EFFECT OF IRRIGATION REGIMES, NITROGEN, AND MULCHING TREATMENTS ON WATER PRODUCTIVITY OF TOMATO UNDER DRIP IRRIGATION SYSTEM

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ABSTRACT

A field experiment was conducted at El-Intelaq area, West Nubaria region, Behaira Governorate (31° 02' N, 30° 28' E, and 6.7 m above mean sea level), Egypt during the 2012 and 2013 summer growing seasons to study the effect of three irrigation treatments (i.e., I_1*=75%,* I_2 *= 100%, and* I_3 *= 125% of reference ETo, which was estimated from class 'A' pan evaporation and Kpan=0.75, two nitrogen fertilizer levels (i.e.,* N_1*= 75%, and* N_2*=100% of recommended nitrogen rate), and two crop residuals mulching treatments (i.e.,* M_0 *= without mulch, and M = with mulch) on tomato yield, amounts of applied irrigation water, water consumption, applied water productivity (AWP), leaf water potential, and to develop a local tomato crop coefficient (Kc) and yield response factor (Ky) under the experimental conditions. Results indicated that, the tested variables had significant effect on tomato yield in the two growing seasons. The highest tomato fruit yields of 80.57 and 64.42 ton/ha were obtained as a result of the interaction of* I_3 *(125%ETo) and* N_2 *treatment in the two growing seasons, respectively. Total depths of applied irrigation water and water consumption of 816.2 and 838.0mm and 573 and 574mm were recorded in the 1st and 2nd growing seasons, respectively, for the* I_3 *irrigation treatment. In both seasons, the highest AWPs values were 9.73 and 9.42 kg/m*^{3} *due to the combined effect of irrigation treatment* I_1 *(75%* E_{pan}*) and* N_2 *(100% of recommended nitrogen fertilizer). Leaf water potential values were lower with the high applied water treatment than with the stressed irrigation treatment. Average crop coefficient values were 0.51 at initial growth stage during June and reached its maximum value of 0.98 during August, and then decreased to 0.71 during October. The local seasonal average tomato crop coefficient (*K_C*=ETc/ETo) and yield response factor (Ky) values under the experimental conditions were 0.74 and 0.82, respectively.*

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It was concluded that, under similar field conditions, applying a depth of water equal to 125% of ET_o and 100% of the recommended nitrogen fertilizer, and adding plant residue mulch is recommended for maximum tomato yield in the studied sandy soils under drip irrigation systems.

Key words: *tomato yield, applied irrigation water, water consumption, applied water productivity, crop coefficient, yield response factor, drip irrigation.*

INTRODUCTION

Water scarcity has become an increasing constraint to the economic development of countries in arid and semi-arid regions, e.g. Egypt, particularly for food production, which represents the biggest water user. To cope with that, many countries have been exploiting their non-renewable fossil water to relieve the immediate pressure of water stress, thus depleting their resource base and undermining their long-term economic development and food security. With the increase of water stress and the limited potential for additional water supply in recent years, improving water productivity is increasingly important. In the agricultural sector, this effort has been expressed as “more crop and higher value per drop” (FAO, 2000). Currently and in the future, irrigation management will shift from emphasizing production per unit land area towards maximizing the production per unit of water consumed, i.e. the water productivity.

Drip irrigation has been used extensively for vegetable crops to save water, fertilizer, and improve production and crop quality. Similarly, mulching has been used for moisture conservation and enhancing the quality of crop products. Drip irrigation in combination with mulch is one of the best management methods that can significantly improve the irrigation practice. Surface mulches have been used to improve soil water retention, reduce soil temperature, and reduce wind velocity at the soil surface of arid lands (Kay, 1978; Jalota and Prihar, 1998). Drip irrigation has proved its superiority over other conventional methods of irrigation, especially in the cultivation of fruits and vegetables, due to precise and direct application of water in the root zone. A considerable water saving, increased growth development and yield of vegetables under drip irrigation has been reported by (Bhella, 1988; Raina et al., 1999; Imtiyaz et al., 2000).

