated (I_3) spraying with micronutrients, potassium, and humic liquid fertilizer produced higher water productivity (WP) and productivity of irrigation water (PIW) in comparison to other irrigation treatments for both yields of leaves and lawsone. The decrease of AW in the treatment I_3 saving about 25.47% of water in the growing season.

Keywords: Alternative Irrigation Technique, Foliar application, Macro and Micro-nutrients, Humic Fertilizer, Henna.

Introduction

Irrigation is the main sector in water consumption at the national level .Water allocated for irrigation is about 85% from the total renewable water resources. So, effective water management at the irrigation sector is the major way towards the rationalization policy for the country. In this aspect, effective on farm irrigation management becomes a must. In Egypt, irrigated agriculture is the dominant type of farming. Moreover, the per capita of water for different purposes is decreasing gradually to less than the water poverty limit 1000 m^3 per annum, (El-Quosy, 1998). To overcome the water shortage, it is necessary to develop water-saving agriculture countermeasures, thereby producing more crops per drop. Shortage irrigation and alternate partial root-zone irrigation are water-saving irrigation strategies being widely used in arid and semi-arid regions, (Jensen et al., 2010). Alternate partial root zone irrigation is a further development of increasing water saving; it includes irrigating only part of the root zone, leaving the other part to dry to a pre-determined level before the next irrigation, (Kang and Zhang, 2004). By alternately wetting and drying part of

Corresponding author: Nahed Mostafa Rashed e-mail: rashed_nahed@du.edu.eg
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the root zone, Partial Rootzone Irrigation (PRI) allows the induction of the abscisic acid (ABA)-based chemical signaling from the drying roots to regulate growth and water use of the shoots, that way increasing water use efficiency, (Loveys et al., 2000).

Henna (*Lawsonia alba*) belongs to the family Lythraceae. It is a perennial shrub or small tree (2 to 6 m in height) native to North Africa, Australia and Asia and it is naturalized and cultivated in the tropical regions of Sudan, America, India, Egypt, and parts of the Middle East, (Chauhan and Pillai, 2007 and Vasudevan and Laddha, 2003). Henna is a medicinal and industrial plant which has been considered as one of the natural dyes. The leaves contain a red-orange color component known as lawsone (2 hydroxy 1,4 napthoquinone), which is also named as hennotannic acid. Lawsone is the main constituent taking charge of the dying properties of henna plants, (Kidanemariam et al., 2013 and Semwal et al., 2014). Moisture and Soil affect Lawsone levels of henna. Iron, dry, hot bearing soils produce henna with high Lawsone levels. Fertile moist soils produce henna with a lower level of Lawsone, (Yogisha et al., 2002). Henna is one of the medicinal plants which tolerant to drought and can grow only if minimum temperatures stay above 11 °C, (Kidanemariam et al., 2013). Mechanisms of drought response displayed by the henna plant were partially different depending on the dose of irrigation. Henna plants were able to tolerate water stress in the moderate stress (50% of the control) by adapting morphological mechanisms to counter drought damage. However, plants seem to be more sensitive to drought at (25% of the control) severe deficit irrigation stress, (Enneb et al., 2015).

On the other side, lack of soil moisture led to the reduction in nutrients distribution rate in the soil to root absorption. According to researchers report about drought effect on sodium, potassium and phosphorus absorption, less access to nutrients is the reason of nutrients absorption reduction by plant root in soil. Uptake and nutrients transmission mechanisms in crops such as mass flow, diffusion, and osmosis are as a function of the moisture amount in soil; in lack of humidity case, intense and amount of nutrients uptake would be changed. Zn and B may provide cereal seedlings with tolerance to drought stress which can be used for further studies for improving drought tolerance in cereals. Therefore, it can be concluded that soil application in early stage combined with foliar application in late stage (especially flowering) is a promising approach to alleviate drought stress, (Karim and Rahman, 2015). Foliar fertilization method may be a good substitute to the predictable soil application to avoid the loss of fertilizers by leaching and thereby minimizing the ground water pollution, (Tomimori et al., 1995)

There isn't enough information about water requirements and consumptive use for ornamental, medicinal and aromatic plants, especially in the North Nile delta region. Abovementioned reviews, according to drought sensitivity index, henna consider as a moderately tolerant plant to drought, (Enneb et al., 2015) and can be achieved overcome drought in these areas. On the other side, rationalization of irrigation water in agriculture sector is becoming a must to save water and reaches with the losses to the minimum level by decreasing the irrigation area in comparison with traditional irrigation method which always practices by local farmers. For that, the aim of this investigation was to study the effect of alternative irrigation technique on henna plant (*Lawsonia alba* Lam.) as well as, foliar applications of micronutrients, potassium and humic liquid fertilizer to mitigate the deficit-irrigated on the growth, yield, its components, water behavior and some water relations.

Materials and Methods

Site description

At the Experimental Farm of Sakha Agricultural Research Station, Kafr El-Sheikh Governorate. Two field experiments were conducted during the two growing summer seasons of 2015 and 2016 to study the water behavior and some water relations of henna (*Lawsonia alba* Lam) under using alternative irrigation method as an effective technique for rationalization of irrigation in comparison with using traditional irrigation method and the role of foliar fertilization to alleviate drought stress and the response of the growth, yield and its components.

Plant material and growing conditions

Hard wood cuttings (20 cm length with 7-8 nodes) from the local cultivar of *Lawsonia alba* Lam (syn. *L. inermis* L) were used in this study. The cuttings obtained from Assiut Agricultural Research Station, ARC, Egypt. The cuttings were taken at April 21st and 29th in the first and second growing seasons, respectively.

Some physical and chemical characteristics of the studied site were shown in Tables (A and B):

The studied physical characteristics of the site such as mechanical analysis were determined according to the international pipette method (Klute, 1986). Soil bulk density (Bd), soil field capacity (F.C) and permanent wilting point (PWP) were determined according to Klute, 1986). Available soil moisture (AW) was calculated as the difference between soil field capacity and permanent wilting point. The studied chemical characteristics such as soil reaction (pH) values were determined in 1:2.5 soil water suspension (Jackson, 1973). Total soluble salts were measured by electrical conductivity (EC) apparatus in the saturated soil paste extract (Jackson, 1973). Soluble cations and anions (Ca^{++}, Mg^{++}, Na^{+}, K^{+}, $CO_3^{=}$, HCO_3^{-}, Cl^{-} and $SO_4^{=}$ as meq/L) were determined in soil paste extract (Jackson, 1973). But $SO_4^{=}$ was calculated by the difference between soluble cations and anions.

