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Sunflower seed yield under trickle irrigation using treated wastewater

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Filed experiment was carried out in land near Ramtha Wastewater Treatment Plant during growing seasons of 2010 and 2011 to determine the effects of using treated wastewater on plant growth, seed yield and yield components of sunflower (*Helianthus annuus* L.) under trickle irrigation. Randomized complete block design (RCBD) for three irrigation treatments namely; I_1= Full irrigation (Actual crop coefficient), I_2= 80% of full irrigation and I_3= 60% of full irrigation randomized over three blocks. The application efficiency of trickle irrigation system was in the range of 88.2 to 90.8%. The applied irrigation water was 4990, 3992 and 2994 m^3 ha^{-1} in 2010 and 5505, 4404 and 3303 m^3 ha^{-1} in 2011 for I_1, I_2 and I_3 irrigation treatments, respectively. Full irrigation treatment (I1) gave the highest plant height, head diameter, number of seeds plant^{-1}, total weight of seeds plant^{-1}, 1000 seeds weight, and seed and oil yield.

Key words: Sunflower production, water shortage, reclaimed wastewater reuse, oilseed crops.

INTRODUCTION

The water availability in arid and semi-arid areas is becoming a main factor to meet the challenges of increasing population. Wastewater reclamation and its reuse have become important components of water resource management plans throughout the world including Jordan (Abdulla et al., 2016).

The scarcity of water resources is one of the major challenges for Jordan, and a limiting factor for economic development particularly for agriculture sector, although additional stress on the water resources comes from population growth, which reaches about 9.5 millions in the end of 2015 as per the population, and housing census report released in late February 2016 (Department of statistics, 2016).

Twenty seven wastewater treatment plants (WWTPs) distributed in Jordan to treat domestic wastewater. Effluent water from these plants is consider an important part of water budget due to water scarcity, and mainly used for unrestricted agricultural production such as forage.

In 2015, about 160 MCM (Million Cubic Meters) is produced from these plants (MWI, 2015). Abdulla et al. (2016) reported that Jordan is considering as a country using the highest ratio of treated wastewater for agricultural productivity in the world. About 160 MCM of treated wastewater was used for irrigation out of 560 MCM of total irrigation purposes, and this form 28.6%.

Effluent from Ramtha wastewater plant (RWWTP) is

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secondary, and nowadays is upgrading to tertiary. Effluent is successfully exploited for irrigated forage production in the surrounded land near the treatment plant (160 ha) (Rusan et al., 2007; Ayoub et al., 2016; Abdulla et al., 2016; Moradi et al., 2016). Effluent of treated wastewater used to save good water quality for domestic use; in the same time using effluent treated wastewater rich in essential nutrient for agriculture will increase agriculture productivity, and achieve economic benefits in by saving the cost of macronutrients (NPK).

Sunflower (*Helianthus annuus* L.) is the most important oilseed crop in the world containing high quality edible oil, and it is easy to grow and developed under different climatic conditions and soils. Sunflower oil is quite tasty, and contains soluble vitamins A, D, E and K. It is used in the manufacturing of margarine; and sunflower cake is used as cattle feed (Hussain et al., 2000). Furthermore, sunflower oil has a high nutritional values, and it has a higher oil percentage in seeds up to 48% (Farokhi et al., 2015). In addition, sunflower seeds are eaten as salted whole seeds as roasted nut meats (Al- Qubaie, 2011; Arshad et al., 2013).

Irrigation treatments for sunflower under semi-arid conditions significantly affected yield and yield attributes (García-López et al., 2016; Abdou et al., 2011). Also, sunflower possesses some genetic potential to grow in low to moderately salt affected areas with a threshold level of ECe 2.5 dS m^{-1} (Heikal et al., 1980; Khatoon et al., 2000; Flagella et al., 2004; El-Kader et al., 2006).

