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Effect of Irrigation Systems, Pulse Irrigation Technique and Cobalt Application on Productivity and Water use Efficiency of Tomato Plants Grown in New Reclaimed Soil

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Abstract

Egypt is one of the countries facing serious shortage of water resources, so it is advised to evaluate new possible approaches to minimize the plant water consumption and hence to rationalize irrigation water use. Realizing the need of water use optimization in the context of water scarcity and increasing agricultural productivity, this can be achieved by choosing the proper water management and improving plant- soil properties. So that a study was carried out at the Experimental Farm of the Water Studies and Research Complex (WSRC) Station, National Water Research Center, Toshka – Abu simbel city, Egypt during the two growth seasons of 2015 and 2016. The experiment aimed to test suitability of new irrigation system approach (integral drip irrigation), influence of cobalt application and pulse technique on water use efficiency (WUE) and tomato yield grown in newly reclaimed soils.

In this study, results demonstrated that the individual influence of using the integral drip irrigation system (IDI) caused significant increases in tomato yield and water use efficiency more than individual influence of cobalt application and pulse technique. The results indicated also that using cobalt application and pulse technique under integral drip irrigation system caused increases in tomato yield by 641.9 % from the lowest average value which had been recorded in control treatment under subsurface irrigation system.

Thus, we can conclude that integral drip irrigation system is more suitable under Toshka climatic condition to improve water consumption and caused significant increases in tomato yield and water use efficiency especially when cobalt application and pulse technique are used. This treatment gives the highest net return and benefit-cost ratio to the farmers.

Keywords: *Tomato, Integral drip irrigation, Cobalt application, Pulse technique.*

Introduction

In arid regions such as toshka district (Aswan), water scarcity is an increasing concern and water costs are rising. These challenges have forced farmers to use water carefully. Thus using innovative water saving strategies are quite important in this environment.

One of these innovative water saving substances are using modern irrigation systems. Proper irrigation management will help in saving more water which can be used to cultivate more land. Rahman (1996) reported that the need for water conservation initiated government efforts to encourage farmers to adopt modern irrigation systems of sprinklers, trickle and bubblers, coupled with agronomic management, institutionalization and augmentation of resources by desalinization, waste water treatment, fog collection and rainwater harvesting through recharge dams. The benefits of this irrigation methods, such as reducing surface soil water evaporation, decreasing fertilizers leaching, enhancing yield and so on, have been documented by different researchers. Improved irrigation methods are considered as the leading water saving technologies in irrigated agriculture, At present the total of world irrigated area about 15% (44 million ha) is equipped with pressurized methods, comprising sprinkler irrigation (35 million ha) and micro irrigation (9 million ha). Most of the pressurized irrigated area is concentrated in Europe and Americas. There is a vast range of sprinkler and micro irrigation systems suiting to small and large farm sizes, soil and crop types. Improved surface irrigation methods like level furrows, dead level basins also provide high application efficiency (Suresh Kulkarni, 2011). Badr *et al.,* (2001) stated that drip irrigation systems is better system used on sandy and sandy loam soils under Egyptian conditions, where surface water with low salinity levels are used. The drip irrigation system conserved about 30% of water as compared with surface irrigation (Cetin *et al*., 2002), as it allows small but frequent application of water with minimum losses. In addition, it does not increase air humidity above crop canopy, as much as sprinkler irrigation. Also in recent years, however, growing competition for scarce water resources has led to applying modified techniques for maximizing water use efficiency and improving crop yields and quality, particularly in arid and semi arid regions (Abdelraouf, 2015).

Another innovative water saving substances are using pulse irrigation, the objective of pulse irrigation is to allow no leaching by applying small amounts of water by micro tube. Intermittent water application allows reducing mean irrigation rate to a level which coincides with soil's hydraulic conductivity and minimizes percolation below the main root zone. Pulsating can be applied in any irrigation method however. Is primarily applicable in drip irrigation systems. Pitts *et al.,* (1991) found that the two drip irrigation frequencies (three times per day, one time per day) had not affected tomato yield, however, root length density was significantly affected by irrigation treatment at the 0 to 0.15 m depth with the more frequent irrigation treatment having less root length density. Also Beeson (1992) stated that pulse-irrigated plants tended to accumulate less daily water stress with less water stress, plants grew faster and remained healthier than plants that were stressed on a daily basis. Another benefit is that disease prevention is less difficult. Alternatively the major drawback with pulsing is the possible increase of soluble salts. It also stated by (Clothier and Green, 1994; Coelho and Or, 1996) that the role of pulse irrigation may play in improving yield and fruit quality. Pulse irrigation under stressful environments results in larger fruit which has a major impact on farm profitability. On the other hand, Evidence shows that root systems under partial soil wetting are dominated by wetting patterns under the drippers. These limited root systems might not affect crop growth when the main nutrients are applied through irrigation system.

In spite of the absence of evidence for direct role of cobalt in plant metabolism, it is considered to be a beneficial element for higher plants and it is promising element in the newly reclaimed soils. Cobalt (Co) is an inhibitor which has a vital role in defining water consumption by growing plants, reducing transpiration rate and leaf water potential (Nagarajah and Rathooriya, 1977), Moral and Gomez (1999) reported that Cobalt treatments did not affect tomato production, but fruit quality, such as electrical conductivity and fruit acidity, seemed to be affected. Fruits tended to become more acidic. Kumari (2002) indicated that cobalt is border elements; it has a positive effect on higher plants to adapt water stress conditions, which include salinity and drought. Mobility of cobalt was greatest with the saline soils but lowest with alkaline ones. Also Abd-El-Moez and Nadia Gad (2002) found that the addition of 8 ppm cobalt in plant media increased fresh and dry weights of shoots and roots of cowpea plants. Also, cobalt increased the contents of macronutrients (N, P and K) as well as micronutrients (Fe, Mn and Zn), while Shanon, (2002) pointed out that cobalt was used to reduce the harmful effect of salinity on tomato plants, where the transpiration rate being reduced. Nadia Gad (2005) indicated that a cuticle tissue of tomato leaves was increased as cobalt addition increased. Also Chao-Zhou *et al.* (2005) reported that the potato leaves were deeply stressed and damaged, through the inhibition of ethylene production, cobalt (Co) alleviated the decline in polyamine content and the activities of anti-oxidative enzymes, and hence alleviated the increment in reactive oxygen species levels and membrane damage and showed protective effects on the leaves.

