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RESEARCH ARTICLE

INFLUENCE OF DIFFERENT LOCALIZED IRRIGATION SYSTEMS ANDTREATED AGRICULTURAL WASTEWATER ON DISTRIBUTION UNIFORMITIES, POTATO GROWTH, TUBER YIELD AND WATER USE EFFICIENCY.

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Manuscript Info ***Abstract***

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A field experiment was conducted during 2012 and 2013 at the Experimental Farm of National Research Center (NRC), El-Noubaria Governor, Egypt, in sandy soil to study the effect of bubbler and drip irrigation systems and water quality on uniformity distribution, vegetative growth, tuber yield and water use efficiency (WUE) of Potato. Field uniformity distribution of bubbler and drip irrigation systems were 95.20 % and 95.97 %, respectively. The parameters of vegetative growth (plant length, LAI; branches number) under Irrigation system, treated agricultural waste water (TAWW) were increased by 6.0 %, 14.6 %; 15.3 % relative to bubbler irrigation system and fresh water (FW), respectively. Yield and WUE under drip irrigation system, TAWW were increased by 5.4 % and 5.7 % relative to bubbler irrigation system and fresh water (FW), respectively. Plant length and leaf are index (LAI) were the highest values under the control treatment (100% ETo water applied), while the branches number increased by decrease of applied water. Vegetative growth, tuber yield and WUE, could be arranged in ascending order: 50% < 75% < 100% due to amount of water applied. The effect of irrigation by drip irrigation systems and using TAWW was positively on vegetative growth parameters, (yield, andWUE). This could be attributed to the improvement in soil physical characteristics under using drip irrigation system relative to bubbler irrigation system and the soluble nutrients in the TAWW relative to fresh water.

Introduction

The Increase for water demand in the world, especially in arid and semi-arid regions such as Saudi Arabia resulted in searching for effective ways to use of water resources rationality by farm. Therefore, prepare the soil for planting and selecting the appropriate method of irrigation and the use of alternatives to fresh water works to increase water use and reduce the need of sweet water demand. Since Egypt is of dry areas that suffer from lack of water needed for agriculture, so it was necessary to use alternative systems of modern irrigation to contribute to the provision of water for irrigation in such a region under study.

The potato (*Solanum tuberosum* L) is one the most important crops vegetables in the world in terms of production and cultivated area, as well as one of the most widely used vegetable crops, consumed by human because it is an important food source contains a lot of nutrients (Hassan, 1999) which led to increased attention this crop, especially in recent years. In arid and semiarid regions, potato is sensitive to water stress and irrigation has become an essential component of potato production in comparison with the other crops (Wright and Stark, 1990). Shock et al. (1992) stated that potato could be tolerating water deficit before tuber set without reduction in tuber quality under some water stress conditions. Potato may be quite sensitive to drought (Van Loon, 1981) as it needs frequently irrigations for suitable growth and optimum yield (Yuan et al., 2003; Kiziloglu et al., 2006). Doorenbos and Kassam (1979) have reported that initial vegetative stage is not sensitive to the moisture stresses. In contrast, Hassan et al. (2002) found that the stalinization and tuberization stages were more sensitive than bulking and tuber enlargement stages. Thornton (2002) and Shock (2004) found that all growing stages of potato, especially tuber formation stage, are very sensitive to water deficit stress. Whereas Wright and Stark (1990) found that some stress could be tolerated during early vegetative growth and late tuber bulking under water deficit conditions. Irrigation management plays a key role in soil organic matter turnover. Soils under organic farming receive frequent organic matter inputs as manures and organic fertilizers (Shepherd et al., 2002).