Seed yield has been found to start decreasing beyond ECe 2.5 dS m^{-1}, and achieve 30% less yield at 11.3 ECe, and also reported 49.21% less seed yield at 10 dS m^{-1} (Hussain and Rehman, 1992). Sakellariou-Makrantonaki et al. (2011) found that reuse of wastewater increased seed yield of sunflower plants. The application of treated wastewater as supplementary irrigation showed significant increase in shoot growth, fruit set, fruit weight and yield as compared with rain-fed agriculture (Ayoub et al., 2016).

Irrigation with wastewater significantly increased the concentrations of Ca, Mg and Na in leaves of sunflower plants (Khan et al., 2009).Crop irrigation with treated wastewater represents ecologically sound method for its removal to the environment. Khan et al. (2009) found that the disc diameter, number of seeds per plant, plant weight and 1000 seed weight were significantly increased by the application of treated wastewater compared to either freshwater and/or freshwater with essential nutrients (NPK).

The present study was undertaken to study the effects of using treated wastewaters through surface trickle irrigation on plant growth, seed yield and yield components of sunflower plants.

MATERIALS AND METHODS

Two field experiments were conducted in 2010 and 2011 during summer growing seasons in land near Ramtha Wastewater Treatment Plant in northern Jordan. The site is located at 32°35′N and longitude 35°59′E with an elevation of 484 m above sea level. The long average yearly rainfall in the winter season extended from November till end of March is 275 mm. Soil samples were collected before planting from soil surface layer (0-30 cm), air dried, passed through 2 mm sieve, analysed for chemical and physical properties. Soil texture is clay based on the following particle distribution of 50.72% clay, 32.90% silt and 16.38% sand, bulk density is 1.38 g cm^{-3}, infiltration rate is 4.8 mm hr^{-1}, pH 7.8, EC 0.61 dS m^{-1}, N 0.13%, P 17.13 ppm, K 210.38 ppm and organic matter is 0.53%. Randomized complete block (RCBD) design for 3 irrigation treatments namely; I_1= Full irrigation (Actual crop coefficient), I_2= 80% of full irrigation and I_3= 60% of full irrigation randomized over 3 blocks. Actual crop water requirement (ETc) was calculated based on potential evapotranspiration (ETp) determined from Penman Monteith equation multiply by crop coefficient (kc) of sunflower crop of FAO 56 (Allen et al., 1998), 3 days irrigation interval was adopted. Each experimental plot dimension 4.0 x 4.8 m, planted with 8 rows and 0.5 meter raw space each raw space has one single GR drip lateral line with emitter discharge of 4.0 liter per hour and space 0.40 meters (96 plants per plot). Two meters spacing separate plot to completely eliminate any interaction. At each emitter along the drip line, sunflower seeds were sown on last week of March for 2 growing seasons 2010 and 2011. After seedling growth, they were thinned, and only single seedling was kept at each emitter before starting the applied irrigation treatments.

Chemical properties of treated wastewater used for irrigation was shown in Table 1. Irrigation treatment extended from beginning of April, 10 days after seed sowing (complete seedling germination), and stopped 2 weeks before harvesting in July for both growing seasons. The life span from planting till harvesting is 128 days.

The yield components were studied on the 4 mid planting rows out of total 8 planting rows from each plot. Plants height, head diameters, number of seeds $head^{-1}$, seeds weight $head^{-1}$, weight of 1000 seeds and seed yield were measured. The harvest plot area (4.4 x 0.5 m) was 2.2 m^2 (44 plants). Seed oil content was determined according to AOAC (1995) using the Soxhlet extraction apparatus by petroleum ether (40 to 60°C boiling point).

The recorded data for yield, yield components and oil content were subjected to statistical analysis by using the analysis of variance (ANOVA) through MSTAT-C program, version 2.1 software (Russell, 1989). The mean values were compared by least significance difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Treated wastewater

Treated wastewater has EC=2.62 dS m^{-1}, SAR= 3.10, pH=7.66. Whereas, nitrate content, heavy metals, BOD5, COD and fecal coliform are within Jordanian standard for reuse of wastewater for irrigated agriculture (Table 1).

