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RESEARCH ARTICLE

EFFECT OF TILLAGE, WATER QUALITY AND DRIP IRRIGATION ON VEGETATIVE GROWTH AND WATER USE EFFICIENCY OF POTATO

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Manuscript Info | *Abstract*

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A field experiment was conducted during 2011 and 2012 at King Faisal University Research Station, altitude: 147 m, (Latitude: 25^{o} 24' 00" N, Ln: 49^{o} 36' 00" E) in sandy loam soil to study the effect of tillage, water quality and drip irrigation on vegetative growth, yield and water use efficiency (WUE) of Potato crop. The parameters of vegetative growth (vine length, LAI; branches number) under Mould-board plough, treated waste water (TWW) were increased by 6.0 %, 14.6 %; 15.3 % relative to disk plough and FW, respectively. Yield and WUE under Mould-board plough, TWW were increased by 5.4 % and 5.7 % relative to disk plough and fresh water (FW), respectively. Nitrogen use efficiency (NUE), phosphorus use efficiency (PUE0 and potassium use efficiency (KUE) under Mould-board plough, TWW increased by 5.4 %, 5.3%; 5.3 % relative to disk plough and FW, respectively. Vine 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. Yield, WUE and FUE, could be arranged in ascending order: 50% < 75% < 100% due to amount of water applied. The effect of tillage by Mould-board plough and using TTW was positively on vegetative growth parameters, (yield, WUE and FUE). This could be attributed to the improvement in soil physical characteristics under using Mould-board plough relative to disk plough and the soluble nutrients in the TWW 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 Saudi Arabia 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 (*Solanumtuberosum 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. Mould-board ploughing is a traditional cultural operation, which incorporates surface organic residues, stimulates mineralization and thereby aids crop nutrition. Tillage 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).** As organic fertilizers are expensive, generally fewer nutrients are supplied in organic farming **(David et al., 2005)**. Thus, the nutrient contributions from soil organic matter are of greater importance in organic farming **(Stockdale et al., 2002)**. Nitrogen (N) is supplied+ by the combined use of N fixed in legumes in the rotation and organic manures. Tillage incorporates and distributes this organic matter through the topsoil providing conditions suitable for mineralizing nutrients, particularly N. Tillage also facilitates seedbed preparation, improving conditions for rooting and nutrient uptake **(Koepke, 2003)**. Soil tillage, especially conventional ploughing, is crucial for the control of weeds in organic farming **(Trewavas, 2004)**. **Hoorn et al, (1993)** states that potato growth and yield are affected by water salinity, more pronounced for potatoes than for wheat. The water-use efficiencies obtained in this experiment correspond with values reported in literature and are not affected by soil and salinity. The stronger sensitivity of potatoes to soil and salinity, compared with wheat, is an expression of its sensitivity to water stress. **(Epstein and Grant, 1973)** significant differences between the three water qualities appeared from the start of the measurements onwards, whereas on clay they appeared first between the control and the saline treatments and afterwards also between the saline treatments. The higher the salinity, the lower the stomatal conductance.

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 mEqCl/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 applied of water is directly to the root zone of plants. **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.

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 tillage 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 2011 and 2012. Using randomize complete design at Al-Hasa oasis, Kingdom of Saudi Arabia, in sandy loam soil. Two tillage machines (Disk &Mould-board ploughs) 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.

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 Al-Hasa,KSA.**Doorenbos and Pruitt, (1977)**. The different ploughs (Disk and Mould-board ploughs) were used to prepare the land in the experiments farm. 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 Mould- board plough. 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 KSA. 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.