Tomatoes (Lycopirsecon esculentum) are one of the most important vegetable crops around the world in terms of human consumption, and they are also the most popular garden vegetable. Sharaf and Azza Hassan (2006) showed that average yield of tomato grown on Alexandria in clay soils during the summer season were 24.19, 26.75 and 27.7 ton/feddan corresponding to water balance with Penman-Monteith, water balance with evaporation pan and tensiometers, respectively. The averages of applied irrigation water were 2130, 2340 and 2445 m3/fed for the same previous order. Also Kamal and El-Shazly (2013) concluded that irrigation tomato plants with 1800 m^3 fed^{-1} combined with soil application of K-humate (2 kg fed^{-1} in every addition, 4 times during the season) incorporated with drip irrigation water could be recommended to improve yield and quality of tomato plants in sandy soil in newly reclaimed lands. While shabana *et al.* (2015) studied improving the productivity of tomato using some safe and natural agents i.e., yeast, sea weeds extracts, vitamin E and C, as well as Marjoram oils and Tangerine oils. At El- Baramoun farm, Mansoura horticulture research station during late hot summer seasons of 2012 and 2013, he indicated that highest yield was obtained by using vitamin C, tomato yield were 16.7 and 15.3 ton / fed. in the first and second seasons, respectively.

Thus the aim of this investigation is to:-

- Test the suitability of new irrigation system approach (integral drip irrigation) on water use efficiency and tomato yield grown on newly reclaimed lands.

- Study the individual and combined influence of irrigations systems, cobalt application and pulse technique on water use efficiency and tomato yield.

Materials and Methods

Field experiments were carried-out at the experimental farm of Water Studies and Research Complex (WSRC) station, National Water Research Center, Toshka – Abu Simbel city, Egypt. The soil texture is loamy sand. Some physical and chemical properties were measured according to Klute (1986) and Page (1982) and are given in Table 1.

Agricultural practices and cultivation:-

In the late summer seasons of 2015 and 2016, tomato seedlings (Super Strain B, variety) were transplanted in plots (50 cm apart) at July 25 in each growth season. All agronomic practices were done as recommended for tomato production at Toshka district. Nitrogen, phosphorus and potassium fertilizers were added according to the recommended levels.

Table 1. Some analytical data of the studied soil and groundwater of the experimental site.

A- Physical properties of the studied soil.

Soil depth (cm)	Particle size distribution (%)			Tex. class	S.P. (%)	F.C (%)	W.P (%)	A.W. (%)	BD (g/cm^3)
	Sand	Silt	Clay						
0-20	86.19	0.86	12.95	L. s	28.70	13.9	2.0	11.9	1.41
20-40	86.21	1.18	12.61	L. s	29.30	13.6	2.0	11.6	1.41
40-60	90.80	1.23	7.97	s	27.40	12.3	2.1	10.2	1.40

L.S = Loamy sand, S = Sandy, S.P= Saturation percent, F.C= Field capacity
W.P = Wilting point, A.W= Available water, B.D= Bulk density

B- Chemical properties of the studied soil.

Soil depth (cm)	CaCO^3 (%)	OM %	*pH (1:1)	EC dS/m) (1:1) Soil extract	Soluble ions (meq/l)						
					Anions			Cations			
					CO_3^{-2}+ $HCO3^-$	SO_4^{-2}	Cl^-	Ca^{+2}	Mg^{+2}	Na^+	K^+
0-20	5.00	0.37	7.88	1.20	0.20	9.20	2.60	6.60	0.40	5.40	0.10
20-40	4.58	0.39	7.90	1.25	0.20	9.30	3.00	7.40	0.40	4.80	0.20
40-60	4.17	0.17	7.92	0.65	0.20	3.50	2.80	4.40	0.60	1.10	0.01

*pH in (1:1) soil to water suspension

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C- Chemical analysis of the ground water (irrigation water).

time	pH	TDS		Cations (meq/l)				Anions (meq/l)			SAR
		EC (dS/m)	mg/l (ppm)	Na^{+}	K^{+}	Mg^{+2}	Ca^{+2}	Cl^{-}	$CO_3^{-2}+HCO3^{-}$	SO_4^{-2}	
2015	6.96	0.71	454.4	4.56	0.22	0.86	1.59	3.52	2.55	1.06	4.12
2016	6.95	0.73	467.2	4.75	0.30	0.89	1.6	3.55	2.6	1.1	4.26

TDS = Total dissolved solids. SAR= sodium adsorption ratio.

Experimental design:-

To fulfill the purpose of the current study, three experimental sites were chosen in the experimental farm of water studies and research complex. Each of studied site was divided into three divisions to study the effect of irrigation systems on water use efficiency and tomato yield. The first experimental site was selected for surface drip irrigation (IS_1) whereas the second one was used for subsurface drip irrigation (IS_2), while the third one was used for integral drip irrigation (IS_3). Each site was subdivided into two areas the first one was used for pulse irrigation ($P.I_{on}$), while the other one was used for continues irrigation ($P.I_{off}$). Finally, each area was further subdivided into two plots to study the effect of cobalt applications; the first one without cobalt application (Co_0) while the other one received cobalt applications (Co_1) at a level of (7.5 ppm of cobalt sulphate), injection in irrigation water. Each treatment was replicated three times. plot area was 40 m^2. Accordingly, the experimental work of tomato crop involved 36 plots {3 irrigation systems × 2 pulse × 2 cobalt applications × 3 replicates}. The experimental plots were distributed in a split-split plot as illustrated in (fig.1).

	surface drip irrigation (IS1)		**Subsurface drip irrigation (IS2)**		**Integral drip irrigation (IS3)**	
R1	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**
	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**
	Buffering zone					
R2	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**
	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**
	Buffering zone					
R3	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**	continues irrigation **($P.I_{off}$)**	non cobalt **(Co_0)**
	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**	pulse irrigation **($P.I_{on}$)**	with cobalt **(Co_1)**

Fig. 1. Layout of field experiment.