Soil characteristics

Soil after harvesting were analysed and compared with initial soil sample before planting (Table 2); the results indicated that the highest values of pH, EC, N, P, K, SAR, B, Cd, and Pb were obtained from I_1 follow by I_2 and I_3. There was no significant different (p = 0.05) between I_1 and I_2 as well as I_2 and I_3 for chemical soil properties. Also, no significant differences were found between I_1, I_2 and I_3 in soil B, Cd and Pb values. No fecal coliform was found in soil samples after harvesting, so the irrigation

Table 1. Chemical and biological analysis of treated wastewater from Al-Ramtha Treatment Plant (RWWTP) as compared to Jordanian standard for reclaimed wastewater for agriculture irrigation (Average 2 seasons).

Parameter	Treated wastewater	Max. limit Jordanian standard*
pH	7.66	6.0-9.0
EC (dS m^{-1})	2.62	<2.5
Cl (ppm)	639.53	360
SAR	3.10	9
NO_3 (ppm)	19.63	45
Cd (ppm)	< 0.002	0.01
Pb (ppm)	< 0.01	5
BOD_5 (ppm)	18.56	200
COD (ppm)	42.00	500
Fecal coliform(100 ml^{-1})	53.82	1000

*Jordanian standard for reclaimed waste water, Ministry of Water and Irrigation, 893/2006.

Table 2. Effect of treated wastewater on soil chemical properties (Average 2 seasons).

Parameter	I_1	I_2	I_3
pH	7.94^{a}	7.87^{a}	7.81^{a}
EC (dS m^{-1})	2.86^{a}	2.79^{ab}	2.70^{b}
N (%)	0.19^{a}	0.15^{ab}	0.12^{b}
P (ppm)	8.89^{a}	8.62^{ab}	7.54^{b}
K (ppm)	354^{a}	322^{ab}	291^{b}
SAR	2.90^{a}	2.36^{b}	2.20^{b}
B (ppm)	0.14^{a}	0.12^{a}	0.12^{a}
Cd (ppm)	0.01^{a}	0.01^{a}	0.01^{a}
Pb (ppm)	<0.01	<0.01	<0.01
Fecal coliform(100mL^{-1})	0.00	0.00	0.00

Column means followed by the same letter are not significantly different at 0.05 probability level.

Table 3. Effect of treated wastewater on plant height, yield and yield components of sunflower (Average 2 seasons).

Treatments	Plant height (cm)	Head diameter (cm)	No. of Seeds plant^{-1} (no.)	Total weight of seeds plant^{-1} (gm)	Weight of 1000 seeds (gm)
I_1 (100% of full irrigation)	156.1^{a}	22.69^{a}	1034^{a}	102.30^{a}	92.77^{a}
I_2 (80% of full irrigation)	147.6^{b}	19.23^{b}	942^{a}	95.00^{a}	87.09^{a}
I_3 (60% of full irrigation)	124.7^{c}	11.85^{c}	405^{b}	44.39^{b}	60.86^{c}
LSD (P=0.05)	5.618	1.453	129.3	13.32	7.686

Column means followed by the same letter are not significantly different at 0.05 probability level.

with treated wastewater can be used without any expected microbial contamination for labour. The increasing in the used amounts of treated wastewater in irrigation led to increase in soil chemical properties particularly soil EC and SAR values for both growing seasons; the same trend was found by Salam et al. (2016) who reported that irrigation with treated wastewater may influence negatively on some soil properties particularly EC, SAR and Na% values, which needs continues observing of these characteristics for long-term.

Growth parameters (plant height)

Plant height of sunflower was significantly (p= 0.05) affected by irrigation treated wastewater under trickle irrigation method (Table 3). The highest plant height (156