Table (1): Soil physical properties of the experimental site

Soil sample Depth (cm)	Particle size distribution (%)				Texture class	* FC	* WP	* AW	BD (g/cm^3)	HC (cm/h)
	Coarse sand	Fine sand	Silt	Clay		(v/v %)				
0-15	3.7	54.5	25.2	16.6	**SL**	0.22	0.11	0.11	1.45	1.11
15-30	3.8	55.8	24.6	15.8	**SL**	0.22	0.11	0.11	1.43	1.28
30-45	4.6	53.7	26.0	15.7	**SL**	0.22	0.11	0.11	1.43	1.28
45-60	4.6	55.9	25.5	14.0	**SL**	0.21	0.10	0.11	1.42	1.53

(*) Determined as percentage in (v/v %) cm^3 Water/ cm^3 Soil, (SL): Sandy loam, Soil; HC: Hydraulic conductivity; and BD: Bulk density.

Table (2): Chemical analysis of the soil

Soil sample Depths(cm)	Cations (Meq/l)				Anions(Meq/l)				pH	E.C (dS/m)
	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}		
0-15	6.43	4.89	185.0	18.84	0	5.64	9.65	58.7	8.10	1.97
15-30	11.53	6.49	237.1	25.01	0	5.21	10.53	62.6	8.13	2.98
30-45	12.15	7.97	279.1	26.63	0	3.68	11.48	64.0	8.11	3.61
45-60	12.56	4.17	307.1	32.28	0	3.62	11.60	66.9	8.03	3.76

Table (3): Chemical analysis of irrigation water

Cations(Meq/l)				Anions(Meq/l)				pH	E.C (dS/m)
Ca^{++}	Mg^{++}	Na^+	K^+	$Co_3^=$	Hco_3^-	Cl^-	$So_4^=$		
0.7	1.72	128	13	0.0	3.4	1.8	67	7.48	2.0

Result and Discussion

1. The effect of different tillage machines, water quality and different amount of irrigation, on vegetative growth of potato.

Table (4) illustrate the effect of tillage methods by disk plough and Mould- board plough, water quality by fresh and waste water types (FW and TWW) and water treatments of 50, 75, 100 % from evapotranspiration on vine length in cm, leaf area index (LAI) and Number of branches. The highest values of vine length were by using TWW with Mould- board plough (53.6, 58.4; 67.3 cm), followed by TWW with disk plough (53.5, 57.6; 64.8 cm). Whereas the lowest values were by using FW with disk plough (50.8, 55.4; 62.1 cm), followed by FW with Mould- board plough (52.4, 56.7; 63.5 cm) under applied water treatments of (50, 75; 100%) from ETo, respectively.

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

Tillage machine (I)	*Water quality (II)*	*Treatments of Water applied (%) from ET (III)*	*Vine length (cm)*	*LAI*	*Average of branches Number*
Disk Plough	***FW***	***50***	*50.8a*	*2.5ad*	*3.4a*
		75	*55.4b*	*3.0be*	*3.0b*
		100	*62.1c*	*3.4c*	*2.9c*
	TWW	***50***	*53.5d*	*2.9d*	*3.8d*
		75	*57.6e*	*3.2e*	*3.6e*
		100	*64.8f*	*3.6f*	*3.3f*
Mould-board Plough	***FW***	***50***	*52.4g*	*2.7g*	*3.7g*
		75	*56.7h*	*3.1h*	*3.1h*
		100	*63.5i*	*3.5ik*	*3.0i*
	TWW	***50***	*53.6j*	*3.1j*	*3.9j*
		75	*58.4k*	*3.5kl*	*3.7k*
		100	*67.3l*	*3.8l*	*3.4l*
LSD 0.01			***0.8***	***0.4***	***0.1***
Interactions					
I X II			***1.2***	***0.1***	***0.2***
I X III			***1.4***	***0.3***	***0.1***
II X III			***1.8***	***0.4***	***0.1***

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

The values of LAI token the same trend of vine length. Highest values of LAI were by using TWW with Mould-board and disk ploughs (3.1, 3.5; 3.8) and (2.9, 3.2; 3.6). In contrast the lowest values of LAI were by using FW with disk plough and Mould-board plough (2.5, 3.0; 3.4) and (2.7, 3.1; 3.5) under applied water treatments of (50, 75; 100%) from ETo, respectively. The average of branches number took the same trend of both vine length and LAI. The average of branches number values were the highest by using TWW with Mould-board plough (3.9, 3.7; 3.4), followed by TWW with disk plough (3.8, 3.6; 3.3). Whereas the lowest values were by using FW with disk plough (3.4, 3.0; 2.9), followed by FW with Mould-board plough (3.7, 3.1; 3.0) under applied water treatments of (50, 75; 100%) from ETo, respectively.