Applied irrigation water amounts can affect the number of fruits per plant, average weight of marketable fruits and total fruit yield/ha. In addition, significant improvement in number of fruits and total fruit yield/ha were reported as a result of mulch treatments. Application of 440mm water in two-day irrigation interval using drip system with straw mulch demonstrated economic profitable and improved water productivity due to consumption of less water (Berihun, 2011). In a study that compared the use of two different types of mulch (polyethylene and straw), mulching significantly increased fruit yield, fruit diameter, and firmness of tomato when compared to an un-mulched control. The highest yield for each mulch (81.12 t/ha for polyethylene, and 79.49 t/ha for straw) was obtained when 50% of water requirement was applied. The highest water productivity of 192 kg/ha/mm was obtained with 50% of full water application under polyethylene mulch. The study revealed that drip irrigation with mulch has an explicit role in increasing the land and water productivity of tomato (Biswas et al., 2015). Nitrogen fertilizer application has also been reported to positively impact yield. The application of 90kg N ha^{-1} produced higher fruit yield than the control treatment by 115%, 78%, and 82 % in 2004/2005, 2005/2006, and 2006/2007 seasons, respectively (Samalia et al., 2011).

The main objectives of this study were to test the effect of three irrigation treatments, two mulch treatments, and two nitrogen fertilizer levels on tomato production, amount of applied irrigation water, water consumptive use, applied water productivity (AWP), and leaf water potential, and to develop a local tomato crop coefficient (Kc) and yield response factor (Ky) under drip irrigation system in sandy soils.

MATERIALS AND METHODS

Experimental site description:

A field experiment was carried out during the 2012 and 2013 summer seasons at the experimental farm of El-Intelak area, West Nubaria Region (31^o 02' N, 30^o 28' E, and 6.7m above mean sea level), El-Behiera Governorate, Egypt. The experimental site represents the newly reclaimed sandy soils of Nubaria region. Soil samples were collected from two depths

(0-30 and 30-60cm) to determine main soil physical and chemical properties at the experimental site. The soil physical parameters (particle size distributions and soil texture class) were determined according to **FAO (1970)**. Soil-moisture constants (soil field capacity, F.C.; wilting point. W.P.; and available soil moisture, ASM) were determined on mass basis by a pressure extractor apparatus, and soil bulk density values were determined in undisturbed soil samples using the core method **(Black and Hartge, 1986)**. The soil chemical parameters (electrical conductivity (EC), soil reaction (pH), cations, and anions concentrations) were determined according to **Page et al. (1982).** The main physical and chemical properties of the soil at the experimental site are listed in Tables 1 and 2.

Table 1. Soil hydro-physical properties of the study area.

Soil depth (cm)	FC (%)	WP (%)	ASM (%)	BD (g cm^{-3})	Particle size distribution			Texture Class
					Sand %	Silt %	Clay %	
0-30 30-60	11.05 9.35	5.2 4.4	5.85 4.95	1.56 1.77	90.9 91.5	3.6 2.8	5.5 5.7	Sand Sand
Average	10.2	4.8	5.4	1.66				

Table 2. Soil chemical properties.

Soil depth (cm)	EC (dS/m)	pH	Soluble cations and anions (meq/L)						
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
0-30	1.38	9.2	1.25	0.60	1.60	0.20	1.18	1.8	0.75
30-60	1.32	9.3	1.10	0.55	1.44	0.15	1.02	1.6	0.63

Samples from irrigation water at the experimental site were collected and the analysis is presented in Table 3.

Table 3. Analysis of irrigation water at the experimental site.

Soluble anions and cations (meq/L)							EC (dS/m)	pH
HCO_3^{-}	SO_4^{2-}	Cl^{-}	Na^{+}	K^{+}	Ca^{2+}	Mg^{2+}		
1.6	0.82	1.8	2.1	0.17	1.6	0.4	0.42	9.37

Experimental design and tested variables:

A split-split plot design with four replicates was used to conduct the field experiment. The main plots were assigned to the irrigation treatments, while the sub-plots were assigned to the nitrogen levels, and the sub-sub-plots were assigned to the mulch treatments. The experimental unit consists of four drip lines.

The tested variables in this experiment were as follows:

Irrigation treatments (main plots):

I_1= irrigation with amounts of water equal to 75% of ET_o

I_2= irrigation with amounts of water equal to 100% of ET_o

I_3= irrigation with amounts of water equal to 125% of ET_o

Nitrogen levels (sub-plots):

N_1= 75% of the recommended nitrogen rate

N_2= 100% of the recommended nitrogen rate

Mulch treatments (sub-sub-plots):

M= mulching with plant residues (groundnuts straw)

M_0= without mulch.

