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EFFECT OF IRRIGATION LEVELS ON GROWTH AND YIELD OF TOMATO UNDER EL-ARISH REGION CONDITIONS

Safaa A.M. El-Labad[1*], M.I. Mahmoud[1], S.A. Abo El-Kasem[2] and A.I. El-Kassas[1]

1. Dept. Plant Prod., Fac. Environ. Agric. Sci., Arish Univ., Egypt.

2. Dept. Self-Pollinated Veg. Res., Inst. Hort. Res., Cent. Agric. Res., Egypt.

ABSTRACT

Field experiments were carried out in summer season of 2017 and 2018 at the Experimental Farm, Faculty of Environmental Agricultural Sciences, Arish University, North Sinai to study the effect of four irrigation levels (100%, 80%, 60% and 40% of irrigation requirements) on growth and yield of tomato. Seeds of "GS_{12} F_1" hybrid were sown in plastic speeding trays on 14th March and transplanting was carried out on 23rd April. Plants were irrigated using drip irrigation system, the distance between dripper lines centers was 1.2 m. The plot area was 14.4 m^2 (12 m length and 1.2 m width), the distance between the plants in the same row was 50 cm, planting density was 1.67 plant/m^2. The highest values of all studied vegetative growth traits, fresh and dry weights, and contents of chlorophyll a, chlorophyll b, and carotenoids were recorded with application of 80% followed by 100% irrigation levels. The highest value for each of grade a, grade b, and total marketable fruit yield per fad., were recorded with the 80% irrigation level in both seasons. The highest unmarketable yield was recorded with the use of the irrigation level of 60%, while the lowest values were recorded with application of 100% or 80% irrigation level.

Key words: Irrigation, tomato, requirements, levels, water use, efficiency.

INTRODUCTION

Increasing water scarcity will observe less increase in irrigated land availability for food production than in the past. While irrigation can benefit yields and enhance water use efficiency (WUE) in water limited environments, the potential for full irrigation is decreasing, so, irrigated agriculture is to improve WUE and sustainable water use for agriculture. Salt stress in soil or water is one of the major stresses especially in arid and semi-arid regions and can severely limit plant growth and productivity **(Allakhverdiev *et al*., 2000; Koca *et al*., 2007). Ismail *et al.* (2007)** found that increasing water supply increased the root development and root biomass. **Al-Omran *et al.* (2010)** studied the effects of water quality, irrigation system, irrigation rates and type of amendment on the yield and quality of tomato plants. They found that at a high irrigation rate (6 l h^{-1}), tomato yields were higher and decreased significantly at a low irrigation rate (2 l h^{-1}) in both seasons. Low quality of irrigation water significantly increased fruit pH".

Berihun (2011) studied the effect of mulch and amount of water on the yield of tomato under drip irrigation system and to assess the potential of deficit irrigation to improve the economic efficiency of tomato production at North Western Ethiopia. He found that amount of water significantly affected the number of fruits per plant and average weight of fruits, marketable and total fruit yield/ha". **Ezekiel (2013)** studied the effect of water regime and mulching on the growth and yield of tomato in Nigeria to

*** Corresponding author:** Tel.: +201090854071
E-mail address: safaaahmed497@gmail.com

evaluate water management options on the performance of tomato. They found that water regime of 0.3, 0.4 and 0.5 litre/day/ plant gave the following yield 112.3, 140.01 and 154.34 g/pot. **Sibomana *et al.* (2013)** subjected tomato Money Maker *cv.* to four soil moistures these hold levels of 100%, 80%, 60% and 40% Field capacity. They reported that severe water stress (40% of FC resulted in significant decreases in chlorophyll content and chlorophyll concentration by 32% compared to the control).

Biswas *et al.* (2015) studied the effects of drip irrigation and mulches on yield, water-use efficiency and economic return of tomato plant at different combinations of three drip irrigation levels (100, 75 and 50% of crop water requirement) and two mulches (black polyethylene sheet and paddy straw). They found that the yield and yield-contributing characters in the mulched treatments for all levels of irrigation were significantly higher compared to those in the un-mulched treatments. The yield of tomato increased with increasing amount of irrigation water in un-mulched treatment. The trend was reversed when drip irrigation was coupled with mulches."