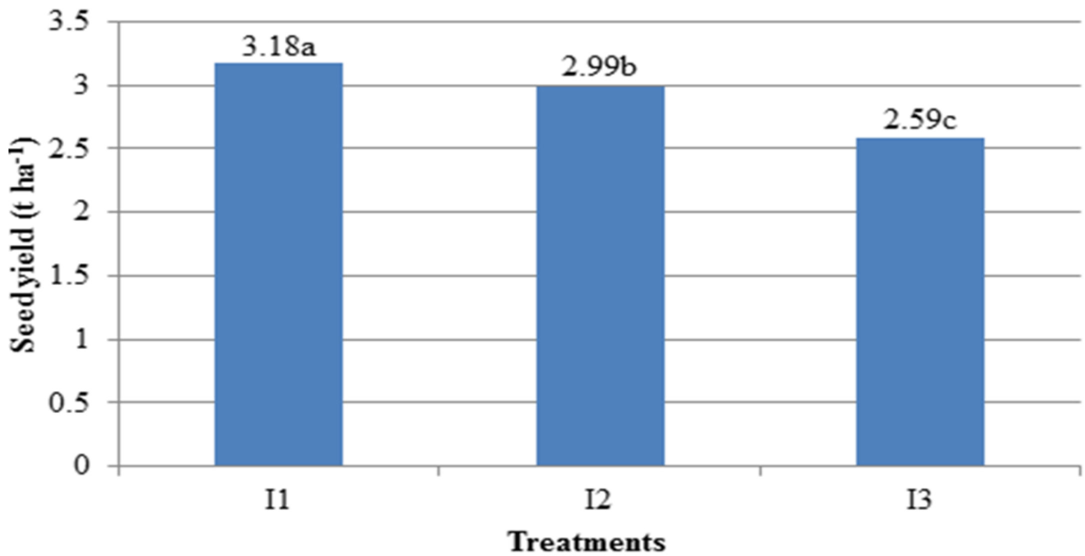

Figure 1. Effect of different level of treated wastewater on seed yield (Average two seasons) (Column means followed by the same letter are not significantly different at 0.05 probability level).

cm) was obtained from I1. Lowest plant height (125 cm) was produced by I_3, the same trend was found by Soomro et al. (2015) were drip irrigation methods significantly increased plant height of sunflower plant.

Yield parameters

Head diameter, number of seeds per plant, total weight of seeds per plant and weight of 1000 seeds were significantly (p= 0.05) affected by irrigated treated wastewater (Table 3). The highest head diameter (22.69 cm), number of seeds per head (935), seed weight per head (93 g) and weight of 1000 seeds (100.8 g) were observed in I_1 (100% of full irrigation). The smallest head diameter, number of seeds per head, seed weight per head and weight of 1000 seeds were obtained at I_3 by applying 60% of full irrigation of the sunflower water requirement. It was also observed that there were no significant differences between I_1 and I_2 in weight of 1000 seeds, total weight of seeds per head and number of seeds per head. These results are in agreement with Moradi et al. (2016) who found that oat plants irrigated by 100% wastewater had a 1000-seed weight increase of 16.5% compared to oat plants irrigated by 100% well water.

Seed yield

Seed yield was significantly (p = 0.05) affected by irrigated treated wastewater (Figure 1). The highest seed yield (3.18 t ha^{-1}) was observed in I_1. The smallest seed yield (2.59 t ha^{-1}) was obtained at I_3 by applying 60% of full irrigation of the sunflower water requirement. Zaki and Shaaban (2015) reported that irrigated with treated sewage water significantly increased seed sunflower yield, and yield components over control.

Oil yield

Oil yield was significantly (p = 0.05) affected by irrigated treated wastewater (Figure 2). The highest oil yield (1.04 t ha^{-1}) was observed in I_1 (100% of full irrigation). The smallest oil yield (0.68 t ha^{-1}) was obtained at I_3 by applying 60% of full irrigation of the sunflower water requirement.

Total volume of treated wastewater used

Total volume of treated wastewater consumed by the sunflower crop under trickle irrigation method in 2010 was 4990, 3992 and 2994 m^3 ha^{-1} whereas in 2011, 5505, 4404 and 3303 m^3 ha^{-1} for I_1, I_2 and I_3, respectively. Differences in water application between the 2 seasons reflect difference in evaporative demand (Table 4). The obtained results indicate that total volume of water consumed under trickle irrigation system was effective on growth and yield components of sunflower. This result is in agreement with Qureshi et al. (2015) who reported that drip irrigation increased sunflower production as compared to the furrow irrigation method.