<u>Agronomic practices:</u>

Seedlings of tomato crop (var. Castle Rock) were transplanted on June 8, 2012 and on June 11, 2013 of the first and second growing seasons, respectively. During land preparation, 24m^3/ha of chicken manure were added. During the growing seasons, nitrogen fertilizer (as ammonium nitrate, 33% N) was added with irrigation water through fertilizer tanks with injection at the rates of 166 kg N/ha (100%), 286 kg K_2O/ha (as potassium sulfate, 50% k_2O), and 71 kg P_2O_5/ha as phosphoric acid (80%) were injected through the irrigation water after transplanting tomato seedlings. Tomato fruits were collected several times up to the 10th of October 2012, and the 5th of October 2013 in the first and second seasons, respectively. All cultural practices for tomato production at this area were followed.

A surface drip irrigation system was used to conduct the experiments. The drip system includes an irrigation pump (50 hr with discharge of 150 m^3/hr) connected to sand and screen filters and a fertilizer injector tank. Main line is made of PVC pipe of 63 mm diameter, while drip lateral lines of 16mm diameter are connected to the main line. Each lateral is 25 m long and 0.8 m apart. Standard built-in emitters of 4.0 l/h discharge at operating pressure of 1.0 bar were spaced 0.5 m apart on the lateral line. Drip irrigation efficiency parameters including Christiansen coefficient and emission uniformity were determined. The values of these parameters were 0.94 and 0.92, respectively. The measured actual emitter average discharge rate was 3.8 l/h.

Studied characters:

Irrigation applied water (AW):

The AW was calculated according to the equation given by Vermeiren and Jopling (1984) for drip system as follows:

$$AW = \frac{ETo \times Kc \times I}{Du} + LR$$

where:

AW = Depth of applied irrigation water (mm).

ET_p = Potential evapotranspiration (mm d^{-1}).

Kr = Reduction factor, that depends on ground cover, a value of 1.0 was used (where the spacing between drip lines is less than 1.8 m, James, 1988).

I = Irrigation intervals (days).

Du = Distribution uniformity of the drip irrigation system, an average value of 0.8 was used as determined in the beginning of each season (Ismail, 2002**).**

LR = Leaching requirements, (LR was not considered to avoid the effect of excess water on the irrigation stress treatment, I_1).

Reference evapotranspiration (ET_o):

The ET_o values were calculated from class 'A' pan measurements located at the experimental site as follows:

$$ET_o = E_{pan} \times K_{pan} \quad \text{(Doorenbos and Pruitt, 1984)}$$

where:

E_{pan} is the measured pan evaporation values (mm/day).

K_{pan} is a pan coefficient used to estimate ET_o based on the siting and local climate. In this experiment, K_{pan}=0.75 employed.

Based on the actual emitter discharges, the irrigation time was calculated according to the equation given by Ismail (2002) as follows:

$$t = \frac{AW \times A}{1000 \times q}$$

where:

t = irrigation time (h)

A = wetted area (m^2)
q = emitter discharge (m^3/h)
AW = depth applied irrigation water (mm)

Crop evapotranspiration (ETc):

Crop evapotranspiration values were calculated according to Israelson and Hansen (1962) using the following equation:

$$ET_c = 10 \times \sum_{i=1}^{2} \left(\frac{\theta_2 - \theta_1}{100}\right) \times B_d \times d$$

Where:
for ET_c in mm, where:
i = number of soil layers
Θ_2 = available soil moisture content 48 hours after irrigation (%)
Θ_1 = available soil moisture content before irrigation (%)
d = depth of soil layers (cm)
B_d = bulk density (g cm^{-3})

Water productivity (WP):

The WP values were calculated according to Jensen (1983) as follows:

$$WP\_ = \frac{Tomato\ fruit\ yield\ (\frac{kg}{ha})}{Applied\ irrigation\ water\ (\frac{m3}{ha})}$$

Leaf water potential (Ψ_{leaf}):

Leaf water potential values (MPa) were measured with a portable pressure chamber apparatus (Soil Moisture Equipment Corp, Santa Barbara, CA, USA). Measurements were carried out on one adult leaf from each irrigation treatment at flowering, yield formation, and ripening growth stages.