Ragab *et al.* (2018) studied the alleviating of water stress for tomato plants cultivated in a sandy soil and were exposed to deficit irrigation (DI) treatments; 100%, 85%, 70% and 55% of Evapotranspiration maximum (ETm), using two irrigation systems (surface drip irrigation (SDI) and subsurface drip irrigation (SSDI), Results clearly indicated that the full irrigation treatment 100% ETm produced the highest significant values of total leaves area and fresh and dry weights of tomato leaf per plant. Increasing the irrigation water from 55% ETm to 100% ETm produced a good vegetable growth of tomato plants which affected positively on the flowering (number of flowers per plant) and fruit yield. Decreasing irrigation water significantly increased TSS, total sugars and ascorbic acid content in tomato fruits, where 55% ETm treatment produced the highest significant values.

Arish soil is characterized as sandy soil, generally, has low moisture holding capacity, single grain structure, susceptibility to erosion and has low levels of nutrients and microorganisms. Irrigation in this area depends on wells of underground water with low quality (high saline water). So, this study aimed to use the prober irrigation level for tomato production which save water under such conditions.

MATERIALS AND METHODS

Field experiments were carried out for two consecutive growing summer seasons of 2017 and 2018 at The Experimental Farm of Environmental Agricultural Sciences Faculty, Arish University, North Sinai to study the effect of four irrigation levels (100%, 80%, 60% and 40% of tomato plant requirements from water during all plant growth stages) on growth and yield of tomato. Seeds of "Gs_{12} F_1" phybrid were sown in plastic seedling trays on 14th March and transplanting was carried out on the 23rd April.

Plants were irrigated using drip irrigation system, the distance between the plants in the same row was 50 cm, while the distance between dripper lines centers was 1.2 m. The plot area was 14.4 m^2 (12 m length and 1.2 m width), planting density was 1.67 plant/m^2. Four irrigation levels were used. Chemical analyses of irrigation water as well as physical and chemical analyses of experimental soil are shown in Tables 1 and 2. Soil parameters determined before conducting the experiments were particle size distribution (**Pipper, 1950**), total carbonate (**Jackson, 1967**), and soil pH value was determined in 1: 2.5 soil water suspension. The soil water extract for 1:5 soil water ratio was chemically analyzed for electrical conductivity (EC) according to **Richard (1954)** and **Jackson (1967).**

Table (1): Chemical properties of irrigation water.

pH	EC dSm^{-1}	Soluble ions ($me\ l^{-1}$)							
		Cations				Anions			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{--}	SO_4^{--}
First season (2017)									
7.55	5.56	20.50	16.80	18.50	0.24	45.92	2.90	-	7.58
Second season (2018)									
7.60	5.71	21.00	17.00	18.80	0.25	46.77	2.99	-	7.29

Table (2): Physical and chemical properties of investigated soil profile of cultivated area.

Particles size distribution (%)		
	First season (2017)	**second season (2018)**
Coarse sand (%)	58.3	59.5
Fine sand (%)	19.8	19.3
Silt (%)	12.9	12.0
Clay (%)	10.0	10.1
Soil texture	**Sandy loam**	**Sandy loam**
Bulk density (Mgm^{-1})	1662	1661
Chemical properties (Soluble ions (in 1:5 soil water extract)		
Ca^{+} (mel^{-1})	3.90	3.90
Mg^{+} (mel^{-1})	3.42	3.43
Na^{+} (mle^{-1})	2.54	2.55
K^{+} (mel^{-1})	0.34	0.32
CO_3^{-} (mle^{-1})	-	-
HCO_3^{-} (mel^{-1})	4.30	4.40
Cl^{-} (mel^{-1})	4.40	4.35
SO_4 (mel^{-1})	1.50	1.45
EC($dSml^{-1}$)	1.04	1.02
pH (in1:2.5 Soil water suspension extract)	8.10	8.13
Organic matter (%)	0.153	0.171
$CaCO_3$ (%)	22.43	22.48

Irrigation treatments started after three weeks from transplanting. Data recorded were as follows: Three plants were randomly chosen for determining the following parameters: vegetative growth; fresh and dry weight of plant; leaves content of photosynthetic pigments (all at 30 and 60 days after transplanting), fruit yield and its component and fruit quality.

