American-Eurasian J. Agric. & Environ. Sci., 10 (4): 658-666, 2011
ISSN 1818-6769

Influence of Organic and Inorganic Fertilizers and Wastewater Irrigation on Yield and Quality Traits of Corn

[1]*Yaser Esmailian*, [2]*Ahmad Ghanbari*, [1]*Mahdi Babaeian* and [1]*Abolfazl Tavassoli*

[1]Department of Agriculture, Shirvan Branch, Islamic Azad University, Shirvan, Iran
[2]Agronomy and Plant Breeding Department, Faculty of Agriculture, University of Zabol, Zabol, Iran

Abstract: In recent years, water shortage and environmental hazards of wastewater have promoted the development of wastewater reuse in irrigation of agricultural lands in many arid and semi-arid regions. An experiment was conducted out at the Experimental Farm of Zabol University, where the effect of treated municipal wastewater, with organic and inorganic fertilizers on yield and yield components, oil and protein content of the seeds, osmotic adjustment compounds and chlorophyll content of corn (*Zea mays*) was studied in the growing season of 2007. Two irrigation levels (W_1: Well water and W_2: Municipal wastewater) and five fertilization levels (F_1: Control, F_2: 30 ton ha^{-1} manure, F_3: 15 ton ha^{-1} manure, F_4: NPK (350, 200, 100 kg ha^{-1}) and F_5: NPK (175, 100, 50 kg ha^{-1})) were studied in a randomized complete block split plot design with three replications. Results illustrated that application of treated wastewater increased grain yield and yield components of corn compared with well water, significantly.The maximum increase of yield components was observed in 1000-grain weight. Among fertilizer treatments, application of F_4 recorded the highest values of grain yield and its attributes. Also, irrigation with wastewater significantly increased oil and protein percentage of the grains than well water. Among fertilizer treatments, F_4 and F_5 were associated with the highest levels of protein content. Highest level of oil content was obtained from manure. Also,the results illustrated that the leaf chlorophyll (SPAD values) was affected by irrigation and fertilizer treatments. Wastewater irrigation due to higher chlorophyll content compared to well water. Also, among the fertilizer treatments, the maximum chlorophyll content observed in F_4 and F_5 treatments. Obtained results have shown that wastewater irrigation resulted in increasing proline and carbohydrate contents in green leaf tissues. Analysis of variance for the carbohydrate content showed the non-significant differences among the fertilizer treatments. In contrast, proline content changed due to fertilizer application. The F_4 treatment positively more affected the content of proline than other treatments and showed a significant reduction in this compound.

Key words: Treated wastewater · Fertilizer · Quality · Yield · Corn

INTRODUCTION

Water resources are steadily decreasing under arid and semi-arid regions and countries (such as Iran) promoted the increasing interest and practice of reclamation and reuse of wastewater which might be used economically and effectively in developing agriculture programs. Whenever good quality water is scarce, water of marginal quality will have to be considered for the irrigation of a variety of field crops and orchards in regions with limited natural water for agricultural purposes [1]. Using of treated municipal wastewater in countries poor in water resources is less expensive and considered an alternative source of irrigation water and the interest in reusing wastewater for irrigation is rapidly growing in these countries [2]. In Iran, wastewater reuse has been an important issue due to water shortage and in many cities has been used in agriculture.

Application of municipal wastewater to irrigation of crops can be an efficient way to reuse waste and conserve valuable ground water resources. On the other hand, when wastewater will be used continuously as the sole source of irrigation water for field crops in arid regions, excessive amounts of nutrients and toxic chemical substances could cause negative effects on quantitative and qualitative characteristics of the plants and the soil

Corresponding Author: Yaser Esmailian, Young Researchers Club, Islamic Azad University, Shirvan Branch, Iran.
E-mail: y.es_2009@yahoo.com.

[3]. But, management of wastewater irrigation should consider the wastewater nutrient content, specific crop nutrient requirements, soil nutrient content and other soil fertility properties [4]. Wastewater is recognized to have direct effect on soil chemical parameters. It affects availability of macro and micro nutrients for plant growth and changes pH, buffer capacity and CEC of the soil. Wastewater may also contain significant quantities of toxic metals [5] and therefore it's long-term application may due to accumulation of heavy metals in toxic values with unfavorable effects on plant growth [6]. Although, the extent of accumulation depends on the application time [7].