Conclusions

This study shows that highest yield components values of the sunflower were obtained at full irrigation treatment by treated wastewater water (I_1). Treated wastewater can be

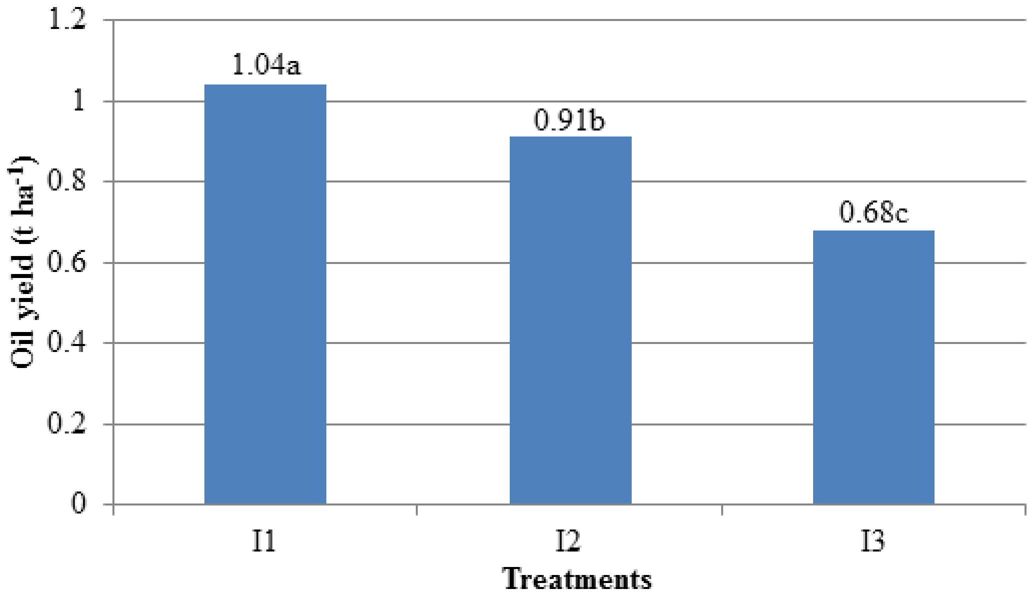

Figure 2. Effect of different level of treated wastewater on oil yield (Average two seasons) (Column means followed by the same letter are not significantly different at 0.05 probability level).

Table 4. Monthly evaporation measurements from a class A pan from seeding to maturity of sunflower, 2010 and 2011

Year	Month					
	March	April	May	June	July	Total
	mm					
2010	23.7*	167.7	231.7	263.1	108.5**	794.7
2011	13.5+	160.0	232.5	309.7	145.4++	861.1

* 25 through 31 March, ** 1 through 12 July, + 27 through 31 March, ++ 1 through 14 July.

used for irrigation sunflower plants to maximize seed yield and oil production as well as other comparable crops to find solution for water scarcity, and availability for irrigation.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Abdou SMM, Abd El-Latif KM, Farrag RMF, Yousef KMR (2011). Response of sunflower yield and water relations to sowing dates and irrigation scheduling under middle Egypt condition. Adv. Appl. Sci. Res. 2(3):141-150.

Abdulla FA, Alfarra A, Qdais HA, Sonneveld B (2016). Evaluation of wastewater treatment plants in Jordan and suitability for reuse. Acad. J. Environ. Sci. 4(7):111-117.

Allen RG, Pereira JS, Raes D, Smith M (1998). Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements. Food and Agriculture Organization of the United Nations, Rome.

AOAC (1995). Association of Official Analytical Chemists.Official Methods of Analysisof A.O.A.C Internacional. 15th ed., Washington, DC.

Al-Qubaie AI (2011). Response of sunflowers cultivar Giza- 102 (*Helianthus annuus* L.) plants to spraying some antioxidants. Nat. Sci. 10(11):1-6.

Arshad M, Khan AM, Ullah I, Amjad M (2013). Development of short duration and high yielding indigenous sunflower (*Helianthus annuus* L.) hybrids. Sci. Technol. Dev. 32(3):205-214.