Crop coefficient (Kc):

The local crop coefficient values for tomato crop were calculated as follows:

$$Kc = \frac{ETc}{ETo}$$

Yield response factor (K_y):

The yield response factor, which links relative yield decrease to relative evapotranspiration deficit, is expressed by the standard formulation given by **Vaux and Pruitt (1983)** as follows:

$$K_y = \left[\left(1 - \frac{Y_a}{Y_m}\right) \Big/ \left(1 - \frac{AW_a}{AW_m}\right)\right]$$

where:

K_y:	yield response factor
Y_a:	actual yield (t/ha)
Y_m:	maximum yield (t/ha)
AW_a:	actual amount of applied irrigation water (m^3/ha)
AW_m:	maximum amount of applied irrigation water (m^3/ha)

Statistical analysis:

The obtained data were analyzed using the Cohort software (1986) statistical package. Average values from the four replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Duncan's Multiple Range Test was used for comparisons between means according to Steel and Torrie (1980).

RESULTS AND DISCUSSION

Tomato yield:

The effect of irrigation, nitrogen fertilizer, and mulch treatments on tomato yield is presented in Table 4. Results showed significant effects of all tested variables on tomato yield. The application of irrigation treatment I_3 produced 69.65 and 56.34 ton/ha in the first and second seasons, respectively. The obtained yields were significantly higher than those obtained from the application of I_1 (50.08 and 43.66 ton/ha) and I_2 (52.28 and 47.92 ton/ha) irrigation treatments in the two growing seasons. Therefore, the application of 125% of ET_o is recommended for high tomato fruit yield in the sandy soil at the experimental site. The results were consistent with the findings of Topcu et al. (2007); they demonstrated that the yield reduction was limited to 10-20% corresponding to about 25-50% reduction of irrigation water applied.

Results revealed also that, application of 100% of the recommended nitrogen rate significantly increased tomato yield by 20.8 and 29.6% compared to that obtained from the application of 75% of the recommended nitrogen rate in the two respective seasons. Also, the application of the plant residue mulch significantly increased tomato yield by 7.6 and 14.7% compared to that obtained from no mulch treatment in the first and second seasons, respectively as shown in Table 4. The interaction between irrigation and nitrogen treatments was significant. The maximum tomato fruit yields of 63.24 and 53.77 ton/ha were obtained by irrigation treatment I_3 and the application of 100% of recommended nitrogen rate (N_2) in the two respective seasons. From the obtained results it could be concluded that, the combined effect of I_3, N_2, and M treatment is recommended to produce the highest tomato yield at the experimental site and in areas with similar conditions. The obtained results are in agreement with those reported by Kay (1978), Sarg (1983), Jalota and Prihar (1998), Mahajan and Singh (2006), Berihun (2011), Samaila et al. (2011), and Biswas et al. (2015).

Table 4: Tomato yield (ton/ha) as affected by irrigation, nitrogen fertilizer, and mulch treatments during the 2012 and 2013 summer growing seasons.

Treatments	2012	2013
Irrigation (I):		
I_1	50.08	43.66
I_2	52.28	47.92
I_3	69.65	56.34
L.S.D. at 5%	**6.24**	**4.48**
Nitrogen(N):		
N_1	51.90	42.95
N_2	62.67	55.66
L.S.D at 5%	**5.57**	**1.48**
Mulch (M):		
M_0	55.18	45.94
M	59.35	52.68
L.S.D at 5%	**3.09**	**1.05**
Interaction (I * N):		
I_1N_1	53.12	45.31
I_2N_1	53.86	46.73
I_3N_1	59.65	49.53
I_1N_2	56.71	49.54
I_2N_2	57.45	50.96
I_3N_2	63.24	53.77
L.S.D at 5%	**9.64**	**2.57**
Interaction (I * M)	N.S.	N.S.
Interaction (N * M)	N.S.	N.S.
Interaction (I * N * M)	N.S.	N.S.