Description of irrigation systems:

1- Description of sub-surface drip irrigation system (IS_1):

Subsurface Drip Irrigation (IS_2) is one of several types of micro irrigation. It is a planned irrigation system in which water is applied directly to the root zone of plants by means of applicators (E.g. orifices, emitters, and porous tubing) placed below the ground surface. It is operated under low pressure. It is one of the more advanced irrigation methods in use today, the lateral lines of 18 mm diameter made of recycled waste tires, the used lines called (leak lines) and the hoses type porous from whole part as shown as (fig.2), the lateral line discharge of one meter is equal 4 l/h at 1 bar. Distance between laterals was 90 cm.

Fig. 2. The subsurface drip leakage lines

2- Description of surface drip irrigation system (IS_2):

Drip irrigation is a technique in which water flows through a filter into special drip pipes, with emitters located at different spacing. Water is distributed through the emitters directly into the soil near the roots through a special slow-release device, which supplies water under pressure from the source to distribute it thought the irrigated area.

3- Description of integral irrigation system (IS_3):

Integral Drip Irrigation (IS_3) is new development in the micro irrigation systems. It is a combination between surface drip line & subsurface drip leak line in shown as (fig.3), therefore it contains the same component in the surface & subsurface drip irrigation (E.g. Head control unit and Pipe lines network), but the only difference was in the two laterals lines which had been used to irrigate each row (in the surface GR drip line parallel with leak line in the subsurface and connecting the two line by tee polyethylene tube and controlled of water pass in the drip lines by using PE valve which was installed on drip line).

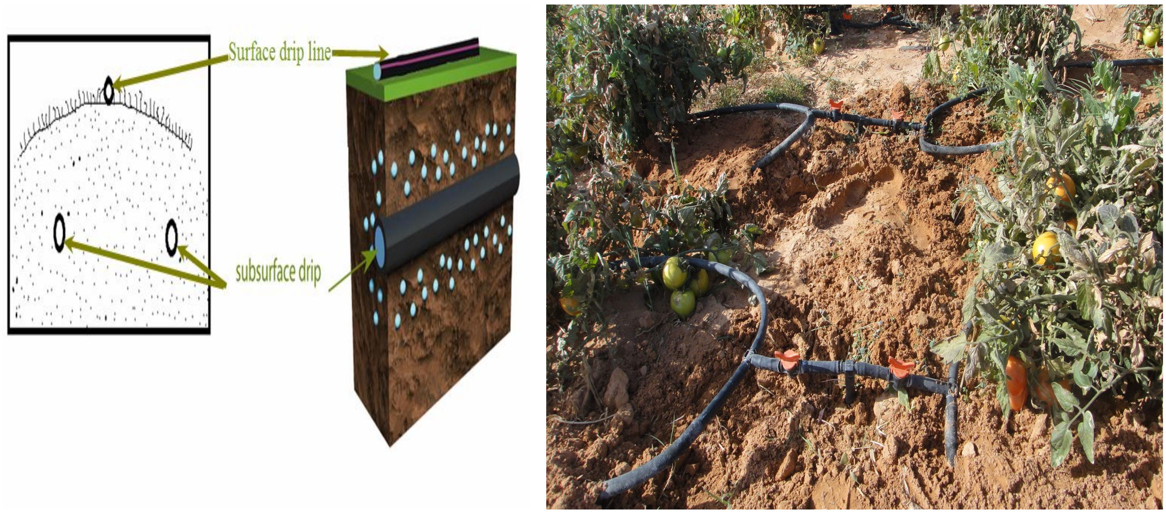

Fig. 3. The installation of integral drip irrigation (IDI).

1- Water relations:-

Actual evapotranspiration (ETa)

Actual evapotranspiration was computed as the difference in soil moisture in the soil samples taken before and after irrigations. It was affected by the amounts and intervals of irrigation. It was calculated according to the equation of Israelsen and Hansen (1962) as follows:

$$\textbf{(ETa)} = D \times Pb \times (Q2-Q1)/100$$

Where:

(ETa) = actual evapotranspiration.
D = the irrigation soil depth (cm).
Pb = Bulk density in g/cm^3.
Q2 = the percent of soil moisture at field capacity.
Q1 = the percent of soil moisture before irrigation.
Er = irrigation system efficiency (%).

Water use efficiency (WUE).

Water use efficiency is the outcome of an entire suite of plant and environmental processes operating over the life of a crop to determine both yield and ET. Consequently, biomass production per unit ET, has been used extensively as an interim measure of water use efficiency, The Water use efficiency (WUE) values was calculated as follows (Vites, 1965) :-

WUE = {Grain yield (kg / fed.) / Actual evapotranspiration (m^3 / feddan)}… (kg / m^3)

Soil sampling:-

The soil moisture percentage was determined gravimetrically on dry weight basis just before irrigation. Soil samples for moisture determination were taken from each 30 cm depth up to 60 cm from the soil surface by a regular auger. The samples were weighted and then oven dried. The sum of the soil moisture deficit of the two layers was added in the next irrigation to reach the field capacity; the moisture allowed depletion (MAD) was 40% from field capacity.