Michael, (2008) reported that its important advantages as compared to other irrigation systems as following: increased crop yields, water and energy saving, increased water and fertilizer use efficiency, tolerance to windy atmospheric conditions, decreased labor cost, protection from the diseased and improved the pest control, using with no problems in sloppy lands conditions, suitability with different types of soils and improved the salinity conditions. Yildirim and Korukcu, (2000) studies the effect of drip irrigation generally achieves better crop yield and balanced soil moisture in the active root zone with minimum water losses. Sharma, (2001) found that the average, drip irrigation saved up to 80% of water as compared to furrow irrigation system. Singh et al, (2005) found by an experiments that the potato yield was 88.20 ton/ha with drip irrigation method compared to 76.17 ton/ha with furrow mode and 84.24 ton/ha with sprinkler irrigation. In addition to Ibragimov et al, (2007) reported that yield was increased by 18-42% and water use efficiency increased by 35 to 103% under drip irrigation system. Tagar et al, (2012) found that Drip irrigation method saved 56.4% of water and gave 22% more yield as compared to that of furrow irrigation method. Moreover thay found that increased in water use efficiency about 4.87 was obtained under drip irrigation system; whereas decreased water uses efficiency about 1.66 was obtained in furrow irrigation system.

Katirji et al, (1992) states that the stomatal conductance clearly differed between loam and clay for the control as well as for the saline water of 15 m Eq Cl/l. These trends were the same in wheat, but much less clear than in potatoes. According to both parameters, potatoes are more sensitive than wheat to water stress caused by soil or by salinity.Water use efficiency (WUE) is defined as the tuber yield obtained per unit of water consumed as evapotranspiration (ET) or water used in cubic meter by the potato (Doorenbos and Pruitt, 1977). Miller and R. L. Donahue, (1992) reported that potato being root crop, may respond differently in puddled low-land rice fields. Soil compaction may affect root bulking. Irrigation can loosen the soil and can improve the root bulking. Rashidi and Gholami (2008) illustrated that WUE of potato in Iran ranged from 1.92 to 5.25 kg per m^3. They added that few numbers of irrigation can reduce compactness of the soil. Potato responds very well to fertilizer application. Nagaz et al. (2007) found that WUE varied around 8-14 kg per m^3 for planted potato. Wright and Stark (1990) reported that the WUE for maximum yield range from approximately 0.05 to 0.1 kg per ha per m^3. Sharma, (2001) state that the high wind velocity has no effect on drip irrigation system because the applies of water is directly to the root zone of plants

The objective of the study is to: Benefit from reuse of agricultural drainage water as an alternative to fresh water. Moreover to study the effect of subsurface irrigation to rationalize the irrigation water., and additionally Study impact of irrigation on soil properties, and natural vitality and their relationship to the growth of the crop.

Material and Methods

A field experiment was conducted during the years 2012 and 2013. Using randomize complete design at the Experimental Farm of National Research Center (NRC), El-Noubaria Governor, Egypt, in sandy soil. Two irrigation methods (Bubbler & Drip irrigation systems) and two irrigation water sources (Fresh & Treated waste water) and three treatments of water applied (50, 75; 100)of the crop ET (%) were applied in uses research work of experiment site. Physical, chemical and hydraulic properties of the soil were carried out and shown in Tables 1, 2 and 3.

Table (1): Some physical properties of the soil.*

Depth, cm	Particle Size distribution, %				Texture class	θ_S % on weight basis			HC (cmh^{-1})	BD)g/cm³(	P (cm³ voids /cm³ soil)
	C. Sand	F. Sand	Silt	Clay		F.C.	W.P.	AW			
0-15	8.4	77.6	8.5	5.5	Sandy	14	6	8	6.68	1.69	0.36
15-30	8.6	77.7	8.3	5.4	Sandy	14	6	8	6.84	1.69	0.36
30-45	8.5	77.5	8.8	5.2	Sandy	14	6	8	6.91	1.69	0.36
45-60	8.8	76.7	8.6	5.9	Sandy	14	6	8	6.17	1.67	0.37

* Particle Size Distribution after (**Gee and Bauder, 1986**) and Moisture retention after (**Klute , 1986**)
F.C.: Field Capacity, W.P.: Wilting Point, AW: Available Water, HC: Hydraulic conductivity(cmh^{-1}), BD: Bulck density(g/cm^3) and P: Porosity (cm³ voids/cm³ soil).

Table (2): Some chemical properties of the soil*.