Leaf water potential (Ψ_{leaf}):

Leaf water potential values for the two growing seasons are presented in Table 5. In general, the leaf water potential (Ψ_{leaf}) values decreased with growing stages of tomato crop under all treatments in the two growing seasons. The mean leaf water potential values were -1.13, -1.23, and -1.29 MPa for the flowering, yield formation, and ripening growth stages, respectively in the first season, and they were -1.19, -1.31, and -1.41 MPa in the second season. Also, mean leaf water potential values were less with increasing irrigation water and mulching. The results agree with those of Goghlan (2007) who stated that decreasing soil moisture increased leaf water potential values of tomato crop.

Table 5: Leaf water potential Ψ_{leaf}, (MPa) for tomato crop as affected by irrigation, nitrogen fertilizer and mulch treatments during 2012 and 2013 summer growing season.

Season	2012				2013			
Treatments	Flowering	Yield formation	Ripening	Season average	Flowering	Yield formation	Ripening	Season average
I_1N_1M	-1.10	-1.20	-1.32	-1.21	-1.30	-1.23	-1.44	-1.32
$I_1N_1M_o$	-1.25	-1.37	-1.45	-1.36	-1.35	-1.35	-1.50	-1.40
I_1N_2M	-1.10	-1.35	-1.38	-1.28	-1.26	-1.23	-1.35	-1.28
$I_1N_2M_o$	-1.40	-1.38	-1.33	-1.37	-1.33	-1.30	-1.50	-1.38
Average I_1	**-1.21**	**-1.33**	**-1.37**	**-1.31**	**-1.31**	**-1.28**	**-1.45**	**-1.35**
I_2N_1M	-1.20	-1.26	-1.30	-1.25	-1.17	-1.13	-1.26	-1.19
$I_2N_1M_o$	-1.40	-1.35	-1.45	-1.40	-1.23	-1.37	-1.38	-1.33
I_2N_2M	-0.97	-1.15	-1.27	-1.13	-1.21	-1.33	-1.43	-1.32
$I_2N_2M_o$	-1.26	-1.26	-1.47	-1.33	-1.30	-1.47	-1.47	-1.41
Average I_2	**-1.21**	**-1.26**	**-1.37**	**-1.28**	**-1.23**	**-1.33**	**-1.39**	**-1.31**
I_3N_1M	-0.95	-1.07	-0.98	-1.00	-1.04	-1.27	-1.34	-1.22
$I_3N_1M_o$	-1.10	-1.18	-1.20	-1.16	-1.12	-1.37	-1.47	-1.32
I_3N_2M	-0.73	-1.00	-1.08	-0.94	-0.93	-1.34	-1.37	-1.21
$I_3N_2M_o$	-1.10	-1.18	-1.20	-1.16	-1.10	-1.40	-1.40	-1.30
Average I_3	**-0.97**	**-1.11**	**-1.12**	**-1.07**	**-1.05**	**-1.35**	**-1.40**	**-1.26**
Overall average	**-1.13**	**-1.23**	**-1.29**	**-1.22**	**-1.19**	**-1.31**	**-1.41**	**-1.30**

Irrigation applied water (AW):

Monthly and total depths of applied irrigation water (mm) during the two growing seasons are presented in Table 6. Results showed the normal trend of increasing applied irrigation water with the advance in plant growth and the decrease at the ripening stage. The highest monthly value of applied irrigation water occurred during July and August in both seasons for all irrigation treatments. The total amount of applied irrigation water for 75, 100, and 125% of ET_o irrigation treatments were 583, 699 and 816 mm in the first season, while they were 526, 682, and 838 mm in the second season, respectively. The data are in agreement with those reported by Hanson and May (2006) who indicated that, the amounts of applied irrigation water for tomato crop varied between 582 and 905 mm/season.

Table 6: Monthly and total depths of applied irrigation water (mm) for tomato crop as affected by irrigation treatments during 2012 and 2013 summer growing season.

