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The Hydraulic Evaluation of MTI and DIS as a Localized Irrigation Systems and treated Agricultural Wastewater for Potato Growth and Water Productivity

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Abstract: A field experiment was conducted during 2013 and 2014 at the Experimental Farm of National Research Center (NRC), El-Noubaria, El-Buhaira Governor, Egypt, in sandy soil to study the hydraulic evaluation of localized irrigation systems (Micro Tubes Irrigation and Drip Irrigation System MTI and DIS, respectively.), water quality (fresh and treated), and water amounts (100, 80, 60 % from ET) on vegetative growth, tuber yield and water productivity (WP). In the hydraulic evaluation of irrigation system used, the pressure head losses by using MTI irrigation system was 0.21 m head or 2.1 %, while in DIS irrigation system pressure head losses was achieved 1.925 m or 19.25 %. In this hydraulic evaluation we can notice that MTI irrigation system saved the operating irrigation system energy by 17.15 % relative to DIS irrigation system. The parameters of vegetative growth (plant length, LAI; branches number) under irrigation system, treated waste water (TWW) were increased by 6.0 %, 14.6 %; 15.3 % relative to MTI irrigation system and FW, respectively. Yield and WP under DIS irrigation system, increased by 5.4 % and 5.7 % relative to MTI 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. The effect of irrigation by DIS irrigation system and using TTW was positively on vegetative growth parameters, (yield and WP). This could be attributed to the improvement in soil physical characteristics under using DIS irrigation system relative to MTI irrigation system and the soluble nutrients in the TWW relative to fresh water.
Keywords: MTI, DIS, Irrigation system, FW, TTW, WP, FP, Potato.

Introduction

The Increase for water demand in the world, especially in arid and semi-arid regions such as new reclaimed lands in west desert of Egypt, 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[1] 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, J.L. et al [2,] Shock C.C.et al 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[4] as it needs frequently irrigations for suitable growth and optimum yield[5,6,7] have reported that initial vegetative stage is not sensitive to the moisture stresses. In contrast, Hassan, M.A.[1] found that the stalinization and tuberization stages were more sensitive than bulking and tuber enlargement stages. Thornton M.K.[9], Shock C.C.[10] found that all growing stages of potato, especially tuber formation stage, are very sensitive to water deficit stress. Whereas [2]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[11]**.**

Michael, A.M.[12] 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. Water productivity (WP) is defined as the tuber yield obtained per unit of water consumed as evapotranspiration (ET) or water used in cubic meter by the potato[13,14] 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, M. et al [15] illustrated that WP 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, K.et al[16] found that WP varied around 8-14 kg per m^3 for planted potato. Wright, J.L. et al[2] reported that the WP for maximum yield range from approximately 0.05 to 0.1 kg per ha per m^3. Sharma, B. R.[17] state that the high wind velocity has no effect on DIS irrigation system because the applies of water is directly to the root zone of plants

The objective of this study is to: The hydraulic evaluation of localized irrigation systems to rationalize the irrigation water and energy, the effect of treated agricultural drainage as an alternative to fresh water. Moreover to study the effect of irrigation water amounts on growth, tuber yield and water productivity of potato crop.

Material and Methods

Field experiments were carried out during the years 2013 and 2014. Using randomize complete design at the Experimental Farm of National Research Center (NRC), El-Noubaria Governor, Egypt, in sandy soil. Two irrigation methods (MTI&DIS irrigation systems) and two irrigation water sources (Fresh & Treated waste water) and three treatments of water applied (60, 80; 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/cm^3)	P (cm^3 voids /cm^3 soil)
	C. Sand	F. Sand	Silt	Clay		F.C.	W.P.	AW			
0-15	8.4	77.6	8.5	5.5	Sandy	14.0	6.0	8.0	6.68	1.69	0.36
15-30	8.6	77.7	8.3	5.4	Sandy	14.0	6.0	8.0	6.84	1.69	0.36
30-45	8.5	77.5	8.8	5.2	Sandy	14.0	6.0	8.0	6.91	1.69	0.36
45-60	8.8	76.7	8.6	5.9	Sandy	14.0	6.0	8.0	6.17	1.67	0.37

* Particle Size Distribution after [18] and Moisture retention after [19]

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 (cm^3 voids/cm^3 soil).