TABLE A. The mean values of some physical characteristics of the studied site before cultivation.

Soil depth (cm.)	Particle size distribution			Texture	F.C %	PWP %	Bd kg/m³	AW%	Total
	sand %	Silt%	Clay %	Class					porosity%
0-15	15.70	31.00	53.30	Clay	44.61	26.56	1.04	18.05	60.75
15-30	22.40	33.10	44.50	Clay	40.20	21.44	1.09	18.76	58.87
30-45	20.70	40.30	39.00	Clay loam	38.70	20.60	1.11	18.10	58.11
45-60	22.90	40.90	36.20	Clay loam	36.30	19.83	1.16	16.47	56.23
Mean	20.43	36.33	43.25	Clay loam	39.95	22.11	1.10	17.85	58.49

FC= Soil field capacity (%), PWP=Permanent wilting point (%), Bd= Soil bulk density (Mg/m^3), AW=Soil available water (%) = (F.C – PWP)

$$\text{Total porosity (\%)} = \frac{\text{Real density - Bulk density}}{\text{Real density}} x100$$

Real density in mineral soils = 2.65 Mg/m^3

TABLE B. The mean values of some chemical characteristics of the studied site before cultivation.

Soil depth, cm	EC dS/ m at 25°C	pH 1:2:5soil water suspension	Cations meq/l				Anions meq/l			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
0-15	1.83	8.65	7.31	2.18	8.70	0.22	0.00	4.30	9.00	5.11
15-30	2.45	8.54	9.54	5.10	9.60	0.19	0.00	3.90	8.90	11.63
30-45	2.56	8.49	9.67	5.47	10.02	0.18	0.00	3.70	7.80	13.84
45-60	3.01	8.37	11.50	6.28	12.00	0.17	0.00	3.60	7.00	19.35
Mean	2.46	8.51	9.51	4.76	10.08	0.19	0.00	3.88	8.18	12.48

$SO_4^{=}$ was estimated by difference between soluble cations and anions.

Meteorological conditions

Meteorological conditions during the two experimental growing seasons (2015 and 2016) for Sakha area are presented in Table (C).

Applied irrigation methods

The plot (strip) area for irrigation treatment was 180 m^2 (3.6 m width x 50 m length) While the plot area for foliar application treatment was 34.2 m^2 (2.6 m width x 9.5 m length). The experimental design was split plot, with three replications. The main plots were randomly assigned by irrigation method (I), where I_1 (traditional irrigation method like to practice by local farmers in the studied area), I_2 (Irrigation furrow and left furrow with a fixed shape during the whole growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the whole growing season). The furrows width was 60 cm apart and the distance between each cutting was about 30-40 cm apart on one side. While the sub plots were randomly assigned to foliar application treatments Fig.1.

TABLE C. Means of some meteorological data at Kafr El-Sheikh (Sakha) area during the two growing seasons of 2015 and 2016.

Months	T (c°)			RH(%)			Wind speed m /sec at 2 m height	Pan Evap. (mm/ day)	Rain mm
	Max.	Min.	Mean	Max.	Min.	Mean			
2015									
April	25.64	13.70	19.67	78.30	48.50	63.40	1.11	6.07	35.85
May	30.19	18.79	24.49	77.3	46.1	61.7	1.33	7.15	0.00
June	30.85	21.4	26.13	78.8	51.2	65.0	1.22	6.95	0.00
July	33.0	22.4	27.7	85.2	54.3	69.8	1.13	6.86	0.00
Aug	35.1	25.0	30.1	83.8	51.7	67.8	1.06	8.15	0.00
Sep	34.6	23.8	29.2	82.7	46.5	64.6	1.14	6.64	0.00
Oct	29.9	20.6	25.3	80.9	54.1	67.5	1.01	4.53	65.9
Nov	24.4	14.42	19.4	87.0	64.2	75.6	0.81	3.19	52.4
2016									
April	30.03	18.62	24.33	81.6	41.8	61.7	1.01	5.94	0.00
May	30.4	22.8	26.6	71.0	45.8	58.4	1.12	6.47	0.00
June	33.6	26.3	29.95	75.7	46.6	61.15	1.31	8.07	0.00
July	33.7	26.1	29.90	82.7	56.8	69.75	1.22	7.84	0.00
Aug	33.6	26.0	29.8	84.3	56.3	70.3	1.07	7.74	0.00
Sep	32.6	24.3	28.45	83.1	51.8	67.45	1.10	5.91	0.00
Oct	29.8	21.7	25.75	82.4	55.3	68.85	1.07	3.57	0.00
Nov	24.9	17.9	21.4	77.9	56.8	67.35	0.65	1.98	0.00

- Source: Meteorological Station at Sakha 31-07' N Latitude, 30-57'E Longitude with an. Elevation of about 6 metres above mean sea.

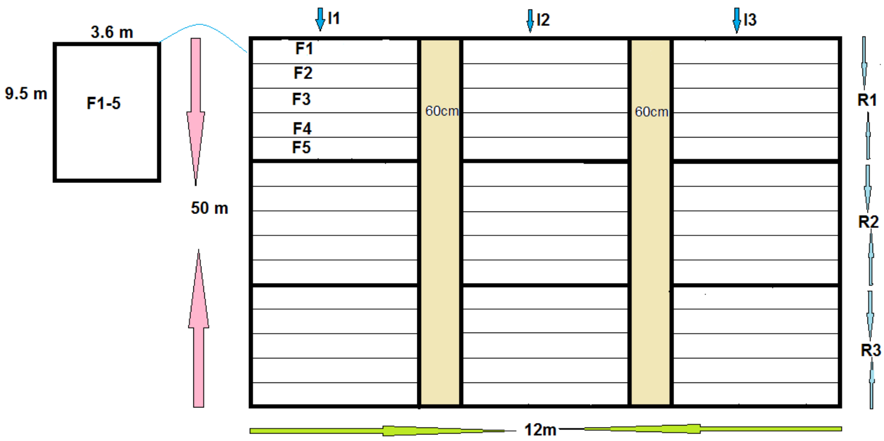

Fig. 1. Schematic figure of the plots

I1: (Traditional irrigation methods like to practice by local farmers in the studied area).
I2:(Irrigation furrow and left furrow with a fixed shape during the whole growing season)
I3: (Irrigation furrow and left furrow with an alternative shape during the whole growing season) .