Treatments were randomly distributed in a complete randomized block design in three replications. Irrigation water levels were randomly distributed in main plots. The normal agricultural practices were carried out as commonly followed in El-Arish region. The obtained data were subjected to statistical analysis of variance according to **Snedecor and Cochran (1980**), and means separation was done according to **Duncan (1955)**. M. Stat C programmer was used for analysis.

RESULTS AND DISCUSSION

Effect of Irrigation Levels

Vegetative growth

Data in Table 3 show significant effects on all vegetative growth traits, except plant height in the first season at 30 days after transplanting, leaf area per plant in both seasons, number of leaves per plant in both seasons, and number of branches in the second season at 30 days after transplanting. The highest values of most studied traits were recorded with applying the irrigation level of 80% followed by 100%.

These results may be due to that drip irrigation had higher efficiency of providing plants with their requirements of water and nutrients. Many researchers came to similar results, **Sibomana *et al.* (2013)** found that' Severe water stress (40% of FC) reduced the tomato plant height by 24%, and stem diameter by 18%'. Also, **Ragab *et al.* (2018)** indicated that 'increasing the irrigation water from 55% ETm to 100% ETm produced a good vegetable growth of tomato plants which affected positively on the flowering and fruit yield, full irrigation treatment (100% ETm) produced the highest significant values of total leaf area'.

Fresh weight

Data in Table 4 show significant effects for irrigation levels on all fresh weight traits in both seasons. The highest values of root fresh weight were recorded with application of 100% irrigation level in both sampling dates in both seasons, the highest values of stem fresh weight were recorded with 80% irrigation level at the first sampling date and with 100% irrigation level at the second sampling date in both seasons. Concerning leaf fresh weight, the highest values was recorded with application of 100 or 80% irrigation level without significant difference between them at both sampling dates in both seasons.

Regarding total plant fresh weight, the highest total fresh weight was recorded with application of 100% or 80 irrigation level at both sampling dates in both seasons. These results may be due to that plants had their requirements from water and nutrients with application of 100% or 80% levels of irrigation using drip irrigation system. In this concern, **Ragab *et al.* (2018)** reported that 'the full irrigation treatment (100%) Etm produced the highest significant value for each of total leaf area and fresh and dry weights of tomato leaves per plant'.

Dry weight

Data in Table 5 show significant effects due to the application of irrigation levels on all dry weight traits in both seasons, except, stem dry weight at 30 days after transplanting in the first season. The highest value for each of dry weight of roots, stem and total plant dry weight followed the same trend of fresh weight in Table 4, while the highest leaves fresh weight was recorded with application of 80% irrigation level at the first sampling date and with application of

100% irrigation level at the second sampling date in both seasons. These results might be due to good vegetative growth (Table 4) which reflected higher photosynthetic process that led to higher dry matter accumulation. These results are in harmony with the findings of **Ragab *et al.* (2018)** who reported that 'the full irrigation treatment (100% Etm) produced the highest significant value for each of total leaf area and fresh and dry weights of tomato leaves per plant'.

Leaves chlorophyll and carotenoids content

Data in Table 6 show significant effects for irrigation levels on all studied traits in both seasons, except, content of chlorophyll a at 30 days after transplanting in the second season, and content of chlorophyll b at the first sampling date in the first season. The highest contents of chlorophyll a was recorded with application of 80% or 100% irrigation level. The highest content of chlorophyll b was recorded with application of 100%, 80% or 60% irrigation level in the first sampling date, while its highest content at the second sampling date was recorded with application of 80% irrigation level in both seasons. The highest content of carotenoids was recorded with application of 100%, 80% or 60% irrigation level in the first sampling date, while its highest content at the second sampling date was recorded with application of 80% irrigation level in both seasons. These results may be due to the effect of irrigation treatments on vegetative growth (Table 4) where higher vegetative growth especially leaves area reflected higher photosynthetic prosses.