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

Depth, cm	pH 1:2.5	EC dS/m	Soluble Cations, meq/L				Soluble Anions, meq/L			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}
0-15	8.3	0.35	0.60	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[20]

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

Fig. (1) Show the component of irrigation system network, the water tank of bubbler system connected to the submain line directly which lateral lines 20 mm in diameter were installed connected to submain lines, The bubblers consists of small on-line convertor connected to small macron tubes 8.0 mm in diameter and had 30 lph flow rate at 1.0 bar pressure. Water in tank has been refilled by the control head unit. DIS irrigation lateral lines were installed were 16 mm in diameter connected to submain lines (63 mm) in diameters which connected to main line from control head unit. The drippers were inline type (GR) from each other and had 4 lph flow rate at 1.0 bar pressure.

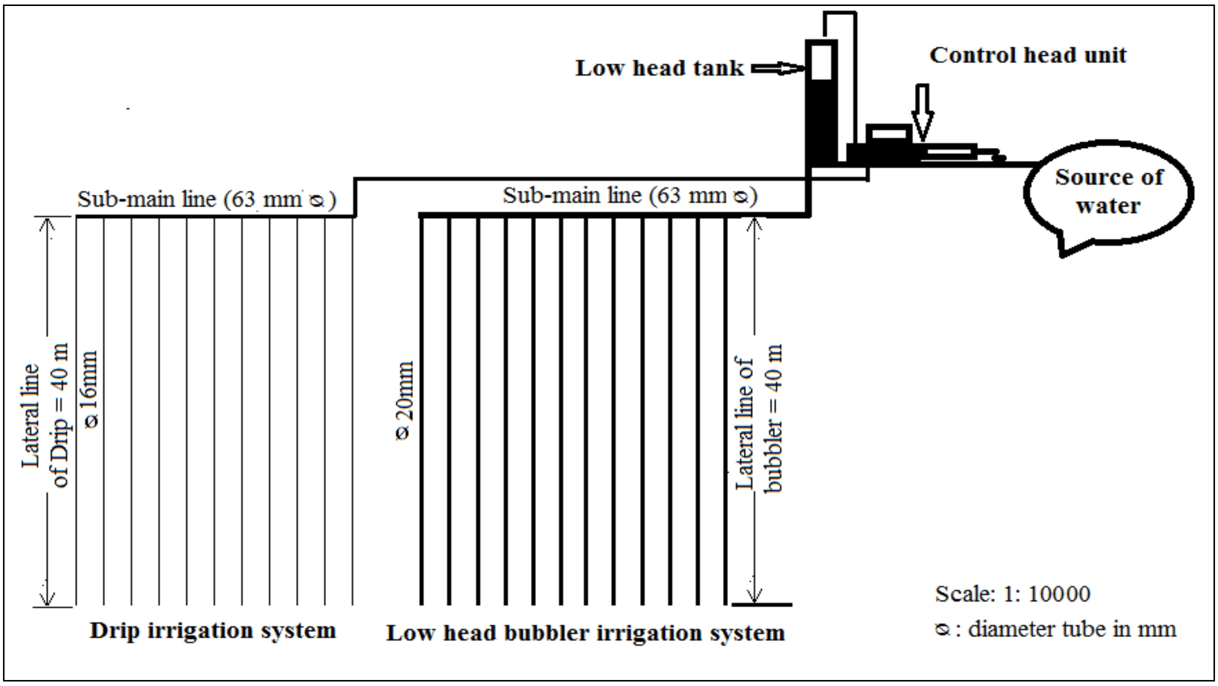

Fig. (1) Lay out of DIS and MTI irrigation systems

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,[13]. 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 %; 80 % and 60 % under Disc plough and DIS irrigation system. All plots were irrigated at 3-4 days interval. Amount of irrigation water was measured at the entrance of each line of DIS 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

The hydraulic evaluation for irrigation system is very important to estimating the water uniformity distribution of irrigation system and in order to provide the good enough of recommended water requirements for plants according to the ET crop calculated. In Table (4) and Figures (2 and 3) show that the highest value of DIS per discharge of MTI system was 29.88 lph achieved at beginning by 2m along lateral tube line and lowest one was 21.17 lph achieved at the end by 40m along lateral tube line. On the other hand the highest value of DIS per discharge of DIS system was 3.79 lph achieved at beginning by 2m along lateral tube line and lowest one was 3.23 lph achieved at the end by 40m along lateral tube line of DIS irrigation system.