2- Crop productivity:

Plant sampling:-

- Measurement of Plant Vegetative Growth: After 60 days from transplanting, Plant height, Fresh weight/plant (g) and Dry weight/plant (g) of tomato plants were recorded.

- Measurement of Fruits Yield Quantity: After 105 days from transplanting, the number of fruits per plant, fruits weight per plant (g) and total yield (kg /fed) of tomato were recorded.

Statistical analysis:

Analysis of variance (ANOVA) was established to determine any statistical significant differences using a SAS version 8.1 computer program. The means were separated through a revised least significant difference (LSD) test at the 0.05 level (Steel and Torrie, 1980).

Results and Discussion

1- Water relations:-

A. Actual evapotranspiration (ETa)

Actual evapotranspiration (ETa) as affected by cobalt application, pulse treatment under different irrigations systems of tomato during the late summer seasons 2015 and 2016 are presented in table 2. The results indicated that the highest values of ETa were recorded in control treatment under surface irrigation system (IS_2). These results may be attributed to the high evaporation from the soil surface and plant absorption under surface irrigation system; while the lowest values were recorded under subsurface irrigation system (IS_1) when cobalt application had been added to tomato plant with pulse technique, These results can be ascribed as that cobalt worked as an inhibitor which has a vital role in defining water consumption by growing plants, reducing transpiration rate and leaf water potential. The subsurface drip irrigation has too many advantages due to the dry soil surface and finally using pulse irrigation saving water. The obtained results are harmonies with Nagarajah and Rathooriya (1977); El-Nesr (2012) and Eid *et al.* (2013).

Table 2. Actual evapotranspiration (m^3/fed.) measured as affected by cobalt application, pulse treatment under different irrigations systems of tomato during the late summer seasons 2015 and 2016.

Irrigation systems	Treatment		Actual evapotranspiration (m^3/ fed.)		
	*Cobalt 7.5 ppm	**Pulse	2015	2016	Average
Sub surface drip (IS_1)	-	-	2154.3	2160.3	2157.3
	+	-	2111.2	2126.4	2118.8
	-	+	2093.6	2105.2	2099.4
	+	+	1987.4	2003.8	1995.6
surface drip (IS_2)	-	-	2757.9	2768.2	2763.1
	+	-	2541	2550.3	2545.7
	-	+	2489.3	2493	2491.2
	+	+	2410.3	2427.9	2419.1
Integral drip (IS_3)	-	-	2546.4	2553.4	2549.9
	+	-	2455.2	2466.5	2460.9
	-	+	2300.6	2313.5	2307.1
	+	+	2232	2243.7	2237.9

Where:
* (-) without or (+) with cobalt application.
** (-) off or (+) on pulse treatment.

The data also revealed that the individual and combined influence of cobalt application, pulse technique under each irrigation system caused decrease in the average seasonal values of ETa. The results indicated that the individual influence of using cobalt application caused decreased in the average ETa seasonal values by 1.8% from the recorded values of control treatment under subsurface irrigation system (IS_1)**;** while it was decreased by 7.9% from the recorded values of control treatment under surface irrigation system (IS_2), and it was decreased by 3.5% from the recorded values of control treatment under integral drip irrigation system (IS_3).

The effect of using cobalt application was more pronounced under subsurface followed by integral drip irrigation system and finally with surface drip. This might be ascribed due to which cobalt worked as an inhibitor and has a vital role in defining water consumption by growing plants, reducing transpiration rate and leaf water potential. So that under surface irrigation system the vegetation was larger than subsurface irrigation system and the most of the water depletion was due to evaporation from the soil surface and plant absorption. The obtained results are in close agreement with these obtained by Nagarajah and Rathooriya (1977).

The results, also indicated that the individual influence of using pulse technique caused decrease in the average seasonal ETa values by 2.7% from the recorded values of control treatment under subsurface irrigation system (IS_1)**.** The ETa was decreased by 9.8% from the control treatment under surface irrigation system (IS_2). While it was, decreased by 9.5% from the recorded values of control treatment under integral drip irrigation system (IS_3). The obtained results are harmonies with El-Nesr (2012) and Eid *et al*. (2013).

On the other hand the results indicated that the combined influence of cobalt application and pulse technique caused decreased of the average seasonal values of ETa by 7.5 , 12.4 and 12.2 % from the recorded values of control treatment under subsurface irrigation system (IS_1), surface irrigation system (IS_2) and integral drip irrigation system (IS_3) , respectively.

2- Tomato productivity:

2.1 Growth characteristics.

The data in figures (4) revealed that the individual influence of using the integral drip irrigation system (IS_3) caused significant increases in the growth characteristics of tomato more than the subsurface and surface drip irrigation .These results may be attributed to the role of integral drip irrigation system which results in large wetted layers, and increase the available soil moisture in the root zone which encourages the tomato plants to absorb sufficient water and consequently increase the photosynthesis activity. The available soil moisture may increase the rate of leaf appearance and leaf growth which resulted in increasing the other growth parameters. These results are agreement with those obtained by Abdel-Gawad *et al*. (2001).