Yield and its components

Data in Table 7 show significant effects for irrigation levels on all marketable fruit yield and its component traits in both seasons, except weight of grade b fruits in both seasons. Concerning mean weight of grade (a) fruit, the heaviest fruits were obtained due to application of 100% irrigation level in both seasons. The irrigation level 0f 80% resulted in the highest value of number of fruits and fruit weight of grade a, grade b, and total fruit yield, except number of fruits of grade b in both seasons. These results are on the same line of results of **Biswas *et al.* (2015)** who found that the yield of tomato increased with increasing amount of irrigation water in un-mulched treatment. The trend was reversed when drip irrigation was coupled with mulches. Concerning unmarketable yield data in Table 8 show significant effects for irrigation treatments on studied traits in both seasons. The highest number of unmarketable fruits was recorded with the use of the lowest irrigation levels (60 and 40% irrigation levels), while the lowest values were recorded with application of 100% or 80% irrigation level. The highest unmarketable fruit yield was recorded with application of 60% irrigation level in both seasons.

Fruit quality

Data in Table 9 indicate significant effects of irrigation levels on all fruit quality traits, except, fruit diameter and fruit shape in both seasons and fruit pH in the second season. The highest value of fruit length was recorded with application of 80% level in both seasons. The highest pericarp thickness was with 100% irrigation level in both seasons, the highest value of fruit TSS% was obtained due to 40% followed by 60% irrigation level in both seasons.Concerning content of Vitam. C and fruit pH, the highest records were with application of 80% irrigation level in both seasons. These results are in agreement with those of **Ragab *et al.* (2018)** who reported that decreasing irrigation water significantly increased TSS%, total sugars and ascorbic acid content in tomato fruits, where 55% ETm treatment produced the highest significant values.

Table (3): Effect of irrigation water levels on vegetative growth of tomato plant in 2017 and 2018 seasons..

Parameter / Irrigation water levels (requirements)	Plant height (cm)		Root length (cm)		Leaf area/ plant (m^2)		Number of leaves/plants		Number of branches/plants	
	Days after transplanting									
	30	60	30	60	30	60	30	60	30	60
	First season									
100%	53.08a	74.08ab	28.4ab	42.58b	2.54b	3.55b	7.66a	13.17a	3.91ab	7.50ab
80%	55.50a	80.83a	31.58a	50.83a	2.88a	3.90a	7.16a	13.67a	4.25 a	8.00a
60%	49.17a	73.08ab	27.92b	48.17a	1.96c	2.22c	6.66a	9.91b	3.33b	6.75b
40%	49.58a	70.92b	26.25b	33.08c	1.85c	2.00c	6.16a	7.58c	3.02b	5.33c
	Second season									
100%	54.33ab	76.33ab	29.08b	44.42b	2.63b	3.09b	8.33a	14.92a	4.33a	8.83ab
80%	57.25a	81.75a	32.50a	51.50a	2.96a	3.66a	9.00a	15.00a	4.50a	9.83a
60%	51.33a	76.08ab	27.96b	9.33ab	2.22c	2.49c	8.00a	11.33b	3.50a	7.91b
40%	51.00ab	71.83b	27.00c	34.28c	1.89d	2.34c	7.25a	8.70c	3.25a	6.75c

Means having the same alphabetical letter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table (4): Effect of irrigation water levels on fresh weight (g) of tomato plant in 2017 and 2018 seasons.

Parameter / Irrigation water levels (requirements)	Root		Steam		Leaves		Total	
	Days after transplanting							
	30	60	30	60	30	60	30	60
	First season							
100%	42.82a	65.74a	30.24b	73.96a	133.3ab	267.7a	206.36a	407.4a
80%	33.96b	50.07b	37.51a	66.94b	139.1a	301.1a	210.57a	418.11a
60%	22.71c	39.58c	23.44c	40.79c	123.0b	226.7ab	169.15b	307.07b
40%	22.01c	33.29d	21.24c	33.86d	134.5ab	170.1b	177.75b	237.25c
	Second season							
100%	43.51a	67.61a	32.73b	78.26a	143.1a	299.5a	219.34a	445.37a
80%	34.89b	52.41b	39.20a	68.29b	141.8a	304.7a	215.89a	443.4b
60%	23.74c	41.46c	25.72c	41.31c	125.3c	228.7b	174.76c	309.5c
40%	25.89c	35.51d	23.92c	35.97d	135.2b	187.6c	185.01b	259.08d

Means having the same alphabetical letter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table (5): Effect of irrigation water level on dry weight of tomato plant in 2017 and 2018 seasons.