Foliar fertilizer application:

Plants were foliar sprayed with five different treatments as explained in Table (D).

All treatments were spraying twice, one at the early growth stage *i.e.* one month after planting and the second application about 2 weeks later. The plants leaves were thoroughly wetted until solution drops.

Measurements

Growth and yield characteristics

Harvesting process was performed after completely flowering stage when most of the branches were painted with brown colour. Then, the leaves of every plant were individually separated from the branches and air dried in shade at room temperature (about 25°C) then, packed in paper bags in September 28th and October 6th in the first and second growing seasons, respectively.

TABLE (D): foliar fertilization treatments.

Fertilizer treatments	Fertilizer component	Application rate	Fertilizer source
F_1: micronutrients liquid fertilizer commercial called (fulv E)	5% Fe, 2%Mn, 1%Zn, 0.2%B,1- 0.2%Cu and 0.1% Mo on the base of fulvic acid.	5 cm^3/L Spraying solutions.	All foliar application was prepared in Soil Fertility and Plant Nutrition Department, Sakha. Agric. Res. Station
F_2: potassium liquid fertilizer commercial called (fulv K)	36% K_2O on the base of fulvic acid.	2.5 cm^3/L Spraying solutions.	
F_3: humic liquid fertilizer commercial called (rich humic)	Humic acid solution	5 cm^3/L Spraying solutions.	
F_4: Mixed F_1+F_2+F_3	F1+F2+F3 (5 : 2.5:5) by volume	F1+F2+F3 (5 :2.5: 5) by volume at 12.5cm^3/L	
F_5: Control distilled water	--------------	-------------	

The following vegetative growth attributes were carried out on the sample size of ten plants chosen randomly from the inner rows in each plot: Plant height (cm), number of main branches, plant fresh and dry weights (g), leaves /stems ratio and leaves yield /fed

Chemical constituents

Active substances:

Lawson and tannins are the main active constituents in henna leaves. Lawsone (2-hydroxy,1,4-aphthoquinone) is mainly responsible for the colour development in leaves of henna.

a. *Lawson pigment content:* was determined in the air dried henna leaves according to (Pratibha and Korwar., 1999). Lawson yield in (g/ plant) was calculated by multiplying leaves dry weight (g/plant) by its lawson percentages.

b. *Tannins content:* was determined in the powdered henna leaves according to the modified Vanillin-HCl method of (Price et al., 1978) as described by (Babiker and El-Tinay, 1992). Tannins yield (g/plant) was calculated by multiplying the dry weight of leaves in gram per plant by its tannins percentage.

Total carbohydrates percentage

Total carbohydrates including polysaccharides in dry leaves of each treatment were colorimetrically determined by the method of (Michel et al., 1956)

Protein percentage was estimated by multiplying nitrogen percentage by 6.25.This was based on the assumption that the protein contains 16% nitrogen, according to the method described by (Ranganna, 1978).

Elemental determination

The extraction was made of a known weight of the dried leaves sample (0.5 g). The wet digestion procedure was performed according to (Jackson, 1973) to determine the following minerals.

a) *Total nitrogen was* determined by using the semi-micro-kjeldahl method according to (Black et al., 1982).

b) Phosphorus percentage was colorimetrically determined following (Jackson, 1973). The developed blue color was measured at the wave length of 660 nm using spectrophotometer.

c) Potassium percentage was determined using a flame photometer as described by (Jackson, 1973).

Irrigation measurements

Applied irrigation water (AW) (cm^3 and m^3/fed):

The amount of applied irrigation water was calculated according to (Israelsen and Hansen, 1962) formula. $q=0.226D^2h^{1/2}$

Where:

q= Irrigation flow rate, cm^3

h= Average effective head and

D= Inside diameter of the pipe, cm.

The amount of applied irrigation water for each plot (treatment) was calculated by using this formula:

$$a = q * T$$

Where:

a= Water volume (m^3/plot)

q= Irrigation flow rate

T= Total recorded time for each plot, minute

Water consumptive use (WCU) (cm^3 and m^3/fed)

The amount of water consumed in each irrigation was obtained from the difference between soil moisture content after and before the following irrigation. Water consumptive use by the growing plants was calculated based on soil moisture depletion (SMD) according to Hansen et al., (1979).

$$CU = SMD = \sum_{i=1}^{i=N} \frac{\theta_2 - \theta_1}{100} * Dbi * D * 4200$$

Where:

CU	=	Water consumptive use in the effective root zone (60 cm).
θ_2	=	Gravimetric soil moisture percentage after irrigation,
θ_1	=	Gravimetric soil moisture percentage before the next irrigation
Dbi	=	Soil bulk density (Mg/m^3) for depth,
Di	=	Soil layer depth (20 cm)
i	=	Number of soil layers (1-3)
4200	=	Feddan area with m^2

Consumptive use efficiency (ECU %)

Values of consumptive use efficiency (ECU %) were calculated according to (Bos, 1980). ECU = (ETC/AW) x 100

Where:

ECU	=	Consumptive use efficiency (%):
ETC	=	Total evapotranspiration $\simeq$ water consumptive use
AW	=	Applied irrigation water to the field.

Water productivity (WP, kg/m^3)

Water productivity is generally defined as crop yield per cubic meter of water consumption. Water productivity is defined as crop production per unit amount of water used (Molden, 1997). Concept of water productivity in agricultural production systems is focused on producing more food with the same water resources or producing the same amount of food with less water resources. It was calculated according to Ali et al. (2007).

WP = Y/ET

Where:

WP	=	Water productivity (kg/m^3)
Y	=	Yield
ET	=	Total water consumption, m^3/fed

Productivity of irrigation water (PIW, kg/m^3)

Productivity of irrigation water (PIW) was calculated according to Ali et al. (2007).

PIW=Y/AW

PIW	=	Productivity of irrigation water (kg/m^3).
Y	=	Yield
AW	=	Applied irrigation water, m^3

Statistical analysis

All data were statistically analyzed approved to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984). Means of the treatments were compared by the least significant difference (LSD) at 5% level of significance which developed by Waller and Duncan (1969) using COSTAT computer program.