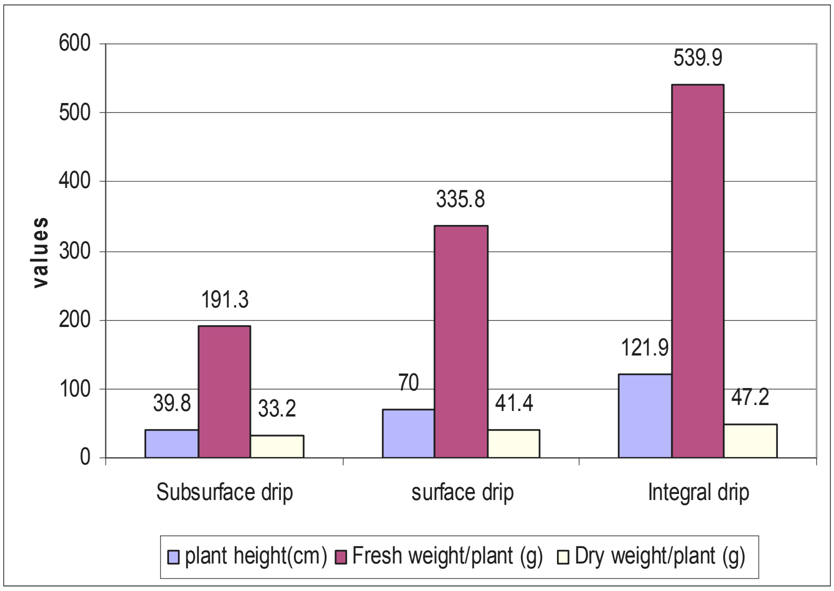

Fig. 4. Effect of irrigation systems on plant height, Fresh weight/plant (g) and Dry weight/plant (g) of tomato.

Results illustrated in figure (5) indicated that cobalt application caused significant increases in plant height, fresh weight/plant (g) and dry weight/plant (g) of tomato. The highest values, obtained were under integral drip irrigation system (IS_3) when cobalt application and pulse technique are used, while the lowest values were obtained under subsurface

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irrigation system (IS_1). The obtained results are in close agreement with these obtained by Kumari (2002); Nadia Gad (2005) and Nadia Gad and Hala Kandil (2010) who reported that cobalt increased the dry matter percentage of tomato shoots and the fresh and dry weights of tomatoes.

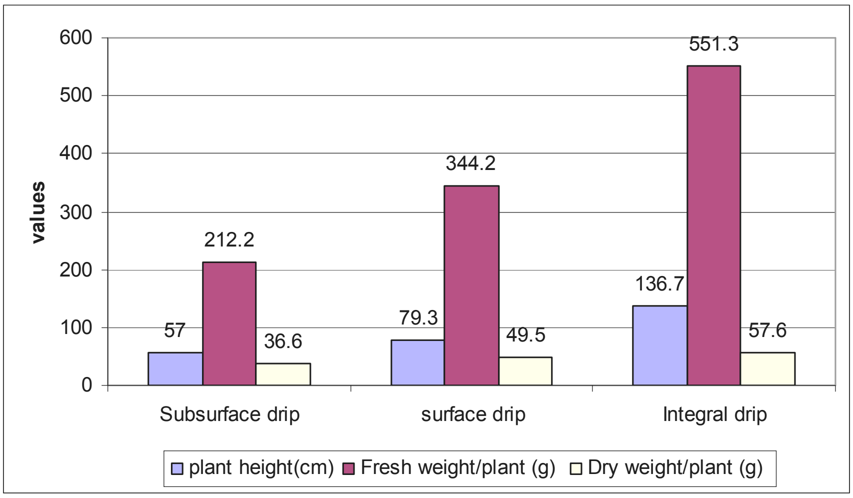

Fig. 5. Effect of cobalt application on plant height, Fresh weight/plant (g) and Dry weight/plant (g) of tomato.

Results in figure (6) indicated that pulse technique caused significant increases in plant height, fresh weight/plant (g) and dry weight/plant (g) of tomato. The highest values of the aforementioned characteristics were under integral drip irrigation system (IS_3) when pulse techniques are used, while the lowest values were under subsurface irrigation system (IS_1) at the same treatment. The obtained results are in close agreement with these obtained by Beeson (1992).

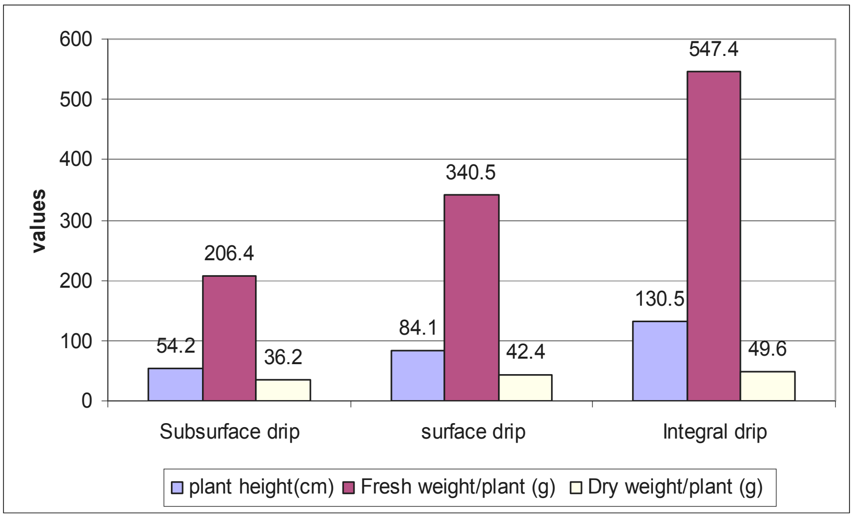

Fig. 6. Effect of pulse technique on Plant height, Fresh weight/plant (g) and Dry weight/plant (g) of tomato.

Results illustrated in figure (7) show the effect of combined influence of cobalt application, pulse technique under different irrigation systems. Results indicated that the combined influence of cobalt application, pulse technique caused an increase in the averages plant height, fresh weight/plant (g) and dry weight/plant (g) of tomato as compared with the control treatment under subsurface irrigation system (IS_1), surface irrigation system (IS_2) and integral drip irrigation system (IS_3), respectively. These results may be attributed of the effect of integral drip irrigation system there were large wetted layers, and the increasing of the available soil moisture in the root zone, which encourage the tomato plants to absorb sufficient water and consequently increase the photosynthesis activity. These results are similar with that obtained by Pitts et al (1991); Clothier and Green (1994); Coelho and Or (1996); Abd-El-Moez and Nadia Gad (2002) and Kumari, 2002.