Parameter / Irrigation water levels (requirements)	Dry weight /plant (g)							
	Root		Steam		leaves		Total	
	Days after transplanting							
	30	60	30	60	30	60	30	60
	First season (2017)							
100%	16.26a	23.51a	7.38a	16.89b	22.09a	51.41a	46.09a	91.81a
80%	12.96a	18.70b	7.88a	17.75a	23.65a	53.27a	44.49a	89.72a
60%	9.48b	11.18c	6.76a	10.94c	18.98b	26.99b	35.22b	49.11b
40%	7.70b	9.04d	6.61a	8.69d	13.13c	18.08c	27.44c	35.81c
	Second season (2018)							
100%	17.38a	25.92a	8.44a	18.43b	23.48a	56.72a	49.3a	101.07a
80%	14.52a	19.83b	9.11a	19.60a	24.69a	55.25a	48.32a	94.68b
60%	10.50b	12.51c	7.73ab	12.12c	20.14c	27.13c	38.37c	51.76c
40%	8.80b	10.18c	6.73b	9.70d	14.55d	19.18d	30.08d	39.06d

Means having the same alphabetical letter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table (6): Effect of irrigation water level on chlorophyll and carotenoids content of tomato leaves in 2017 and 2018 seasons.

Parameter / Irrigation water levels (requirements)	Chlorophyll a ($mgg^{-1}FW$)		Chlorophyll b ($mgg^{-1}FW$)		Carotenoids ($mgg^{-1}FW$)	
	Days after transplanting					
	30	60	30	60	30	60
	First season (2017)					
100%	3.125a	3.905ab	1.809a	1.947b	2.193a	2.642 b
80%	3.174a	4.305a	1.769a	2.207a	2.203 a	2.892 a
60%	3.115a	3.506bc	1.657a	1.781b	2.090 a	2.384 c
40%	2.537b	3.232c	1.316a	1.697b	1.689 b	2.208 c
	Second season (2018)					
100%	3.093a	4.184a	1.753a	2.04b	2.214 a	2.682 a
80%	2.980a	4.216a	1.762a	2.213a	2.206 a	2.830 a
60%	2.995a	3.715b	1.765a	1.879bc	2.224 a	2.453 b
40%	2.623a	3.207c	1.577b	1.783c	1.903 b	2.289 b

Means having the same alphabetical letter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table (7): Effect of irrigation water level on marketable yield of tomato plants in 2017 and 2018 seasons.

Parameter / Irrigation water requirements	Grade A fruits			Grade B fruits		Total Yield	
	Mean fruit weight (g)	No. fruits (m^2)	Weight of fruits (ton fad^{-1})	No. fruits (m^2)	Weight of fruits (ton fad^{-1})	No. fruits (m^2)	Weight of fruits (ton fad^{-1})
				First season (2017)			
100%	92.63a	31.58b	12.91b	3.693b	12.00a	43.58c	16.61b
80%	71.59b	44.00a	14.09a	4.442ab	17.42a	61.42a	18.53a
60%	70.24b	31.50b	10.67c	4.744ab	20.67a	52.17b	15.41c
40%	71.40b	30.25b	9.361d	5.654a	19.92a	50.17b	15.05c
				Second Season (2018)			
100%	91.85a	33.56b	13.45b	3.485b	12.00a	44.66c	17.32b
80%	70.75b	45.63a	14.66a	4.563ab	17.42a	62.45a	19.41a
60%	71.66b	33.51b	11.36c	4.522ab	20.67a	45.20b	16.32c
40%	71.42b	33.35b	10.61d	5.632a	19.92a	53.23b	16.10c

Means having the same alphabetical letter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table (8): Effect of irrigation water level on fruit un-marketable yield of tomato in 2017 and 2018 seasons.