Municipal wastewater contains relatively high amounts of sodium, which can be accumulated in the soil during irrigation with this wastewater and display harmful effects on the crops. Of particular concern in arid and semi-arid areas are the possible consequences arising from the high salinity of wastewater.

Several studies have been carried out to investigate the effects of municipal wastewater on agroecosystems. Yaryan [8] studied the effects of irrigation with treated wastewater, well water and irrigation systems on the yield of sugar beet, corn and sunflower and properties of soil. Who obtained that the yield of sunflower and corn was higher under wastewater treatment, compared to well water treatment. However, the differences were not statistically significant. Wastewater treatment increased pH, available N, P, K, Mn, Pb, Ni and Co, but EC_e decreased significantly. Kiziloglu *et al.* [9] showed that wastewater irrigation affected significantly soil chemical characteristics and nutrient content of cauliflower and red cabbage. Also, soil salinity, organic matter, available P and microelements increased as influenced by wastewater treatment.

Day *et al.* [10] compared the effect of irrigation with wastewater than pump water on wheat. They concluded that wastewater irrigation produced taller plants, more heads per unit area, heavier seeds and higher grain yields than pump water.

Rahmani [11] found that the organic matter content, total nitrogen, available P and K and some heavy metals increased in soil due to municipal wastewater application than well water.

The objective of this study was assessed the impacts of municipal wastewater irrigation with manure and chemical fertilizers on yield and yield components, protein and oil contents, osmotic components and leaf chlorophyll of corn.

MATERIALS AND METHODS

This experiment was conducted out at the Experimental Field of the Department of Agronomy and Crop Breeding, Faculty of Agriculture, University of Zabol, Iran (61°29× N, 31°2× E; 483 m above sea level) in 2007. Mean annual precipitation and temperature value are 85 mm and 16.5°C, respectively.

The soil characteristics are given in Table 1. The experiment was performed as split plot randomized complete block design with three replications. The treatments were comprised of two levels of irrigation (W_1: Well water and W_2: Wastewater) in main plot and five levels of fertilizer (F_1: Control, F_2: 30 ton ha^{-1} manure, F_3: 15 ton ha^{-1} manure, F_4: NPK (350, 200, 100 kg ha^{-1}) and F_5: NPK (175, 100, 50 kg ha^{-1}) in sub plot.

Analytical data of the treated wastewater and the well water are shown in Table 2. In this experiment total manure to both irrigations were applied prior sowing and for chemical fertilizer, half of N and total P and K fertilizers were applied prior sowing seeds. Experimental plots were seeded with hybrid corn, 704 cultivar at 30 kg ha^{-1} with 70 cm intervals and 22 cm between plants. Corn was planted manually using two seeds per hill in June 2007. In the three-to-four-leaf stage in order to achieve a desirable density, thinning was performed maintaining one plant per hill. Irrigation was applied during the growing season. Treated wastewater was obtained from Zabol City pond.

To determine the grain yield, plants in five center rows at each experimental plot were harvested in November 2007. The yield components included 1000-grain weight, number of grain per ear, rows per ear, ear diameter and ear length were obtained from six selected plants in each experimental plot.

Table 1: Soil properties measured prior to the inhibition of the experiment.

Depth (cm)	Soil texture	pH	Ec_e	OM (gkg^{-1})
0-30	Sandy-Loam	7.4	1.8	2.3

Table 2: Chemical characteristics of treated municipal wastewater and well water

Parameters	Units	Wastewater	Well water
Ec	dS m^{-1}	3.2	2.1
pH	mgL^{-1}	7.9	7.2
N	mgL^{-1}	23.12	-
P	mgL^{-1}	11.1	-
K	mgL^{-1}	25.6	6.7
Zn	MgL^{-1}	0.01	-
Mn	MgL^{-1}	0.05	-
Cu	MgL^{-1}	0.01	-

Total oil was extracted using Soxhlet apparatus with petroleum ether as solvent. The N contents of grains were obtained by the Kjedahl method and protein percentage was calculated by multiplying nitrogen percentage with 6.25. Leaf chlorophyll content was measured by "SPAD 502" chlorophyll-meter system in the end of flowering stage. Two osmotic adjustment compound included carbohydrate and proline in youngest leaves was measured. Soluble carbohydrate was measured by use of ethanol and on the basis of sulfuric acid method [12] and proline was determined according to the method of Bates *et al.* [13].