According to LDS values in Table (4) of vine length and average branches number, the differences were significant at 1% level between all values. Whereas concerning LAI, the differences were significant at 1% 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)**.

2. The effect of different tillage, water quality and different irrigation rates, on yield and water use efficiency.

Table (5) showing the effect of tillage methods by disk plough and Mould-board plough, water quality by fresh and waste water types (FW and TWW) and water treatments of 50, 75, 100 % from evapotranspiration on potato yield and WUE. The values of yield took the same trend of vegetative growth parameters. The highest values of potato yield were by using TWW with Mould-board and disk ploughs (9221.7, 11125.3; 11820.3 kg/ha) and (9175.2, 10810.5; 11547.8 kg/ha), respectively. While the lowest values of potato yield were by using FW with disk plough and Mould-board plough (8570.6, 10582.2; 11287.3 kg/ha) and (8897.1, 10715.5; 11458.4 kg/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 yield. WUE values were the highest by using TWW with Mould-board plough (221, 191; 142 $kg.m^{-3}$), followed by TWW with disk plough (220.6, 185.7; 138.8 $kg.m^{-3}$). Whereas the lowest values of WUE were by using FW with disk plough (206.0, 181.8; 135.7 $kg.m^{-3}$), followed by FW with Mould-board plough (213.9, 184.1; 137.7 $kg.m^{-3}$) under applied water treatments of (50, 75; 100%) from ETo, respectively.

According to LSD values in Table (5) of potato yield and WUE, the differences were significant at 1% 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 1% level. The data obtained agreed with **(Nasseri and Bahramloo, 2009).**

Table (5): Effect of tillage, water quality and different irrigation rates, on yield and water use efficiency of potato.

Tillage machine (I)	*Water quality (II)*	*Treatments of water applied (%) from ET (III)*	*Water amount (m^3/ha)*	*Yield (Kg/ha)*	*WUE (kg/m^3)*
Disk Plough	***FW***	***50***	*41.6*	*8570.6a*	*206.0a*
		75	*58.2*	*10582.2b*	*181.8b*
		100	*83.2*	*11287.3c*	*135.7c*
	TWW	***50***	*41.6*	*9175.2d*	*220.6d*
		75	*58.2*	*10810.5e*	*185.7e*
		100	*83.2*	*11547.8f*	*138.8f*
Moul- board Plough	***FW***	***50***	*41.6*	*8897.1g*	*213.9g*
		75	*58.2*	*10715.5h*	*184.1h*
		100	*83.2*	*11458.4i*	*137.7i*
	TWW	***50***	*41.6*	*9221.7j*	*221.7j*
		75	*58.2*	*11125.3k*	*191.2k*
		100	*83.2*	*11820.3l*	*142.1l*
LSD 0.01				***216.2m***	***2.4m***
	Interactions				
I X II				***221.5***	***2.8***
I X III				***201.8***	***3.1***
II X III				***208.7***	***3.3***

FW= Fresh water, TWW= Treated waste water; ET= Evapotranspiration.

3. The effect of different tillage, water quality and irrigation, on fertilizers use efficiency (FUE).

Table (6) illustrate the effect of tillage (disk plough and Mould-board plough), water quality by (FW and TWW) and irrigation treatments of (50, 75, 100 %) on FUE (NUE, PUE and KUE). NUE, PUE; KUE took the same trends of previous characteristics, the values of potato FUE were the highest when using TWW with Mould-board and disk ploughs as following: the values of TWW under Mould-board plough were (106.0, 127.9; 135.9), (329.3, 397.3; 422.2) and (163.9, 197.8; 210.1) whereas under disk plough were (102.3, 132.2; 131.7), (317.8, 382.7; 409.2) and (158.2, 190.5; 203.7) for FTo treatments (50, 75; 100 %), respectively.