Results and Discussion

Growth and yield characteristics

Irrigation effect: Evidently, a significant decrease in henna growth characters under alternative irrigation technique I_2 and I_3 was obtained, Table (1 and 2). So that, maximum of plant height, number of branches, leaves / stems ratio, fresh and dry weights/plant, leaves yield/plant and leaves yield/fed were observed in control I_1 (traditional irrigation method) in the two seasons followed by I_3 treatment which increased all growth characters as compared to I_2. Alternative irrigation technique I_3 slightly decreased leaves yield/plant for about 7.62 and 28.36% in the first and second seasons, respectively. Reduction in plant growth characters under water stress could be attributed greatly to moisture stress significantly effect on stomata closure, decline in growth rate, photosynthesis, leaf area reduction, leaf senescence and reduction in cell development, (El Naim and Ahmed, 2010 and El Naim et al., 2010). Similarly, (Jabereldar et al., 2017) found that water stress at the eight-leaf stage of sorghum reduced panicle weight, panicle length, number of grains per panicle, seed yield, 100- grain weight, and water use efficiency . (Rodriguez et al., 2004) indicated that leaf growth in the seedling stage is highly sensitive to these stresses. However, water stress reduces the rate of cell expansion and finally cell size and growth rate. (Jami et al., 2015) were observed the too negative impact on these attributes.

Foliar Fertilization

Data in Table 1 showed that all foliar fertilization treatments significantly increased all growth criteria of henna plants under study as compared with the control. The highest increments in plant height, number of branches and leaves /stems ratio were obtained as a result of spraying henna plants with micronutrients in the two seasons. While, spraying henna with micronutrients combined with potassium and humic recorded the highest significant result on fresh and dry weights, leaves yield/plant and leaves yield /fed in the two seasons. Spraying plants with micronutrients combined with potassium and humic increased the leaves yield /fed for about 35.16% and 32.86% in the two seasons, respectively. These results are due to foliar fertilization is functional to plant leaves and leaves are green factories where the chemical process is multipart of photosynthesis produces the compounds for plant growth. These results agreed with findings of (Jami et al., 2015 and Asgharipour and Mosapour, 2016) who found that foliar feeding of nutrients has become an established procedure to increase yield and improve the quality of crop products.

TABLE 1. Effect of irrigation methods and foliar fertilization on plant height, branches No /plant and leaves / stems ratio of (Lawsonia alba Lam) during the two seasons 2015 and 2016.

Irrigation treatments (I)	Foliar application treatments (F)	Plant height(cm)		Branches No/plant		Leaves /stems ratio	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
I_1	F_1	203.33	176.67	3.00	5.33	87.62	104.41
	F_2	193.33	173.33	4.00	4.00	89.03	82.15
	F_3	181.00	146.33	3.00	3.00	68.71	81.94
	F_4	190.00	176.67	3.00	4.00	81.52	88.01
	F_5	182.33	164.67	2.33	3.00	64.10	81.15
I_2	F_1	170.00	130.00	3.00	3.67	61.47	56.71
	F_2	143.33	118.33	2.00	3.00	46.45	73.88
	F_3	165.00	160.00	2.00	3.00	59.21	45.66
	F_4	150.00	123.33	3.00	3.00	78.68	87.89
	F_5	150.67	125.00	2.00	3.00	55.25	52.95
I_3	F_1	186.67	167.67	4.00	3.67	98.61	91.20
	F_2	180.00	143.33	3.00	5.00	86.24	47.16
	F_3	186.00	134.33	2.00	4.00	62.84	86.05
	F_4	175.00	138.33	3.00	3.33	41.92	43.66
	F_5	151.67	128.00	3.00	3.00	68.64	55.67
$LSD_{0.05}$		22.88^{ns}	12.74**	0.28**	0.743**	10.83**	11.15**
Irrigation mean	I_1	190.00	167.40	3.07	3.87	78.20	87.53
	I_2	175.87	142.33	2.40	3.13	60.21	63.42
	I_3	155.80	131.33	3.00	3.80	71.65	64.75
$LSD_{0.05}$		13.20*	7.35**	0.162**	0.429**	6.25**	6.44**
Foliar application mean	F_1	186.67	158.11	3.33	4.22	82.57	84.10
	F_2	172.22	145.00	3.00	4.00	73.91	67.73
	F_3	177.33	146.11	2.33	3.33	63.58	71.22
	F_4	171.67	145.89	3.00	3.44	67.37	73.19
	F_5	161.56	139.22	2.44	3.00	62.67	63.26
$LSD_{0.05}$		8.48**	5.71**	0.114**	0.161**	3.31**	5.30**

*, **, *** and NS: significant at $p \leq 0.05$, 0.01, 0.001or not significant, respectively. Means separated at $P \leq 0.05$, LSD test. I_1 (traditional irrigation method like to practice by local farmers in the studied area), I_2 (Irrigation furrow and left furrow with a fixed shape during the whole growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the whole growing season). F_1 (Micronutrient), F_2 (Potassium), F_3 (Humic), F_4 (Micro +Pot +Hum) and F_5 (Fresh water).

TABLE 2. Effect of irrigation methods and foliar fertilization on fresh and dry weight/plant (g),leaves yield/plant(g) and leaves yield /fed (kg) of (Lawsonia alba Lam) during the two seasons 2015 and 2016.

Irrigation treatments (I)	Foliar application treatments (F)	Fresh weight/plant (g)		Dry weight/plant (g)		Leaves yield/plant (g)		Leaves yield /fed (ton)	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
I_1	F_1	798.47	1089.72	547.44	490.35	207.74	177.44	3531.52	3016.42
	F_2	1348.67	749.61	479.99	346.13	170.59	146.96	2900.09	2498.26
	F_3	1112.23	762.11	400.02	312.43	162.73	108.14	2522.86	1838.49
	F_4	1262.05	1052.35	738.86	564.83	325.30	264.07	5530.10	4489.13
	F_5	1390.15	633.98	516.61	327.95	148.40	102.56	2766.47	1743.57
I_2	F_1	592.13	356.13	225.58	170.27	105.35	86.92	1790.89	1477.64
	F_2	821.98	476.55	399.44	219.89	155.56	99.05	2644.58	1683.96
	F_3	541.45	321.84	273.06	214.83	109.25	96.12	1886.32	1633.98
	F_4	713.99	611.39	295.91	202.48	132.73	94.70	2256.35	1609.90
	F_5	706.23	514.95	231.84	127.90	110.96	57.29	1857.19	974.04
I_3	F_1	1371.55	523.99	233.71	152.71	116.02	72.82	1972.28	1237.88
	F_2	1223.77	869.69	524.25	378.21	213.47	120.70	3628.99	2051.96
	F_3	972.66	713.65	399.02	325.19	250.23	116.29	2616.92	1976.99
	F_4	1501.12	773.03	691.59	391.90	203.78	118.69	3464.20	2017.79
	F_5	764.04	833.89	539.99	312.89	153.93	144.00	4253.91	2448.40
$LSD_{0.05}$		169.78**	84.39**	43.26**	37.86**	15.21**	16.78**	435.98**	160.14**
Irrigation mean	I_1	1182.31	857.55	536.58	408.34	202.95	159.83	3450.21	2717.18
	I_2	675.16	456.17	285.17	187.07	122.76	86.82	2087.07	1475.91
	I_3	1166.63	742.85	477.71	312.18	187.49	114.50	3187.26	1946.52
$LSD_{0.05}$		98.02**	48.72**	24.98**	21.86**	8.78**	9.68**	149.28**	164.73**
Foliar application mean	F_1	920.72	656.61	335.58	271.11	143.03	112.39	2431.57	1910.65
	F_2	1131.47	698.62	467.89	314.74	179.87	122.24	3057.88	2078.06
	F_3	875.45	599.20	357.37	284.15	174.07	106.85	2342.03	1816.49
	F_4	1159.06	812.26	575.45	386.41	220.60	159.15	3750.22	2705.61
	F_5	953.47	660.94	429.48	256.24	137.76	101.29	2959.19	1721.87
$LSD_{0.05}$		85.07**	46.54**	16.52**	13.13**	8.40**	4.21**	142.94**	71.62**