Depth,	pH	EC	Soluble Cations, meq/L				Soluble Anions, meq/L			
cm	1:2.5	dS/m	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
0-15	8.3	0.35	0.5	0.39	1.02	0.23	0	0.11	0.82	1.27
15-30	8.2	0.36	0.51	0.44	1.04	0.24	0	0.13	0.86	1.23
30-45	8.3	0.34	0.56	0.41	1.05	0.23	0	0.12	0.81	1.23
45-60	8.4	0.73	0.67	1.46	1.06	0.25	0	0.14	0.86	1.22

*Chemical properties after **Rebecca, (2004)**

Table (3): Some chemical properties of irrigation water used.

pH	EC dS/m	Soluble cations, meq/L				Soluble anions, meq/l				SAR
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{--}	
7.3	0.37	0.76	0.24	2.6	0.13	0	0.9	0.32	2.51	4.61

Localized irrigation systems distribution uniformities:

The distribution uniformity (DU) of water was estimated along laterals of automation controller drip irrigation system in every plot area under pressure range of 1.0 bar by using 20 collection cans and following Equation:

$$DU = (q_m / q_a)\ 100 \ \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where:
DU = distribution uniformity, %;
qm = the average flow rate of the emitters in the lowest quartile, (l/h); and
qa = the average flow rate of all emitters under test, (l/h).

Potential evapotranspiration (ETo) and Irrigation Water Requirement (IWR) of potato during growing season for agricultural seasonal period were respectively 83.2 and 76.1 m^3/ha for El-Noubaria district, Egypt,. Doorenbos and Pruitt, (1977). One experiment was planted on April, 9 during all the two years using seeding rate of 2000 kg ha^{-1} in 70 cm spaced rows. Fertilizers N, P and K were applied at 145, 80, 125 kg ha^{-1}, respectively. To prevent any possible water deficit stress during the vegetative growth stage, irrigation was applied at 9, 13 days after sowing.

Early-season water applied treatments comprised three levels at 100 %; 75 % and 50 % under Disc plough and Drip irrigation system. All plots were irrigated at 3-4 days interval. Amount of irrigation water was measured at the entrance of each line of drip irrigation by a connected-flow-meter. Irrigation operation was stopped two weeks before harvested the potato yield. Net fertilizers were added by rates of 60 : 35 : 45 % for N : P_2O_5 : K_2O, so the plants had been received 87, respectively, according to the recommended amounts by the ministry of agriculture in Egypt. Leaf area was calculated by digital plan meter in cm^2. Whereas LAI (Leaf area index) was calculated by dividing the total leaf area with the corresponding land area.

LAI = total leaf area / unit land area

Treatment means were compared using the technique of analysis of variance (ANOVA) and the least significant at 1% level difference (L.S.D) between systems had been done.

Result and Discussion

Bubbler irrigation uniformity distribution:

Distribution uniformity is a scale for known the validation of bubbler irrigation system for its application in the experimental work. This scale estimates the homogeneity of irrigation water distribution. Data in Table (4)include volume of received water through 20 cans, which were put below randomized 20 bubbler drippers.

Operating time of this test was 5 minutes, Part of yellow color in Table (4)and Fig. (1)Showing thataverage of the lowest quarter = 1.230 (l/h) and average of received water = 1.292 (l/h) and distribution uniformity were shown on Fig. 3. Emission uniformity of bubbler irrigation system under study was high (95.20 %) this indicates the water distribution has positively affects.

Drip irrigation uniformity distribution:

Data in Table (4)included volume of received water through 20 cans, which were put below randomized 20 (Built-in) GR drippers. Distribution uniformity estimated for known the validation of drip irrigation system for its application in the experimental work.

Table 4. Data for estimating distribution uniformity for bubbler and drip irrigation system.