Parameter / Irrigation water requirements	Number of fruits/m²	Yield/fad. (ton)	Number of fruits/m²	Yield/fad. (ton)
	First Season (2017)		Second Season (2018)	
100%	9.672b	1.262b	9.650 b	1.283 b
80%	9.904 b	1.233 b	9.904 b	1.264 b
60%	10.97 a	1.384 a	10.85 a	1.412 a
40%	11.07 a	1.202 b	11.11 a	1.227 b

Means having the same alphabetical letter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

Table (9): Effect of irrigation water levels on quality of tomato fruits in 2017 and 2018 seasons.

Parameter / Irrigation levels	Fruit Length (cm)	fruit diameter (cm)	Fruit shape (L/D)	Pericarp thickness (mm)	Fruit TSS (%)	Vitamin. C (mg/100 g)	pH of fruits
				First season (2017)			
100%	49.38ab	55.29a	0.8983a	2.375a	5.417c	19.83ab	4.525b
80%	52.76a	53.94a	0.9858a	1.942ab	5.583bc	20.83a	4.642a
60%	48.07b	49.84a	0.9775a	1.842ab	6.833ab	18.50bc	4.550ab
40%	47.79b	49.04a	0.9842a	1.517b	7.083a	17.33c	4.500b
				Second season (2018)			
100%	48.56b	52.29a	0.9167a	2.417a	5.583b	18.92b	4.533a
80%	52.18a	51.94a	0.9958a	2.058a	5.667b	20.92a	4.625a
60%	48.36b	50.84a	0.9558a	1.975a	6.583ab	17.75bc	4.583a
40%	46.74b	50.04a	0.9558 a	1.442b	7.083a	17.000c	4.517a

Means having the same alphabetical letter (s) are not significantly differ at 0.05 level according to Duncan's multiple range test.

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الملخص العربى

تأثير مســـتويـات الري علـى نمـو ومحصـول الطماطم تحت ظروف منطقة العريش

صفاء أحمد محمود اللباد[١]، محمود إبراهيم محمود[١]،
سامح عبد الحفيظ أبو القاسم[٢]، على إبراهيم القصاص[١]

١- قسم الإنتاج النباتي، كلية العلوم الزراعية البيئية، جامعة العريش، مصر.

٢- قسم بحوث الخضر ذاتية التلقيح، معهد بحوث البساتين، مركز البحوث الزراعية، مصر.

نفذت تجربة حقلية في الموسم الصيفي لعامي ٢٠١٧، و٢٠١٨م بالمزرعة البحثية لكلية العلوم الزراعية البيئية- جامعة العريش بهدف دراسة تأثير استخدام أربع مستويات من الري (١٠٠%، ٨٠%، ٦٠%، و٤٠% من الإحتياجات المائية) على نمو وإنتاجية الطماطم، زرعت بذور هجين الجيل الأول"حي إس ١٢" في صواني بلاستيكية لإنتاج الشتلات في ١٤ مارس، وتم الشتل في ٢٣ أبريل في الموسمين. استخدم نظام الري بالتنقيط، حيث كانت المسافة بين خطوط الري بالتنقيط ١,٢متراً، وبين النباتات في نفس الخط ٥٠سم، كانت مساحة الوحدة التجريبية ١٤,٤م٢ (١٢م طول×١,٢م عرض)، وبذلك فإن الكثافة النباتية كانت ١,٦٧نبات/م٢، تحققت أعلى القيم لكل صفات النمو الخضري، والوزن الطازج والجاف للنبات، وكذا محتوى الأوراق من صبغات كلوروفيل أ، وب، والكاروتين مع استخدام مستوى الري ٨٠% تبعه مستوى الري ١٠٠%، ونتج أعلى محصول قابل للتسويق من ثمار الدرجة الأولى والثانية والمحصول الكلي مع استخدام مستوى الري ٨٠% في الموسمين. أما أعلى محصول غير قابل للتسويق فنتج من استخدام مستوى الري ٦٠%.

الكلمات الإسترشادية: الرى، محصول الطماطم، ، مستويات، المياه، كفاءة.

المحكمون:

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