*, **, *** and NS: significant at $p \leq 0.05$, 0.01, 0.001or not significant, respectively. Means separated at $P\leq 0.05$, LSD test.
I_1 (traditional irrigation method like to practice by local farmers in the studied area), I_2 (Irrigation furrow and left furrow with a fixed shape during the whole growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the whole growing season). F_1 (Micronutrient), F_2 (Potassium), F_3 (Humic), F_4 (Micro +Pot +Hum) and F_5 (Fresh water).

Interaction

The interaction influence between irrigation methods and foliar fertilization was highly effective on all growth henna characters for the two seasons, except plant height in the first season which did not significantly affected. Spraying plants with micronutrients and micronutrients combined with Potassium and humic under all irrigation treatments observed highly growth characters comparing with the control in most cases in the two seasons. Decreases in plant growth due to drought may be referring to a disturbance in the nutrients, resulting in the decreases in K, Ca, Mg, P and N uptake, (Yuncai et al., 2008). Similar results about the impact of foliar fertilizer with water stress on fennel were reported, (Asgharipour and Mosapour, 2016).

Chemical constituents

Irrigation effect

chemical characters of henna plants significantly increased by using alternative irrigation technique (Table 3 and 4). So that, maximum of N, P, K and Lawson %, lawson yield/plant (g), tannins %, tannins yield/(g) plant, Protein and total carbohydrates % were observed in I_3 treatment which increasing all chemical characters in most cases as compared to I_1. These results can be attributed to the accumulation of soluble carbohydrates play an important role in osmoregulation, turgidity and stability of biomolecules and membranes. In addition, soluble carbohydrates help to reduce cell water potential and cell turgidity under water deficit, (Farahat et al., 2007). These results agreed with other reports on tarragon, (Lotfi et al., 2014).

Foliar Fertilization

All foliar fertilization treatments significant increased all chemical characters of henna plants under study as compared with the control Table (3 and 4). The highest increment as a result of spraying henna plants was micronutrients combined with potassium and humic on N %, P %, lawson %, Lawson yield/plant, tannins %, tannins yield/plant, protein % and total carbohydrates % in the two seasons. Spraying henna plants with micronutrients combined with potassium and humic increased tannins yield/plant for about (32.74 and 35.64%) and lawson yield/plant by about (43.37 and 38.01%) in the two seasons, respectively. This may be due to when plants suffer from a nutrient deficiency; the efficacy of foliar fertilization is higher than that of soil fertilization. The reasons for this are because of the supply of the required nutrient directly to the location of demand in the leaves and its relatively quick absorption, independence of root activity and soil water availability, Romemheld and El-Fouly (1999). Mineral elements have numerous functions in plants including maintaining charge balance, electron carriers, structural components, enzyme activation, and providing osmotic for turgor and growth (Waraich et al., 2011 and Salim et al., 2014).

Interaction

The interaction effects between irrigation methods and foliar fertilization were significant on all chemical characters for the two seasons, except N and protein % in the first season was not significant. Spraying plants with micronutrients under I_3 observed highly P and lawson % in the two seasons while, micronutrients combined with potassium and humic under I_3 recorded the highly significant effect on lawson yield/plant, tannins yield/plant and protein % in the two seasons. The highest significant effect on N and tannins % showed under spraying humic with I_2. Plants spraying with Potassium under I_3 recorded the highly significant effect on K and total carbohydrates % in the two seasons. However, plants sprayed with micronutrients under I1 contained the highest total carbohydrates % in the first season. These results attributed to application of nutrients like potassium help maintaining high tissue water potential under drought condition and improve drought tolerance by osmotic adjustment. The micronutrients like Cu and B alleviate the adverse effects of drought indirectly by activating the physiological, biochemical and metabolic processes in the plants, (Salim et al., 2014). Similarly, the application of some micro- nutrients like Zn, Si, and Mg also increase antioxidants concentration and improves drought tolerance in plants. In other mechanism, nutrients like P, K, Mg, and Zn improve the root growth which in turn increases the intake of water which helps in stomatal regulation and enhances the drought tolerance. Increasing evidence suggests that mineral-nutrients status of plants plays a critical role in increasing plant resistance to environmental stress factors, (Waraich et al., 2011).

TABLE 3 . Effect of irrigation treatments and foliar fertilizer on N%, P%, K% and Protein % of (*Lawsonia alba* Lam) during the two seasons 2015 and 2016.