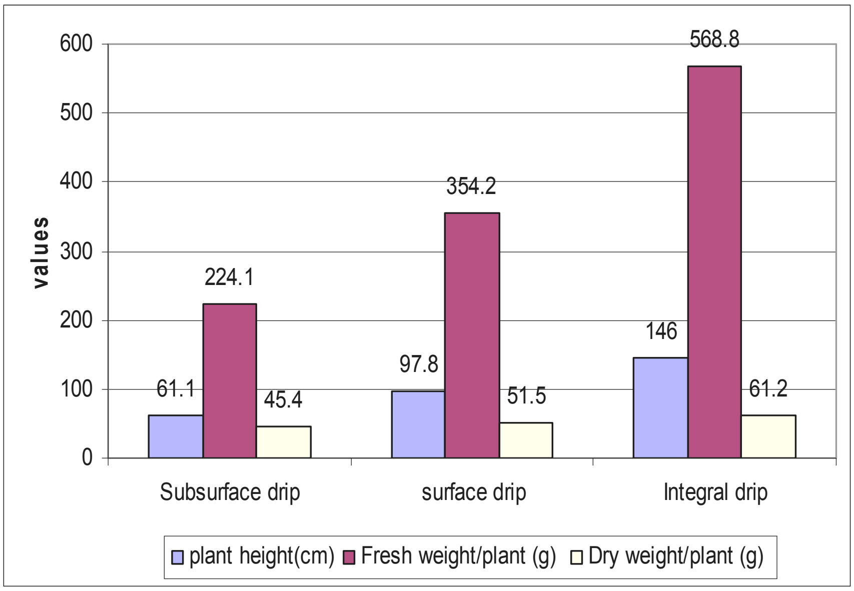

Fig. 7. Combined influence of cobalt application, pulse technique under different irrigation systems on Plant height, Fresh weight/plant (g) and Dry weight/plant (g) of tomato.

2.2 Tomato yield.

A- The Effect of irrigation systems on tomato yield.

Data presented in table (3) and figure (8) indicates that the separate influence of using the integral drip irrigation system (IS_3) caused significant increases in tomato yield. The results show that the average values of tomato yield were slightly increased in summer season of 2016 compared to that in summer season of 2015. This may be due to the variation in the weather condition especially temperature. These results are similar with that obtained by El-Bassiony *et al.* (2012) and Shehata (2013).

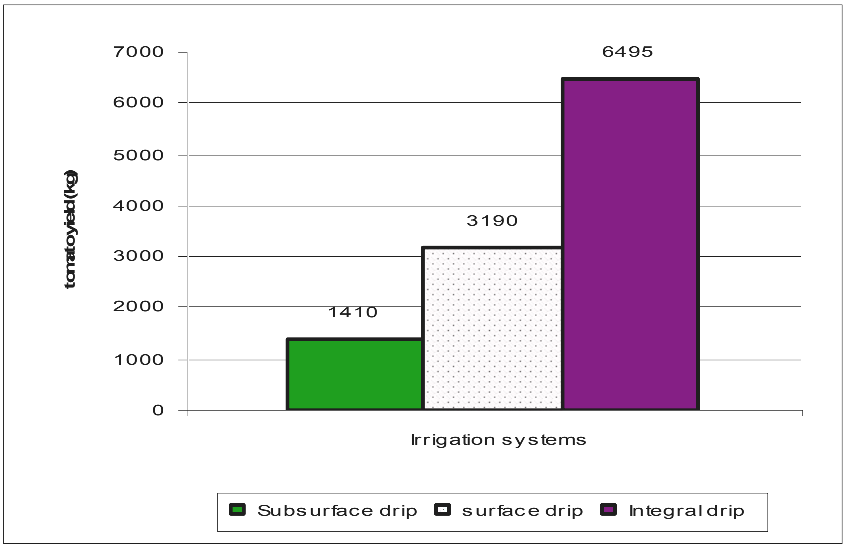

Fig. 8. Effect of irrigation systems on tomato yield.

Table 3. Effect of irrigation systems, pulse irrigation technique and cobalt applications on yield and water use efficiency (WUE) of tomato plant.

Treatment		Characters	Tomato yield (kg / fed)			Water use efficiency (Kg / m^3)		
			2015	**2016**	**average**	**2015**	**2016**	**average**
Irrigation systems	**Subsurface drip (IS_1)**	Control (**P.I** $_{off}$ + Co_0)	1380 a	1440 a	1410	0.64	0.67	0.66
		with Co (**P.I** $_{off}$ + $Co_{7.5\ ppm}$)	3100 c	3190 c	3145	1.47	1.5	1.49
		with **pulse** (**P.I** $_{on}$ + Co_0)	2770 b	2800 b	2785	1.32	1.33	1.33
		with **pulse** + Co (**P.I** $_{on}$ + $Co_{7.5\ ppm}$)	4110 d	4250 d	4180	2.1	2.1	2.1
	surface drip (IS_2)	Control (**P.I** $_{off}$ + Co_0)	3200 a	3180 a	3190	1.16	1.16	1.16
		with Co (**P.I** $_{off}$ + $Co_{7.5\ ppm}$)	3910 c	4150 c	4030	1.54	1.63	1.59
		with **pulse** (**P.I** $_{on}$ + Co_0)	3510 b	3750 b	3630	1.41	1.50	1.46
		with **pulse** + Co (**P.I** $_{on}$ + $Co_{7.5\ ppm}$)	4980 d	5340 d	5110	2.1	2.2	2.2
	Integral drip (IS_3)	Control (**P.I** $_{off}$ + Co_0)	6460 a	6530 a	6495	2.54	2.56	2.56
		with Co (**P.I** $_{off}$ + $Co_{7.5\ ppm}$)	7200 c	7320 c	7260	2.93	2.97	2.96
		with **pulse** (**P.I** $_{on}$ + Co_0)	6860 b	7180 b	7020	2.98	3.10	3.04
		with **pulse** + Co (**P.I** $_{on}$ + $Co_{7.5\ ppm}$)	10390 d	10530 d	10460	4.66	4.69	4.68

Means in each column for each treatment followed by different letters are significantly different using revised LSD at 0.05 level.