Table (4) Evaluation for discharge of MTI and DIS irrigation system along lateral line with operating pressure 1.0 bar

Lateral length (m)	Discharge (lph)	
	MTI system	DIS system
2	29.88	3.79
4	28.85	3.76
6	28.84	3.75
8	28.82	3.73
10	27.98	3.67
12	27.86	3.66
14	27.84	3.65
16	26.92	3.64
18	26.58	3.63
20	26.19	3.59
22	25.83	3.56
24	25.82	3.56
26	25.81	3.48
28	24.52	3.48
30	24.81	3.36
32	24.42	3.34
34	23.09	3.31
36	22.73	3.24
38	21.78	3.23
40	21.17	3.23

From Figuers (2 and 3) we can noticed that for DIS irrigation system, the line equation resulted as following:

(Y = -0.0155x + 3.8592) -- (1)
Where :
X = length of lateral line (m), and
Y = discharge of DISper (lph).

Regression among discharge (lph) values was (R^2 = 0.9585), while for MTI irrigation systemthe line equation resulted as following:

(Y = -0.0141x + 29.924) --(2)
Where :
X = length of lateral line (m), and
Y = discharge of DISper (lph).
Regression among discharge (lph) values was (R^2 = 0.9585), R^2 = 0.9872

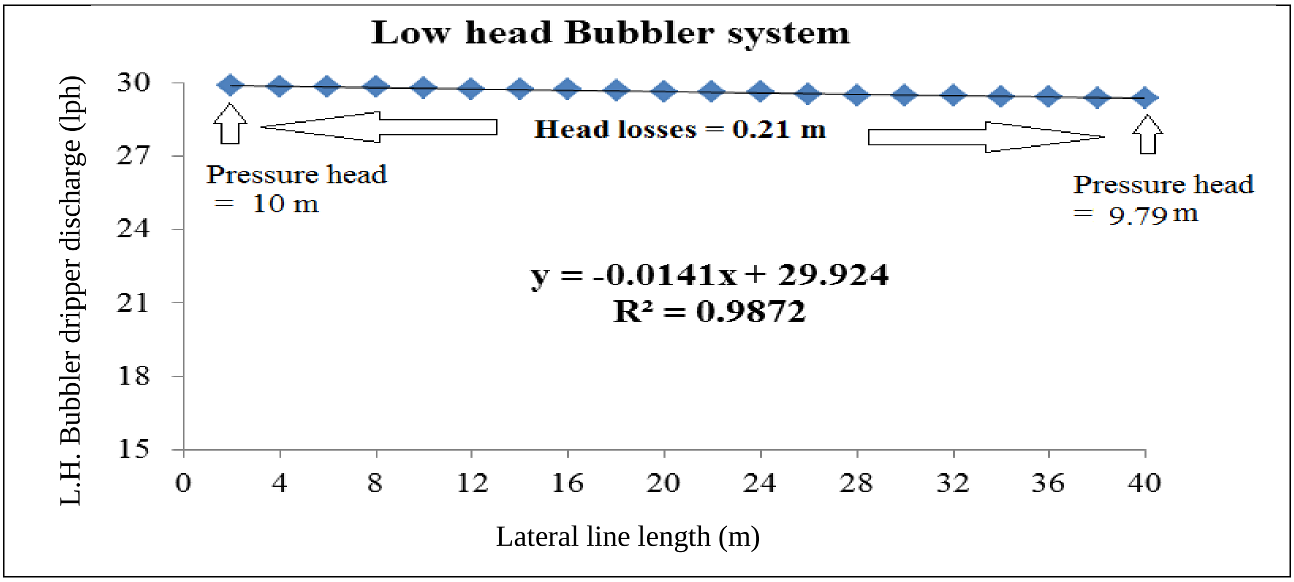

Fig.(1) Evaluation for discharge of MTI irrigation system along lateral line with operating pressure 10.0 mhead