Season	2012						2013					
Irrigation treatments	Jun.	Jul.	Aug.	Sep.	Oct.	**Total**	Jun.	Jul.	Aug.	Sep.	Oct.	**Total**
I1	32.7	199.7	139.5	132.0	78.8	**582.7**	57.0	157.0	159.0	127.5	24.7	**525.7**
I2	32.7	199.7	186.0	176.0	105.0	**699.4**	57.0	210.0	212.0	170.0	33.0	**682.0**
I3	32.7	199.7	232.5	220.0	131.3	**816.2**	57.0	262.5	265.0	212.5	41.0	**838.0**

Yield response to water:

Data illustrated in Fig (1) indicated that the relation between tomato yield "Y" (t/ha) and applied irrigation water "AW" (mm) was a liner relation. The obtained relation is expressed by the following formula

$$Y = 12.9 + 0.06\,AW \qquad R^2 = 0.64$$

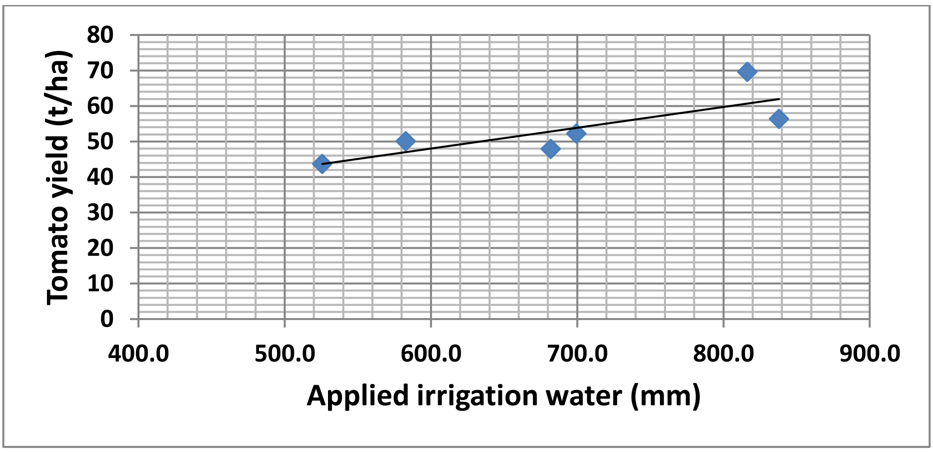

Fig. 1. Relationship between seasonal applied irrigation water (mm) and tomato yield (t/ha).

Crop evapotranspiration (ET_c):

The calculated ET_c values for tomato crop during the two growing seasons are presented in Table 7. The values were 498, 549, and 573mm in 2012 for the 75, 100, and 125% of ET_o irrigation treatments, respectively. The respective values for the 2nd season were 431, 501, and 574 mm. The highest monthly ET_c values occurred during August. The results are in agreement with those reported by Hanson and May (2006) who indicated that the calculated ET_c values for tomato crop varied between 528 and 630 mm per season. The results were also in close agreement with those reported by Goghlan (2007) who showed that water consumption by tomato crop varied between 455 mm per season for regulated deficit irrigation treatment and 532 mm/season for full irrigation treatment.

Table 7. Water consumptive use values (mm) for tomato crop as affected by irrigation treatments during 2012 and 2013 summer growing season.

Season	2012						2013					
Irrigation treatments	Jun.	Jul.	Aug.	Sep.	Oct.	**Total**	Jun.	Jul.	Aug.	Sep.	Oct.	**Total**
I_1	16	140	160	112	70	**498**	25	132	144	110	20	**431**
I_2	16	140	181	130	82	**549**	25	140	170	132	34	**501**
I_3	16	140	197	139	81	**573**	25	168	191	151.	39	**574**

Applied water productivity (AWP):

The effect of irrigation and nitrogen fertilizer treatments on AWP values for the two growing seasons is presented in Table 8. Results showed that maximum AWP values were obtained from the interaction of I_1N_2 in both seasons. The maximum values were 9.73 and 9.42 kg tomato/m^3 based on the applied irrigation water for first and second seasons, respectively. It is clear from the results that AWP values from the first were higher than those from the second growing season due to higher tomato yield. The findings were in line with those reported by Doorenbos et al. (1979). Results agree also with those of Goghlan (2007) who stated that, AWP values decreased with increasing irrigation water. He reported AWP values for tomato crop of 6.15 and 7.20 kg/m^3 for applied water using the 100 and 75% of ETo irrigation treatments, respectively.

Table 8: The AWP for tomato crop (kg tomato/m^3 water applied) as affected by irrigation and fertilizer treatments during 2012 and 2013 growing seasons.