Also the results show that the values of integral drip irrigation system (IS_3) caused increases in tomato yield by 360.6 % from the lowest average value which had been recorded under subsurface irrigation system (IS_1), while surface irrigation system (IS_2) caused increases in tomato yield by 126.9 % from the same average value which mention above. These results indicate that the integral drip irrigation system may resulted in a large wetted layers, and increased the available soil moisture in the root zone, which encourages the tomato plants to absorb sufficient water and consequently increase the photosynthesis activity. These results are in agreement with those obtained by Abdel- Gawad *et al.* (2001).

B- The effect of cobalt application and irrigations systems on tomato yield.

Results illustrated in figure (9) show the positive effect of cobalt application on tomato yield. The results show that using pulse technique under integral drip irrigation system (IS_3) caused increases in tomato yield by 130.4 % from the lowest average value which had been recorded in cobalt addition under subsurface irrigation system (IS_1). These results are agreement with those obtained by Abd-El-Moez and Nadia Gad (2002) and Kumari (2002).

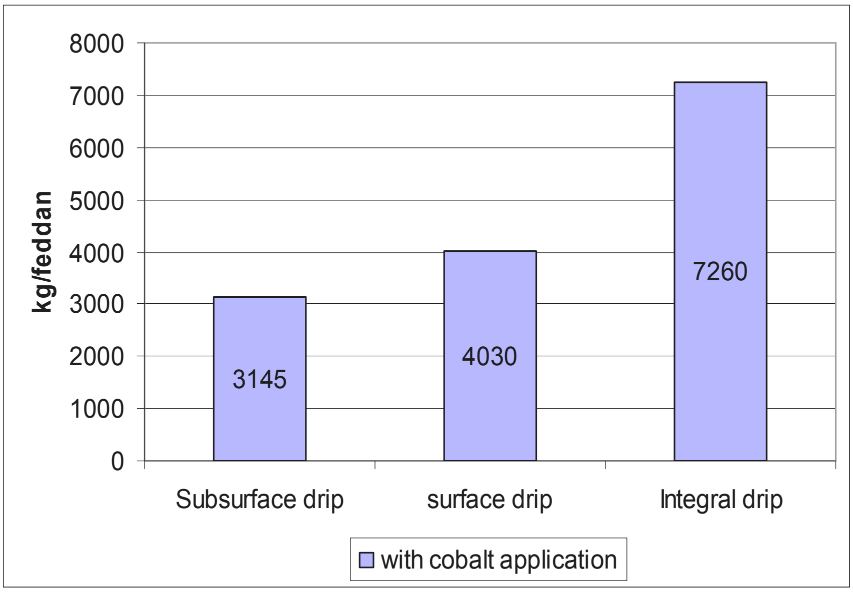

Fig. **9**. Effect of cobalt application on tomato yield.

C- The effect of pulse technique and irrigations systems on tomato yield.

Results illustrated in figure (10) show the positive effect of pulse technique on tomato yield. The results show that using pulse technique under integral drip irrigation system (IS_3) caused increases in tomato yield by 152.1% from the lowest average value which had been recorded in pulse technique under subsurface irrigation system (IS_1). These results are similar with that obtained by Pitts *et al* (1991); Clothier and Green (1994) and Coelho and Or (1996).

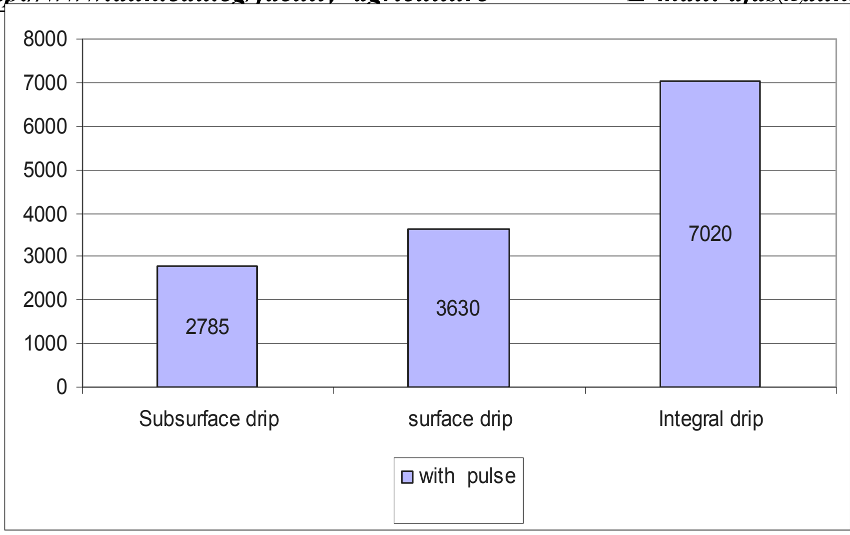

Fig. 10. Effect of pulse technique on tomato yield.

D- The combined effect of cobalt application, pulse technique and irrigations systems on tomato yield.

Results illustrated in figure (11**)** show the combined influence of cobalt application, pulse technique under different irrigation systems on tomato yield. The results show that cobalt application and pulse technique under integral drip irrigation system (IS_3) caused an increase in tomato yield by 641.9 % from the lowest average value which had been recorded in cobalt application and pulse technique under subsurface irrigation system (IS_1). These results may mean that under integral drip irrigation system there were large soil wetted layers, and the increasing of the available soil moisture in the root zone which encourages the tomato plants to absorb sufficient water and consequently increase the photosynthesis activity. These results are similar with that obtained by Pitts *et al* (1991), Clothier and Green (1994); Coelho and Or (1996); Abd-El-Moez and Nadia Gad (2002) and Kumari (2002).