Cans number	Bubbler system test	Drip system test
	Water volume (l/h)	Water Volume (l/h)
1	1.22	0.23
2	1.22	0.24
3	1.23	0.24
4	1.24	0.24
5	1.24	0.24
6	1.25	0.24
7	1.25	0.24
8	1.26	0.24
9	1.27	0.24
10	1.27	0.24
11	1.28	0.24
12	1.29	0.25
13	1.29	0.25
14	1.30	0.25
15	1.31	0.25
16	1.31	0.25
17	1.32	0.25
18	1.32	0.26
19	1.33	0.26
20	1.33	0.26

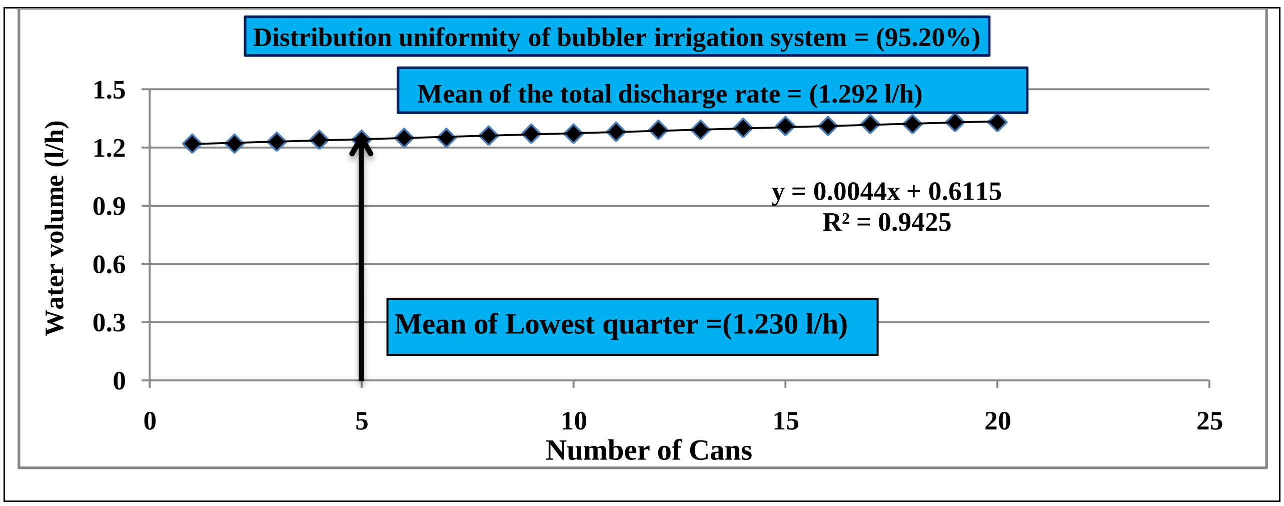

Fig. (1). Distribution uniformity of bubbler irrigation system.

Fig. (2)showing that **a**verage of the lowest quarter = 0.238 (l/h) and average of received water = 0.248 (l/h) and distribution uniformity were shown on Fig. 3. Emission uniformity of drip irrigation system under study was high (95.97 %) this indicates the water distribution has positively affects.

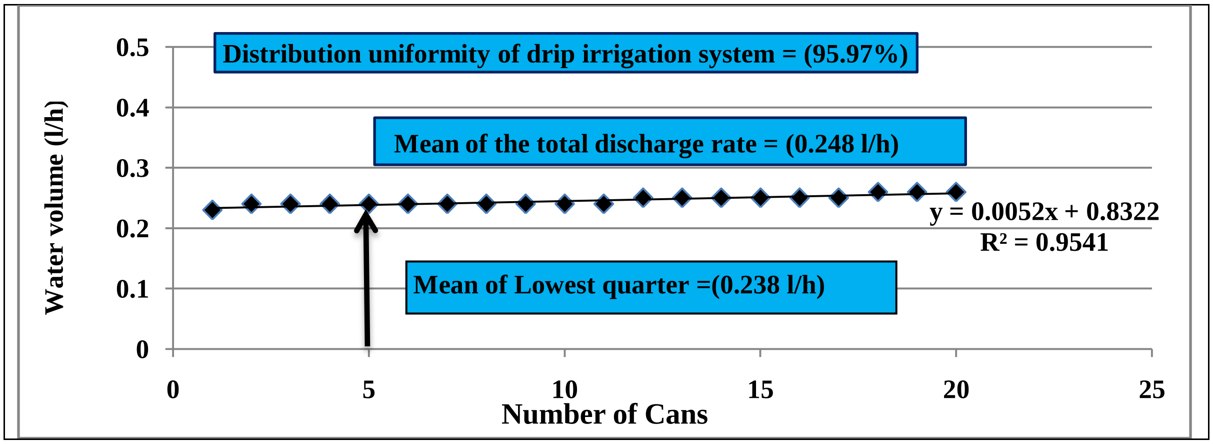

Fig. (2). Distribution uniformity of drip irrigation system.