While the lowest values were by using FW with disk plough and Mould-board plough as flowing: values of FW under Mould-board plough were (98.5, 121.6; 129.7), (306.1, 377.9; 403.1) and (152.4, 188.1; 200.7) in contrast under disk plough were (105.5, 124.3; 132.7), (327.7, 386.1; 412.4) and (163.1, 192.2; 205.3) for FTo treatments (50, 75; 100 %), respectively.

The improvement in fertilizer use efficiencies by using Mould-board plough under the soil attributed to improve soil physical properties which allowing to conditions for fertilizers good spread with added water area of the plant roots zones and also ease in the absorption of fertilizers added called fertigation. This improvement in the soil physical properties does not appear effect only in the presence of Mould-board plough under the soil because this is the soil physical characteristics are usually renewable and does not appear in the presence of superficial farming operations using disc ploughs. On the other side improved fertilizer use efficiencies due to the use of treated water because the water plentifully contain a number of nutrients, which in turn helps to take advantage of the added fertilizer and these elements are not present new water.

According to LSD values in Table (6) of potato FUE and LSD values, the differences were significant at 1% level between all values. Also the interaction between the different factors (I x II, I x III; II x III) were significant at 1% level. The data obtained agreed with **(Adrien*et al*, 2013 and N'Dayegamiye 2006).**

Table (6):Effect of tillage method, water quality, and different irrigation rates on Fertilizers use efficiency of potato.

Tillage machine	*Water quality*	*Treatments of Water applied (%) from ET*	*N*	*P_2O_5*	*K_2O*	*Yield (Kg/ha)*	*NUE*	*PUE*	*KUE*
(I)	*(II)*	*(III)*		*Kg/ha*			*Kg yield / Kg fertilizer*		
Disk Plough	**FW**	**50**	**87.0**	**28.0**	**56.3**	8570.6a	98.5a	306.1a	152.4a
		75				10582.2b	121.6b	377.9j	188.1b
		100				11287.3c	129.7c	403.1c	200.7c
	TWW	**50**				9175.2d	105.5d	327.7d	163.1d
		75				10810.5e	124.3e	386.1e	192.2e
		100				11547.8f	132.7f	412.4f	205.3f
Mouldboard Plough	**FW**	**50**				8897.1g	102.3g	317.8g	158.2g
		75				10715.5h	132.2h	382.7h	190.5h
		100				11458.4i	131.7i	409.2i	203.7i
	TWW	**50**				9221.7j	106.0j	329.3j	163.9j
		75				11125.3k	127.9k	397.3k	197.8k
		100				11820.3l	135.9l	422.2l	210.1l
	LSD 0.05					**216.2m**	**6.7**	**8.2**	**1.2**
	Interactions								
	I X II					**221.5**	**7.6**	**8.4**	**1.1**
	I X III					**201.8**	**6.3**	**6.3**	**0.8**
	II X III					**208.7**	**6.8**	**7.6**	**1.3**

FW= Fresh water, TWW= Treated waste water; ET= Evapotranspiration,

Conclusion

The effect of Mould-board plough and use of TWW was found to be positive on vegetative growth parameters, such as yield, WUE and FUE. This can be attributed to the improvement in soil physical characteristics with use of Mould-board plough relative to disk plough and the soluble nutrients in the treated waste water relative to fresh water. It could be included that:

The averages for parameters of vegetative growth (vine length, LAI; branches number) under Mould-board plough, TWW were increased by (6.0, 14.6; 15.3 %), relative to disk plough and FW, respectively, Yield and WUE under Mould-board plough, TWW were increased by (5.4 and 5.7 %) relative to disk plough and FW, respectively, NUE, PUE and KUE under Mould-board plough, TWW were increased by (5.4, 5.3; 5.3 %) relative to disk plough and FW, respectively, Increases both Vine 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, WUE and FUE, they could be arranged in the following ascending order: 50% < 75% < 100% amount of water was applied from ETo.

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