Ayoub S, Al-Shdiefat S, Rawashdeh H, Bashabsheh I (2016). Utilization of reclaimed wastewater for olive irrigation: Effect on soil properties, tree growth, yield and oil content. Agric. Water Manage. 176:163-169.

Department of Statistics (2016). The Hashemite Kingdom of Jordan. Population and housing census report 2016. Amman, Jordan.

EL-Kader AAA, Mohamedin AAM, Ahmed MKA (2006). Growth and yield of sunflower as affected by different salt affected soils. Int. J. Agric. Biol. 8(5):583-587.

Farokhi H, Shirzadi MH, Afsharmanesh G, Ahmadizadeh M (2015). Response of azargol sunflower cultivar to different micronutrients in Jiroft region, southeast of Iran. South West. J. Hortic. Biol. Environ. 6(1):53-64.

Flagella Z, Giuliani MM, Rotunno T, Di Caterina R, De Caro A (2004). Effect of saline water on oil yield and quality of a high oleic sunflower (*Helianthus annuus* L.) hybrid. Euro. J. Agron. 21(2):267-272.

García-López J, Lorite IJ, García-Ruiz R, Ordoñez R, Dominguez J (2016). Yield response of sunflower to irrigation and fertilization under semi-arid conditions. Agric. Water Manage. 176:151-162.

Heikal MM, Ahmad AM, Shaddad A (1980). Changes in dry weight and mineral composition of some oil producing plants over a range of salinity stress. Biol. Plant. 22(1):25-33.

Hussain MK, Rehman OU (1992). Breeding sunflower for salt tolerance: Genetic variability for yield and yield components for salt tolerance in sunflower (*Helianthus annuus* L.). In: Proc. All Pakistan Sci. Conf. 16-21 May, Khanspur, Pakistan pp. 112-115.

Khan MA, Shaukat SS, Khan MA (2009). Growth, yield and nutrient content of sunflower (*Helianthus annuus* L.) using treated wastewater from waste stabilization ponds. Pak. J. Bot. 41(3):1391-1399.

Khatoon A, Hussain MK, Sadiq M (2000). Effect of Salinity on some Growth Parameters of Cultivated Sunflower under Saline Conditions. Int. J. Agric. Biol. 2(3):210-213.

Moradi S, Heidari H, Saeidi M, Nosratti I (2016). Effect of sewage-contaminated water on seed production, heavy metals accumulation and seedling emergence in oat. Glob. NEST J. 18(2):329-338.

MWI (Ministry of Water and Irrigation) (2013). Jordan Water Sector Facts and Figures. Available online at www.mwi.gov.jo.

Qureshi AL, Gadehi MA, Mahessar AA, Memon NA, Soomro AG, Memon AH (2015). Effect of drip and furrow irrigation systems on sunflower yield and water use efficiency in dry area of Pakistan. Am. Eur. J. Agric. Environ. Sci. 15(10):1947-1952.

Rusan H, Kamre L, Manser T (2007). Wastewater irrigation impacts on crops with respect to heavy metals. Crop Sci. 5:114-118.

Russell DF (1989). MSTAT-C Statistical Package Program ver. 2.1. Michigan State University, East Lansing, USA.

Sakellariou-Makrantonaki M, Giouvanis V, Bota V, Koliou A (2011). Reuse of wastewater in sunflower. Water saving. Proceedings of the 3rd International CEMEPE and SECOTOX Conference Skiathos, Athens, Greece, June 19-24, pp. 423-428.

Soomro A, Mirjat MS, Tunio M, Chandio FA,Tagar AA, Soomro AG (2015). Effect of drip and furrow irrigation methods on water saving, yield and yield components of sunflower crop. Sci. Int. (Lahore) 27(3):2235-2242.

Zaki SS, Shaaban MM (2015). Impact of treated sewage water irrigation on some growth parameters, yield and chemical composition of sunflower, Helianthus annuus L. plants. Int. J. Chem. Technol. Res. 8(9):114-122.