The effect of localized irrigation systems, water quality and different amount of irrigation, on vegetative growth of potato.

Table (5) illustrate the effect of irrigation methods by bubbler and drip irrigation system, water quality by fresh and waste water types (FW and TAWW) and water treatments of 50, 75, 100 % from evapotranspiration on plant length in cm, leaf area index (LAI) and Number of branches.

Table (5): Effect of different localized irrigation systems, water quality and irrigation rates, on growth of potato.

Localized rrigation system (I)	Water quality (II)	Treatments of Water applied (%) from ET (III)	Plant length (cm)	LAI	Average of branches Number
Bubbler	FW	50	0.51a	2.1a	4.1a
		75	0.55b	2.2b	3.7b
		100	0.62c	3.3c	3.3c
	TAWW	50	0.53d	2.5d	4.3d
		75	0.58e	3.2e	4.2e
		100	0.65f	3.4f	4.6f
Drip	FW	50	0.52g	2.3g	4.4g
		75	0.57h	3.3h	4.0h
		100	0.64i	3.4i	3.5i
	TAWW	50	0.54j	3.2j	4.6j
		75	0.58k	3.3k	4.5k
		100	0.67l	3.5l	4.1l
	LSD 0.05		0.03	0.1	0.1
Interactions					
	I X II		0.01	0.1	0.2
	I X III		0.02	0.2	0.1
	II X III		0.01	0.1	0.1

FW= Fresh water, TWW= Treated waste water; ET= Evabotranspiration, LAI= Leaf area index.

The highest values of plant length were by using TAWW with drip irrigation system (0.54, 0.58; 0.67cm), followed by TAWW with bubbler irrigation system (0.53, 0.58; 0.64 cm). Whereas the lowest values were by using FW with bubbler irrigation system (0.53, 0.58; 0.65 cm), followed by FW with drip irrigation system (0.52, 0.57; 0.64 cm) under applied water treatments of (50, 75; 100%) from ETo, respectively. The values of LAI token the same trend of plant length. Highest values of LAI were by using TAWW with drip and bubbler irrigation systems (3.2, 3.3; 3.5) and (2.5, 3.2; 3.4).

In contrast the lowest values of LAI were by using FW with bubbler and drip irrigation systems (2.3, 3.3; 3.4) and (2.1, 2.2; 3.3) under applied water treatments of (50, 75; 100%) from ET, respectively. The average of branches number took the same trend of both plant length and LAI. The average of branches number values were the highest by using TAWW with drip irrigation system (4.6, 4.5; 4.1), followed by TAWW with bubbler irrigation system (4.3, 4.2; 4.6). Whereas the lowest values were by using FW with bubbler irrigation system (4.1, 3.7; 3.3), followed by FW with Drip irrigation system (4.4, 4.0; 3.5) under applied water treatments of (50, 75; 100%) from ET, respectively.

According to LDS values in Table (5) of plant length and average branches number, the differences were significant at 5% level between all values. Whereas concerning LAI, the differences were significant at 5% level between LAI values exception under some similar and non-similar water treatments. Concerning the vegetative characteristics of potato under study, the interaction between the different main factors I, II and III (I x II, I x III; II x III) were significant at 1% level. The data obtained agreed with Nedunchezhiyan et al, (2012) and Roy Chowdhury et al, (2002).

The effect of irrigation system, water quality and different irrigation rates, on tuber yield and water use efficiency.

Table (6) showing the effect of irrigation methods by bubbler and drip irrigation systems, water quality by fresh and waste water types (FW and TAWW) and water treatments of 50, 75, 100 % from evapotranspiration on potato tuber yield and WUE.