Irrigation treatments (I)	Foliar application treatments (F)	N%		P%		K%		Protein %	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
I_1	F_1	2.49	2.52	0.67	0.56	2.42	2.19	15.56	15.76
	F_2	2.39	2.29	0.56	0.64	2.68	2.46	14.94	14.31
	F_3	2.69	2.29	0.51	0.52	1.68	1.55	16.81	14.31
	F_4	2.72	2.52	0.61	0.56	1.42	1.31	17.02	15.77
	F_5	2.39	2.29	0.64	0.59	1.41	1.26	14.94	14.31
I_2	F_1	2.52	2.35	0.41	0.45	1.57	1.48	15.75	14.69
	F_2	2.46	2.32	0.45	0.37	1.68	1.55	15.38	14.52
	F_3	2.76	2.32	0.55	0.40	1.53	1.48	17.25	14.52
	F_4	2.49	2.49	0.63	0.60	1.42	1.27	15.56	15.56
	F_5	2.49	2.12	0.41	0.37	1.38	1.27	15.56	13.27
I_3	F_1	2.49	2.22	0.55	0.51	2.03	1.87	15.56	13.90
	F_2	2.46	2.16	0.55	0.51	2.66	2.50	15.38	13.48
	F_3	2.39	2.39	0.64	0.51	1.41	1.30	14.94	14.94
	F_4	2.75	2.31	0.55	0.51	1.52	1.47	17.19	14.46
	F_5	2.49	2.26	0.45	0.41	1.45	1.33	15.56	14.11
LSD 0.05		0.37ns	0.13*	0.02**	0.02**	0.04**	0.05**	2.30 ns	0.80*
Irrigation mean	I_1	2.54	2.38	0.60	0.56	192	1.76	15.88	14.89
	I_2	2.54	2.32	0.49	0.45	1.52	1.41	15.88	14.52
	I_3	2.51	2.27	0.55	0.51	1.81	1.69	15.69	14.18
LSD 0.05		0.21ns	0.07**	0.01**	0.01**	0.02**	0.03**	1.33ns	0.46**
Foliar application mean	F_1	2.50	2.37	0.54	0.53	2.01	1.85	15.63	14.80
	F_2	2.43	2.26	0.52	0.51	2.34	2.17	15.19	14.10
	F_3	2.61	2.33	0.57	0.48	1.54	1.44	16.32	14.56
	F_4	2.66	2.44	0.60	0.56	1.45	1.35	16.63	15.26
	F_5	2.46	2.22	0.50	0.46	1.41	1.29	15.38	13.89
LSD 0.05		0.20ns	0.01**	0.01**	0.01**	0.02**	0.02**	1.26ns	0.42**

*, **, *** and NS: significant at $p \leq 0.05$, 0.01, 0.001or not significant, respectively. Means separated at $P \leq 0.05$, LSD test.

I_1 (traditional irrigation method like to practice by local farmers in the studied area), I_2 (Irrigation furrow and left furrow with a fixed shape during the whole growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the whole growing season). F_1 (Micronutrient), F_2 (Potassium), F_3 (Humic), F_4 (Micro +Pot +Hum) and F_5 (Fresh water).

TABLE 4. Effect of irrigation treatments and foliar fertilizer on Lawson %, Lawson yield/plant (g), Tannins %, Tannins yield/plant (g) and Total carbohydrates % of (*Lawsonia alba* Lam) during the two seasons 2015 and 2016.

Irrigation treatments (I)	Foliar application treatments (F)	Lawson%		Lawson yield/ plant (g)		Tannins%		Tannins yield/ plant(g)		Total carbohydrates %	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
I_1	F_1	2.23	2.01	61.69	47.96	3.41	2.91	490.21	499.24	31.56	30.65
	F_2	1.87	1.75	54.13	43.73	3.24	2.74	549.92	400.26	33.25	31.72
	F_3	2.07	1.87	52.23	34.32	2.90	2.39	470.97	289.16	33.22	26.63
	F_4	2.09	1.94	115.36	86.96	3.41	2.91	963.03	649.65	32.51	30.15
	F_5	1.74	1.59	61.46	35.05	3.35	2.85	689.74	257.76	32.56	27.16
I_2	F_1	1.75	1.54	32.47	26.24	2.93	2.43	312.90	211.01	31.04	28.31
	F_2	1.74	1.65	46.01	27.75	3.38	2.88	485.33	259.62	30.67	28.46
	F_3	1.64	1.60	31.00	26.14	3.47	2.97	384.65	285.19	30.83	29.60
	F_4	1.86	1.78	41.86	28.65	3.12	2.62	448.59	272.72	32.41	29.18
	F_5	1.92	1.78	34.33	14.99	2.86	2.36	308.28	135.48	31.52	29.88
I_3	F_1	1.92	1.81	81.52	19.89	3.31	2.81	837.66	211.92	34.12	27.97
	F_2	2.06	1.75	74.77	35.85	2.96	2.46	727.38	350.70	31.82	27.27
	F_3	1.85	1.66	48.49	32.88	3.17	2.67	445.96	278.73	32.39	28.45
	F_4	2.01	1.82	69.75	36.72	3.22	2.72	660.23	325.21	32.37	31.54
	F_5	1.66	1.61	32.67	44.40	3.01	2.51	395.59	409.95	29.21	28.77
LSD 0.05		0.04**	0.05**	6.36**	3.62**	0.02**	46.29**	49.48**	0.02**	0.96**	1.58**
Irrigation mean	I_1	1.99	1.83	68.97	49.60	3.26	2.76	632.77	419.21	32.62	29.26
	I_2	1.78	1.67	37.13	24.75	3.15	2.65	387.95	232.80	31.29	29.09
	I_3	1.90	1.73	61.44	33.95	3.14	2.64	613.36	315.30	31.98	28.80
LSD 0.05		0.02**	0.03**	2.38**	2.37**	0.01**	0.01**	28.57**	26.73**	0.56**	0.91**
Foliar application mean	F_1	1.97	1.79	58.56	31.36	3.22	2.72	546.92	307.39	32.24	28.98
	F_2	1.89	1.71	58.30	35.77	3.19	2.69	587.54	336.86	31.91	29.15
	F_3	1.86	1.71	43.90	31.11	3.17	2.68	433.86	284.36	32.15	28.22
	F_4	1.99	1.85	75.65	50.78	3.25	2.75	690.62	415.85	32.43	30.28
	F_5	1.77	1.66	42.82	31.48	3.07	2.57	464.54	267.73	31.10	28.23
LSD 0.05		0.02**	0.02**	2.37**	1.62**	0.01**	0.01**	27.19**	11.67**	0.57**	0.68ns

*, **, *** and NS: significant at $p \leq 0.05$, 0.01, 0.001or not significant, respectively. Means separated at $P \leq 0.05$, LSD test.

I_1 (traditional irrigation method like to practice by local farmers in the studied area), I_2 (Irrigation furrow and left furrow with a fixed shape during the whole growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the whole growing season). F_1 (Micronutrient), F_2 (Potassium), F_3 (Humic), F_4 (Micro +Pot +Hum) and F_5 (Fresh water).