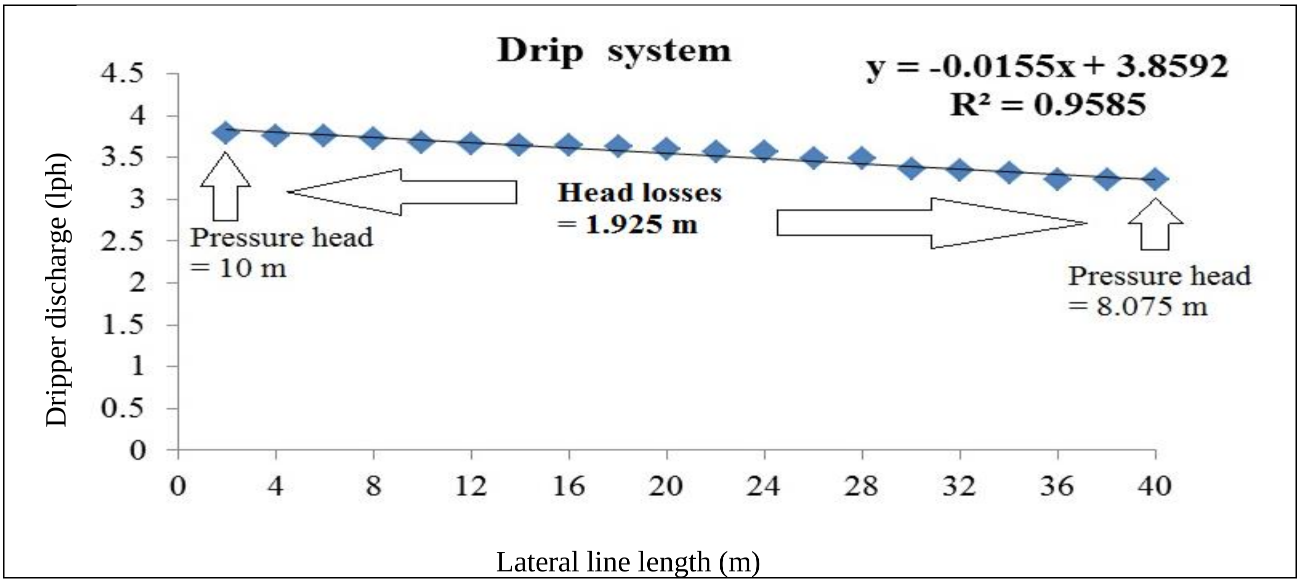

Fig. (2) Evaluation for discharge of DIS irrigation system along lateral line with operating pressure 10.0 mhead

Figures (2 and 3) show that the pressure head losses by using MTI irrigation system was 0.21 m head or 2.1 %, while in DIS irrigation system pressure head losses was achieved 1.925 m or 19.25 %. In this hydraulic evaluation we can notice that MTI irrigation system saved the operating irrigation system energy by 17.15 % relative to DIS irrigation system. The improving of MTI results due to the high values of regression R^2 and the high uniformity distribution of bubblers.

Table (4) illustrate the effect of irrigation methods by MTI and DIS irrigation system, water quality by fresh and waste water types (FW and TWW) and water treatments of 60, 80, 100 % from evapotranspiration on plant length in cm, leaf area index (LAI) and Number of branches. The highest values of plant length were by using TWW with DIS irrigation system (0.61, 0.65; 0.62cm), followed by TWW with MTI irrigation system (0.64, 0.66; 0.67 cm). Whereas the lowest values were by using FW with MTI irrigation system (0.53, 0.58; 0.65 cm), followed by FW with DIS irrigation system (0.62, 0.67; 0.69 cm) under applied water treatments of (60, 80; 100%) from ETo, respectively. The values of LAI token the same trend of plant length. Highest values of LAI were by using TWW with DIS and MTI irrigation systems (3.3, 3.5; 3.8) and (2.8, 3.4; 3.7).

Table (4): Effect of irrigation, water quality and irrigation rates, on growth of potato.