Table (6): Effect of localized irrigation system, water quality and different irrigation rates, on tuber yield and water use efficiency of potato.

Localized irrigation system (I)	Water quality (II)	Treatments of water applied (%) from ET (III)	Water amount (m^3/ha)	Tuber yield (ton/ha)	WUE (ton/m^3)
Bubbler	FW	50	41.6	8.6a	0.21a
		75	58.2	10.6b	0.18b
		100	83.2	11.3c	0.14c
	TAWW	50	41.6	9.2d	0.22d
		75	58.2	10.8e	0.19e
		100	83.2	11.5f	0.14f
Drip	FW	50	41.6	8.9g	0.23g
		75	58.2	10.7h	0.18h
		100	83.2	11.5i	0.13i
	TAWW	50	41.6	9.2j	0.24j
		75	58.2	11.2k	0.19k
		100	83.2	11.8l	0.14l
LSD 0.05				**2.2**	**0.02**
Interactions					
I X II				**1.2**	**0.01**
I X III				**1.1**	**0.01**
II X III				**1.3**	**0.02**

FW= Fresh water, TAWW= Treated agricultural waste water; ET= Evapotranspiration,

The values of tuber yield took the same trend of vegetative growth parameters. The highest values of tuber yield were by using TAWW with drip and bubbler irrigation systems (9.2, 11.12; 11.8 ton/ha) and (9.17, 10.8; 11.6 ton/ha), respectively. While the lowest values of tuber yield were by using FW with bubbler and drip irrigation system (8.6, 10.6; 11.3 ton/ha) and (8.9, 10.7; 11.5 ton/ha) under applied water treatments of (50, 75; 100%) from ETo, respectively.

The water use efficiency WUE took the same trend of both potato vegetative growth and tuber yield. WUE values were the highest by using TAWW with drip irrigation system (0.24, 0.19; 0.14 ton.m^{-3}), followed by TAWW with bubbler irrigation system (0.22, 0.19; 0.14 ton.m^{-3}). Whereas the lowest values of WUE were by using FW with bubbler irrigation system (0.21, 0.18; 0.14 ton.m^{-3}), followed by FW with drip irrigation system (0.23, 0.18; 0.13 ton.m^{-3}) under applied water treatments of (50, 75; 100%) from ETo, respectively. This finding is inconsistent with Nagaz et al. (2007), who reported that the range of WUE was from 44.1 to 63.4 kg ha^{-1} mm^{-1} and from 8 to 14 kg m^{-3}, respectively.

According to LSD values in Table (6) of potato yield and WUE, the differences were significant at 5% level between all values. Also the interaction between the different factors I, II and III (I x II, I x III; II x III) were significant at 5% level. The data obtained agreed with (Nasseri and Bahramloo, 2009).

Conclusion

The effect of drip irrigation system, treated agricultural wastewater, and treatment 100% ET were found to be positive on potato vegetative growth, tuber yield and WUE. This can be attributed to the improvement in sandy soil hydro-physical properties by using of drip irrigation system relative to bubbler irrigation system and the soluble nutrients in the treated waste water relative to fresh water. It could be included that:

Estimated field uniformity distribution of bubbler and drip irrigation systems were 95.20 % and 95.97 %, respectively. These data indicates the water distribution has positively affects.

The averages for parameters of vegetative growth (plant length, LAI; branches number) under drip irrigation system, TAWW were increased by (6.0, 14.6; 15.3 %), relative to bubbler irrigation system and FW, respectively, tuber yield and WUE under drip irrigation system, TAWW were increased by (5.4 and 5.7 %) relative to bubbler irrigation system and FW, respectively, Increases both Plant length and LAI the greater amount of water added, under ETo treatment (50, 75; 100%) values average were (52.6, 57.0; 64.5 m) and (2.8, 3.2; 3.6), While increasing the branches number, the lower amount of water added, were (3.7, 3.4; 3.2) under (50, 75; 100%) ETo treatments, According to yield, and WUE, they could be arranged in the following ascending order: 50% < 75% < 100% amount of water was applied from ETo.

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