Treatments	AWP (kg tomato/m^3 water applied)	
	2012	2013
I_1N_1	9.12	8.62
I_2N_1	7.70	6.85
I_3N_1	7.31	5.91
I_1N_2	9.73	9.42
I_2N_2	8.21	7.47
I_3N_2	7.75	6.42

Reference evapotranspiration (ET_o) and crop coefficient (K_C):

Monthly ET_o values determined from class 'A' pan, water consumption for the I_3 (125% ET_o) treatment, and the calculated crop coefficient (K_C) values are presented in Table 9. Monthly ET_o values were low in June and increased to reach maximum values in July for both growing seasons. Average K_c values were 0.51 at initial stage of growth during June, reached its maximum value of 0.98 during August, and then decreased to 0.71 during October. The results agree well with the K_C values reported by Doorenbos et al. (1979) and Doorenbos and Pruitt (1984). The Kc values were close to those of Amayreh and Al-Abed (2005) who reported K_c values of 0.69, 0.82, 1.19, and 0.76 for the vegetative, flowering, yield formation, and ripening growth stages, respectively. On the other hand, the average K_c values reported by Hanson and May (2006) ranged from 0.19 at 10% canopy coverage to 1.08 at 90% canopy coverage.

Table 9: Crop coefficient (K_C) for tomato crop as affected by irrigation treatments under drip irrigation system in sandy soils during 2012 and 2013 summer growing seasons.

Season	2012			2013			2-yr average K_c
Month	ET_o (mm)	ET_c (mm)	K_C	ET_o (mm)	ETc (mm)	K_c	
June	32.7	16	0.49	48.0	25	0.52	0.51
July	208.2	140	0.67	217.0	168	0.77	0.72
August	188.9	197	1.04	210.0	191	0.91	0.98
September	177.9	139	0.78	198.0	151	0.76	0.77
October	107.5	81	0.75	58.0	39	0.67	0.71
Season average			**0.75**			**0.73**	**0.74**

Yield Response factor (Ky):

Average tomato yields obtained from the irrigation treatments in the two growing seasons were fitted into a linear equation relating the relative yield decrease to the relative decrease in applied irrigation water (Fig. 2). The equation representing the relation is:

$$Y = 0.82\,X, \quad R^2 = 0.55$$

where:

Y: represents relative yield reduction ($1 - Y_a/Y_m$),

X: represents relative reduction in applied irrigation water ($1 - AW_a/AW_m$), the constant 0.82 represents the yield response factor (Ky) that indicates the sensitivity of tomato crop to the deficit of applied irrigation water.

The obtained Ky value under the experimental condition was about 22% less than the Ky = 1.05 value reported for tomato crop by Doorenbos et al. (1979) under deficit irrigation conditions for the whole growing season. This difference could be due to the fact that the tested treatments were not applied from seedlings transplanting (i.e. not exposing tomato plants to water stress for the whole season). Also, the short irrigation intervals (2 to 3 days) in this experiment could have a pronounced effect on decreasing the effect of water stress on the yield. The observed Ky value was close to that reported for tomato crop (Ky = 0.68) by Kirda et al. (2004) and (Ky = 0.78) by Goghlan (2007).

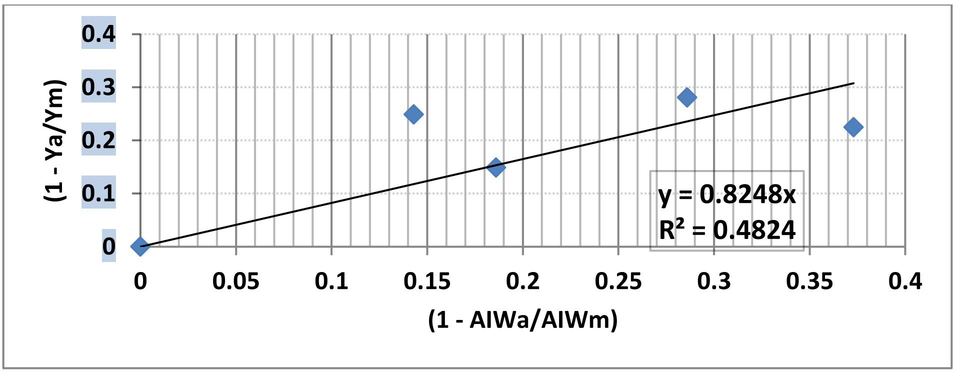

Fig. 2. Relative yield decreases as a function of relative decrease in applied irrigation water.