Effect of irrigation and foliar fertilizer treatments on:

Seasonal amount of applied irrigation water (AW) and amount of saving water (% & m^3/fed.)

The seasonal values of AW were affected by irrigation treatments, not by foliar fertilizer treatments in the two seasons Table 5. The highest AW were recorded under I_1 in comparison with other irrigation treatments I_2 and I_3 while, there are high amounts of water saving under using alternative irrigation technique in comparison with using traditional irrigation method (irrigation all furrows).The highest amount of water saving was recorded under I_3comparing with I_2. Data of AW for henna plant can be descended in order $I_1 > I_2 > I_3$ in the two seasons. Increasing the AW under irrigation treatment I_1 in comparison with alternative irrigation technique may be attributed to increasing irrigated area with a low irrigated area by irrigating the half of cultivated area and hence increasing the time of irrigation. So, decreasing AW. Also, data indicated that AW was increased under irrigation treatment I2 in comparison with I_3 which received the lowest values comparing with I_1 and I_2 in the two seasons. These findings are in the same line with those reported by (Aiad, 2003 and Shabana, 2010). Also, increasing amount of water saving under using alternative irrigation technique comparing with traditional irrigation could be attributed to decreasing amount of applied water by decreasing irrigated area. Also, increasing the amount of water losses under using traditional irrigation by evaporation from the soil surface. Therefore, low water saving comparing with alternative irrigation technique which receives low water amount, decreasing losses by evaporation, decreasing applied water and increasing amount of water saving. These results are in a great harmony with those reported by (Aiad, 2003) who demonstrated that alternative furrow irrigation saved irrigation water by 25.6 and 31.8% with decreasing seed cotton yield by 15.17 and 4.0% for both seasons compared with the irrigation of all furrows (traditional irrigation). Also, these results are at the same time with those found by (Shabana, 2010).

TABLE 5. Effect of irrigation treatments on seasonal amount of water applied (m3/fed), water consumptive use and amount of saving water (m^3/fed and %) of Lawsonia alba Lam plant in the two seasons.

criteria / Irrigation	Water applied (m^3/fed)	water consumptive use (m^3/fed)	amount of saving water		Water applied (m^3/fed)	Amount water consumptive use (m^3/fed	amount of saving water	
			m^3/fed	%			m^3/fed	%
	1st season				2nd season			
I_1	4523.17	2774.54	-	-	4610.37	2846.64	-	-
I_2	3470.28	2116.24	1052.89	23.28	3490.77	2142.53	1119.60	24.28
I_3	3397.09	2001.95	1126.08	24.90	3410.32	2020.49	1200.05	26.03

I_1 (traditional irrigation method like to practice by local farmers in the studied area), I_2 (Irrigation furrow and left furrow with a fixed shape during the whole growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the whole growing season).

Water consumptive use (CU) m^3/fed and Consumptive use efficiency (ECU%)

Water consumptive use and Consumptive use efficiency (is a parameter which indicates the capability of plants to utilize the soil moisture stored in the effective root zone) were tabulated in Table 6. The values of (CU and ECU) were greatly affected by both irrigation and nutrients foliar application treatments in the two seasons. Concerning, the effect of irrigation treatments, the highest values of (CU and ECU) were recorded under I_1 in the two seasons. Meanwhile, the lowest values for water consumptive were recorded under I_3. Increasing the values of water consumptive use under irrigation treatment I_1 in comparison with I_2 and I_3 led to increasing the values of ECU and this could be attributed to increasing the amount of applied water which may be led to increase the irrigated area and hence, increasing the losses of evaporation from the soil surface and this considers one of the two main components for water consumptive use. Also, increasing the amount of applied water might be led to increased availability of soil nutrients and hence, increasing uptake rate of these nutrients by plants for that, forming strong plants with a thick canopy which exposes to the sunlight therefore, increasing a number of losses by transpiration from plant surface. Also, this considers one of the two main components for water consumptive use. Consequently, increasing evaporation and transpiration which led to increasing the values of water consumptive use because these components are the components of CU. These results are in a great harmony with those reported by (Hua and Zhong., 2000) indicated that alternative furrow irrigation didn't decrease photosynthetic rate by decreased evapotranspiration (water consumptive use). Also, these findings are in the same line with those reported by (Aiad, 2003). El-Shahawy (2004) concluded that the seasonal water consumptive use increased with irrigation of all furrows under traditional land leveling. Also, the lowest values for water consumptive use were obtained by using alternative furrow irrigation technique. Also, these results are in the same harmony with those reported by Shabana (2010). Regarding, the effect of nutrients foliar application on the values of water consumptive use and ECU data in the same table declared that the values of CU and ECU were clearly affected by nutrients foliar application. Plants spraying with mixed of micronutrients liquid fertilizer combined with potassium liquid fertilizer and humic liquid fertilizer (F_4) under all irrigation treatments recorded the highest values for CU and ECU. It might be attributed to increasing canopy area under the conditions of this treatment and hence, increasing area of the plant which exposed to sunlight. Therefore, increasing transpiration from plant surface. So, increasing amount of seasonal CU and ECU.

Water productivity (WP, kg/m³) and productivity of irrigation water (PIW, kg/m³)

The Water productivity and productivity of irrigation water were affected by irrigation and foliar application treatments for both henna leaves yield and Lawson yield Table 7. Concerning irrigation treatments, the highest overall mean values were recorded under irrigation treatments I3 for the two yields. Increasing the overall mean values for WP and PIW under the conditions of irrigation treatments (I_3) in comparison with other irrigation treatments I_2 and I_1 could be attributed to decreasing amount of both water applied and consumptive use. These results are identically with those reported by (Shabana, 2010) and (Moursi et al., 2014). Regarding the impact of foliar application, the highest overall mean values

TABLE 6. Effect of irrigation and foliar application treatments on consumptive use efficiency (ECU %) and water consumptive use (CU) m³/fed of (*Lawsonia alba* Lam) plant in the two seasons.