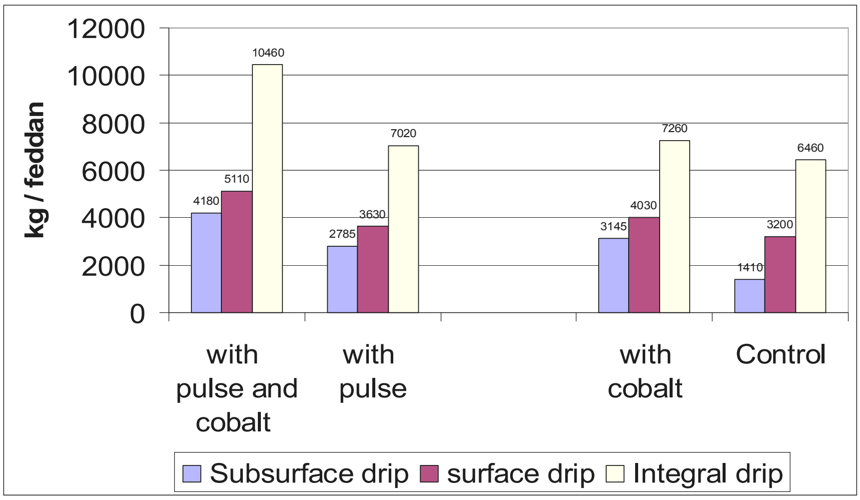

Fig. **11**. The combined effect of cobalt, pulse and irrigations systems on tomato yield.

2.3 Tomato water use efficiency (WUE).

The values of tomato WUE could be increased by increasing crop yield or by decreasing evapotranspiration and /or by both. The data in Table (3) indicated that the individual and the combined influences of cobalt application and pulse technique under integral drip irrigation system (IS_3) caused the highest average value of (WUE) compared to the control treatment under subsurface irrigation system (IS_1) and surface irrigation system (IS_2). The results show that the values of tomato (WUE) in the first season (2015) were 4.66 kg / m^3, while it was in the second season (2016) 4.69 kg / m^3 when cobalt and pulse technique were used under integral drip irrigation system (IS_3). These results may be attributed to the advantages of integral drip irrigation (IS_3) which had been noticed in both growth seasons, which resulted in increasing crop yield by improving all growth characteristics and decreasing evapotranspiration from the soil. Advantages of the subsurface drip irrigation especially the dry soil surface and also the larger vegetation under integral drip irrigation worked as natural inhibitor substances reducing evaporation from soil. On the other hand cobalt application decreased evapotranspiration from tomato plants by acting as an inhibitor which has a vital role in defining water consumption by growing plants, reducing transpiration rate and leaf water potential. Finally pulse drip irrigation is applied allover the world because it has positive effects on increasing yield, improving quality, saving water. These results are similar with that obtained by Pitts *et al* (1991), Clothier and Green, (1994); Coelho and Or (1996); Abd-El-Moez and Nadia Gad (2002), El-Nesr (2012) and Abdelraouf *et al* (2013).

Conclusion

It can that concluded that integral drip irrigation system is more suitable under Toshka climatic condition to improve water consumption and caused significant increases in tomato yield and water use efficiency especially when cobalt was applied with pulse technique, which give the highest net return and benefit-cost ratio to the farmers.

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تأثير نظم الرى وتقنية الرى النبضى وإضافة الكوبالت على إنتاجيه وكفاءة إستخدام المياه لنباتات الطماطم المزروعه فى أرض حديثة الإستصلاح

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الملخص

نظراً لأهمية البحث العلمي في إيجاد حلول حديثه مبتكره لترشيد الإحتياجات المائيه وزياده الإنتاجيات المحصوليه بالإضافه إلى التحسين المستمر في شبكات الري الحديثه للمساعده في زياده إنتشارها ، لذا فقد أجريت هذه الدراسة في مزرعة تجارب الأبحاث بمجمع الدراسات والبحوث المائية بتوشكي خلال موسمي ٢٠١٥ و ٢٠١٦ وذلك بغرض إختباريه تطوير نظام رى حديث (نظام الري التكاملي) وأثر إستخدامه علي الإنتاجيه وعلي كفاءة لإستخدام المياه ومقارنته بإستخدام نظم ري أخري تقليديه (تنقيط تحت سطحي – تنقيط سطحي) كذلك تم دراسة تأثير إستخدام إضافه الكوبالت وتقنية الري النبضي على العلاقات المائية لمحصول الطماطم وكذلك على المحصول ومكوناته تحت الظروف المناخية لمنطقة توشكى.

وكانت أهم النتائج كما يلي:

- ان التأثير الفردي لإستخدام نظام الري التكاملي علي ظهور زياده معنويه في إنتاجيه محصول الطماطم كان أعلي من التأثير الفردي لكل من إستخدام تقنية الري النبضي أو إستخدام إضافه بالكوبالت.
- كذلك أظهرت النتائج أن إستخدام نظام الري التكاملي مع إستخدام الإضافه بالكوبالت و الري النبضي أدي إلى حدوث زيادة في إنتاجيه محصول الطماطم بمقدار ٩, ٦٤١% عن أقل متوسط قيمه تم التحصل عليها والتى كانت بالمعامله الكنترول تحت نظام الري بالتنقيط التحت سطحي.
- وبناءً عليه فإن هذه الدراسه توصي بإستخدام الإضافه بالكوبالت مع إستخدام تقنية الري النبضي تحت نظام الري التكاملي على محصول الطماطم المنزرعه بالعروه الصيفيه المتأخره لما لهذه التقنيات الحديثة مردود إيجابي علي الإنتاجيه وعلى ترشيد الإحتياجات المائيه تحت ظروف منطقة توشكى المناخيه.