CONCLUSIONS

The results of this research could be summarized as following:

- There is a significant effect of irrigation, nitrogen fertilizer, and plant residue mulch treatments on tomato fruit yield.
- Applied irrigation water values were 583, 699 and 816 mm for the 75%, 100%, and 125% of ETo irrigation treatments respectively in the first season, while in the second season they were 526, 682 and 838 mm for the same respective treatments.
- Crop evapotranspiration values (ET_c) were 498, 549, and 573 mm for the 75%, 100%, and 125% of ETo irrigation treatments respectively in the first season. While in the second season, the ET_c values were 431, 501 and 574 mm for the same respective treatments.

- Maximum AWP values were 9.73 and 9.42 kg/m^3 of applied irrigation water in the first and second seasons, respectively.
- Seasonal mean crop coefficient (K_c) and yield response factor (K_y) values for tomato crop grown under the newly reclaimed sandy soil conditions at Nubaria region were 0.74 and 0.82, respectively.
- Under similar field conditions, the irrigation with amount of water equal to 125% of ET_o, 100% of recommended nitrogen fertilizer, and adding mulch of plant residues is recommended to produce high tomato crop yield in sandy soils.

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الملخص العربي

تأثير مستويات الرى، التسميد النيتروجينى، وتغطية التربة على الإنتاجية المائية للطماطم تحت نظام الرى بالتنقيط

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أجريت التجربة البحثية فى المحطة البحثية بالبستان بمنطقة غرب النوبارية فى محافظة البحيرة تحت ظروف التربة الرملية ونظام الرى بالتنقيط. وتم تطبيق ثلاث معاملات رى وهى (٧٥%، ١٠٠% و١٢٥%) من البخر نتح المرجعى ومستويين من التسميد النيتروجينى وهى (٧٥% و١٠٠%) من الإحتياجات السمادية الموصى بها. وتم دراسة تأثير هذه المعاملات على إنتاجية محصول الطماطم والإنتاجية المائية والإستهلاك المائى ومعامل المحصول تحت معاملات تغطية سطح التربة وبدون تغطية.

وأشارت النتائج إلى أن المتغيرات التى تم دراستها كان لها تأثير كبير علي محصول الطماطم في موسمي النمو محل الدراسة. وقد تم الحصول علي أعلي إنتاجية للطماطم ٨٠,٥٧ و ٦٤,٤٢ طن/هكتار تحت المعاملة I3 وN2 (١٢٥% من البخر نتح المرجعى وتسميد نيتروجينى بمعدل ١٠٠% من الموصى به) للموسمين محل الدراسة على التوالى. وسجلت كميات مياه الرى المضافة الاجماليه واستهلاك المائى ٨١٦,٢ و ٨٣٨,٠ mm و ٥٧٣ و ٥٧٤mm في الموسم الأول والثانى على التوالى. كما كانت الإنتاجية المائية ٩,٧٣ و ٩,٤٢ كجم/م٣ للموسمين الأول والثانى على التوالى.

وبلغ متوسط قيم معامل المحصول ٠,٥١ في مرحله النمو الاولي خلال شهر يونيو ووصلت قيمته القصوى إلى ٠,٩٨ خلال شهر أغسطس، ثم انخفضت إلى ٠,٧١ خلال شهر أكتوبر. وكان المتوسط الموسمى لمعاملى المحصول والإستجابة لإستخدام المياه في ظل ظروف التجريبية ٠,٧٤ و٠,٨٢ علي التوالي. وعليه أوصت الدراسة فى ظروف الأراضى الرملية وتحت نظام الرى بالتنقيط للحصول على أعلى محصول للطماطم، أن يتم الرى بمعدل ١٢٥% من البخر نتح المرجعى ولغضافة سماد نيتروجينى مع ماء الرى بالمعدل ١٠٠% من الموصى به مع عمل تغطية لسطح التربة بمخلفات المحصول لتقليل البفقد بالبخر من التربة.

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