Irrigation treatments (I)	Foliar application treatments (F)	ECU%		CU m³/fed		The overall mean value through the two growing seasons	
		1st season	2nd season	1st season	2nd season	ECU%	CU m³/fed
I_1	F_1	62.79	63.56	2840.18	2930.30	63.18	2885.24
	F_2	59.67	60.52	2699.17	2790.25	60.10	2744.71
	F_3	61.07	61.41	2762.32	2831.25	61.24	2796.79
	F_4	63.69	64.38	2880.72	2968.27	64.04	2924.50
	F_5	59.48	58.85	2690.33	2713.12	59.17	2701.73
Mean		61.34	61.74	2774.54	2846.64	61.55	2810.59
I_2	F_1	62.82	63.03	2180.17	2520.25	62.93	2190.21
	F_2	59.37	59.89	2060.38	2090.77	59.63	2075.58
	F_3	60.24	60.19	2090.37	2100.99	60.22	2095.68
	F_4	63.97	65.03	2220.08	2270.17	64.50	2245.13
	F_5	58.50	58.74	2030.22	2050.45	58.62	2040.34
Mean		60.98	61.38	2116.24	2142.53	61.18	2129.39
I_3	F_1	59.47	59.83	2020.37	2040.42	59.65	2030.40
	F_2	58.29	58.68	1980.17	2001.18	58.49	1990.68
	F_3	58.84	58.95	1998.79	2010.25	58.90	2004.52
	F_4	60.35	60.71	2050.17	2070.33	60.61	2060.25
	F_5	57.70	58.07	1960.23	1980.25	57.89	1970.24
Mean		58.93	59.25	2001.95	2020.49	59.11	2011.22

I_1 (traditional irrigation method like to practice by local farmers in the studied area), I_2 (Irrigation furrow and left furrow with a fixed shape during the whole growing season) and I_3 (irrigation furrow and left furrow with an alternative shape during the whole growing season). F_1 (Micronutrient), F_2 (Potassium), F_3 (Humic), F_4 (Micro +Pot +Hum) and F_5 (Fresh water) for WP and PIW for both leaves and lawson yield were recorded under F_4 in comparison with other treatments. Generally, the overall mean values for WP and PIW for both leaves and Lawson yield can be descended in order $F_4>F_2>F_5>F_1>F_3$ with slight difference between F_1 and F_3.

Conclusion

For the first time, we can use innovative irrigation practices like alternative irrigation technique (irrigation furrow and left furrow with an alternative shape) on henna grown under heavy clay soil and enhance water efficiency, Water productivity (WP) and productivity of irrigation water (PIW) and gaining an economic advantage in rationalization of irrigation by saving irrigation water for about 25.47% and this saving compensates the yield reduction.

We can spray plants with micronutrients combined with potassium and humic which increasing the leaves yield /fed by 35.16%, lawson yield/plant by 43.37% and tannins yield/plant by 35.64% and alleviate water stress.

TABLE 7. Effect of irrigation and foliar application treatments on water productivity (WP, kg/m³) and productivity of irrigation water (PIW, kg/m³) for leaves yield and Lawson yield of (*Lawsonia alba* Lam) plant during the two seasons.

Irrigation treatment (I)	1st season				2nd season			
	WP		PIW		WP		PIW	
	leaves	Lawson	leaves	Lawson	leaves	Lawson	leaves	Lawson
I_1	1.24	0.025	0.76	0.015	0.95	0.017	0.59	0.011
I_2	0.99	0.018	0.60	0.011	0.69	0.012	0.42	0.007
I_3	1.59	0.031	0.94	0.018	0.96	0.017	0.57	0.010
Foliar application								
F_1	1.04	0.018	0.64	0.011	0.80	0.013	0.50	0.008
F_2	1.36	0.026	0.81	0.015	0.91	0.016	0.54	0.009
F_3	1.03	0.019	0.62	0.012	0.79	0.013	0.47	0.008
F_4	1.57	0.032	0.99	0.020	1.11	0.021	0.71	0.013
F_5	1.32	0.026	0.78	0.015	0.77	0.014	0.45	0.008

F_1 (Micronutrient), F_2 (Potassium), F_3 (Humic), F_4 (Micro +Pot +Hum) and F_5 (Fresh water).

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Conflicts of interest

None declared.

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الري التبادلى كأسلوب فعال لترشيد الري مع التسميد الورقى على نبات الحناء

ناهد مصطفى راشد *و السيد ابو الفتوح مرسى**
* قسم الخضر والزينة – كلية الزراعة – جامعة دمياط - دمياط و** قسم بحوث المقننات المائية والري الحقلى-
معهد بحوث الأراضي والمياه والبيئة - مركز البحوث الزراعية - القاهرة - مصر.

إن مشكلة نقص المياه التي تواجه مصر تتزايد باستمرار، ومن المتوقع أن تصل إلى حد الفقر المائى الذي يقل عن ٥٠٠ م٣ / سنة / فرد وهو ما يسمى بحد ندرة المياه ولذلك، فإن توفير المياه في السنوات المقبلة أمر حتمى. أجريت هذه الدراسة في المزرعة التجريبية بمحطة سخا للبحوث الزراعية بمحافظة كفر الشيخ لاستخدام تقنية الري التبادلى (الري التقليدي الذي يمارسه المزارعون المحليون في منطقة الدراسة - رى خط وخط ثابت خلال موسم النمو الكامل- رى خط وترك خط بالتبادل خلال موسم النموالكامل). مع الرش الورقى بالبوتاسيوم والعناصر الصغري والهيوميك السائل على نبات الحناء. على الرغم من تشجيع النمو الخضري الا ان الصفات الكيميائية زادت معنويا عند معاملة الرى الثالثة .وسجلت معاملة الرى الثالثة أدنى كمية ماء مضاف (٣٣٩٧,٠٩و٣٤١٠,٣٢م٣/فدان) وادنى كمية ماء مستهلك (٢٠٠١,٩٥و ٢٠٢٠,٤٩ م٣/فدان) للموسمين على التوالى. رش النباتات بالعناصر الصغرى فقط او مخلوطة بالبوتاسيوم والهيوميك سجلت اعلى صفات النمو والصفات الكيميائية ومكونات النبات فى معظم الحالات حيث زادت محصول الاوراق للفدان بنسبة ٣٥,١٦٪ ومحصول اللواسون/النبات زاد بنسبة ٤٣,٣٧٪ ومحصول التانينات/النبات ٣٥,٦٤٪. ورش النباتات بالعناصر الصغرى مخلوط بالبوتاسيوم والهيوميك سجل اعلى انتاجية للماء وانتاجية مياة الرى بالمقارنة بمعاملات الرى الاخرى فى كل من محصول الاوراق واللواسون، قلة الماء المضاف فى المعاملة رى خط وترك خط بالتبادل وفرت ٢٥,٤٧٪ من الماء خلال موسم النمو.