Irrigation system (I)	Water quality (II)	Treatments of Water applied (%) from ET (III)	Plant length (cm)	LAI	Average of branches Number
MTI	FW	60	0.53a	2.2a	4.3a
		80	0.57b	2.3b	3.9b
		100	0.64c	3.4c	3.6c
	TWW	60	0.52d	2.8d	4.5d
		80	0.58e	3.4e	4.4e
		100	0.66f	3.7f	4.4f
DIS	FW	60	0.51g	2.4g	4.3g
		80	0.58h	3.5h	3.9h
		100	0.65i	3.6i	3.4i
	TWW	60	0.53j	3.3j	4.8j
		80	0.59k	3.5k	4.4k
		100	0.69l	3.8l	4.0l
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= Evapotranspiration, LAI= Leaf area index.

In contrast the lowest values of LAI were by using FW with MTI and DIS irrigation systems (2.4, 3.5; 3.6) and (22, 2.3; 3.4) under applied water treatments of (60, 80; 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 TWW with DIS irrigation system (4.8, 4.4; 4.0), followed by TWW with MTI irrigation system (4.4, 4.4; 4.5). Whereas the lowest values were by using FW with MTI irrigation system (4.3, 3.9; 3.6), followed by FW with DIS irrigation system (4.3, 3.9; 3.4) under applied water treatments of (60, 80; 100%) from ET, respectively. According to LDS values in Table (4) 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 [21], [22], [23], [24] and [25].

Table (5): Effect of irrigation, water quality and different irrigation rates, on tuber yield and water productivity of potato.

Irrigation system (I)	Water quality(II)	Treatments of water applied (%) from ET (III)	Water amount (m^3/ha)	Tuber yield (ton/ha)	WP (ton/m^3)
MTI	FW	60	41.6	9.7c	0.23a
		80	58.2	11.7b	0.20b
		100	83.2	12.4a	0.15c
	TWW	60	41.6	10.3c	0.25a
		80	58.2	11.9b	0.20b
		100	83.2	12.6a	0.15c
DIS	FW	60	41.6	10c	0.24a
		80	58.2	11.8b	0.20b
		100	83.2	12.6a	0.15c
	TWW	60	41.6	10.3c	0.25a
		80	58.2	12.3b	0.21b
		100	83.2	12.9a	0.16c
LSD 0.05				2.2	0.01
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, TWW= Treated waste water; ET= Evapotranspiration, WP= water productivity.

Table (5) showing the effect of irrigation methods by MTI and DIS irrigation systems, water quality by fresh and waste water types (FW and TWW) and water treatments of 60, 80, 100 % from evapotranspiration on potato tuber yield and WP. The water productivity WP took the same trend of both potato vegetative growth and tuber yield. WP values were the highest by using TWW with DIS irrigation system (0.24, 0.19; 0.14 ton.m^{-3}), followed by TWW with MTI irrigation system (0.22, 0.19; 0.14ton.m^{-3}). Whereas the lowest values of WP were by using FW with MTI irrigation system (0.21, 0.18; 0.14ton.m^{-3}), followed by FW with DIS irrigation system (0.23, 0.18; 0.13 ton.m^{-3}) under applied water treatments of (60, 80; 100%) from ETo, respectively. This finding is inconsistent with [16], who reported that the range of WP 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 (5) of potato yield and WP, 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. This can be attributed to the improvement in soil hydro-physical properties by using of DIS irrigation system relative to MTI irrigation system and the soluble nutrients in the treated waste water relative to fresh water. The data obtained agreed with [26], [27], [28] and [29].

Conclusion

In the hydraulic evaluation of irrigation system used, the pressure head losses by using MTI irrigation system was 0.21 m head or 2.1 %, while in DIS irrigation system pressure head losses was achieved 1.925 m or 19.25 %. In this hydraulic evaluation we can notice that MTI irrigation system saved the operating irrigation system energy by 17.15 % relative to DIS irrigation system.

The effect of DIS irrigation system, treated wastewater, and control water treatment 100% ET were found to be positive on potato vegetative growth, tuber yield and WP. It could be noticed that the best interaction between factor under study was under DIS irrigation system, TWW and 100 % ET according to data obtained vegetative growth, yield, and WP, were arranged in the following ascending orders: MTI Irrigation system >DIS irrigation system, FW >TWW and 100%>80% >60% amount of water was applied from ETo. This can be attributed to the improvement in soil hydro-physical properties by using of DIS irrigation system relative to MTI irrigation system and the soluble nutrients in the treated waste water relative to fresh water.

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