All data were analyzed by analysis of variance using SAS Institute Inc 6.12. Data were first analyzed by ANOVA to determine significant ($P \leq 0.05$) effects. Significant differences between individual means were determined using grouped in Duncan Multiple Comparison Test.

RISULTS AND DISCUSSION

Grain Yield: Data cited in Table 3 show a significant effect due to wastewater irrigation on grain yield of corn. The yield of those treatments which used treated wastewater was higher than treatments which used well water (Table 4). Grain yield was 64.6% higher in plants that irrigated with wastewater in comparison with plants irrigated with well water. Similar results were reported by Erfani *et al.* [14]. This increase of yield may be due to the nitrogen and phosphorus in the applied wastewater [10].

Results also indicated that grain yield responded to manure and chemical fertilizers, significantly (Table 3). The comparison of treatments' means revealed that the highest grain yield was obtained from F_4 (NPK=350, 200, 100 kg ha^{-1}) and lowest amount was obtained from F_1 (control). The F_4 treatment 50% increased grain yield than control (Table 4).

The interaction effect between irrigation and fertilizer treatments had significant influence on corn yield (Table 3). Among all treatments, W_2F_5 (wastewater and NPK=175, 100, 50 kg ha^{-1}) had the highest and W_1F_1 (well water and control) had the lowest effect (Fig. 1). Hussain *et al.* [15] illustrated that application of treated sewage effluent promoted the yield of wheat and caused savings of 1/3 of the recommended N fertilizer rates without decrease on grain yield.

Yield Components: Data presented in Table 3 indicated that irrigation and fertilizer treatments were very effective on the yield components. As shown in Table 4, all selected yield attributes were appreciably higher in plants grown in treated wastewater compared with well water. This might be due to availability and better utilization of nutrients from wastewater. Among various components contributing to the economic yield of a crop, 1000-grain weight is of prime importance. Among yield components, wastewater had the most influence on the 1000-grain weight and increased it 19.1% than well water. Also, results of this experiment indicated that wastewater increased number of grain per ear (13.1%), ear length (10.4%), ear diameter (9.7%) and row per ear (7.9%), respectively (Table 3).

Table 3: Analysis of variance of yield and it's components as affected by irrigation and fertilizer treatments

S.O.V	df	Grain yield	1000-grain weight	Grain per ear	Row per ear	Ear length	Ear diameter
Replication	2	4385.02 ns	1374.05 ns	4.053 ns	0.39 ns	0.383 ns	0.132 ns
Irrigation (A)	1	566041.32**	32958.39**	75.05**	7.301**	12.339**	1.438**
Error (A)	2	17219.2	1202.90	30.877	0.540	3.063	0.076
Fertilization	4	51014.47**	2990.98	22.691*	3.403**	0. 708 ns	0.211**
Irrigation× Fertilization (A×B)	4	30794.6*	1105.71 ns	24.265*	2.272*	1.567 ns	0.0406 ns
Error (B)	16	7371.73	596.012	7.431	0.533	0.968	0.036
CV (%)		15.2	10.9	10.8	5.5	8.1	4.49

Ns= Non significant; * and ** = Significant at 5% and 1% probability, respectively.

Table 4: Mean comparison of grain yield and quality and osmotic adjustment compounds as influenced by different treatment treatments

Treatment	Grain yield (g m^{-2})	1000-grain weight (g)	Grain per ear	Row per ear	Ear length (cm)	Ear diameter (cm)
Irrigation						
W_1	426.3b	189.3b	23.6b	12.6b	11.5b	4.1b
W_2	701.1a	225.6a	26.7a	13.6a	12.7a	4.5a
Fertilization						
F_1	438.1c	194.6c	22.8c	12.4c	11.6a	3.9c
F_2	593.9ab	226.3ab	24.1bc	12.9bc	12.2a	4.3ab
F_3	499.2b	202.3bc	24.7abc	12.4c	12.3a	4.1bc
F_4	657.2a	248.7a	27.6a	14.1a	12.5a	4.4a
F_5	630.2a	237.5a	26.8ab	13.8ab	12.1a	4.4a

Means of each column designated by the same latter are not significantly different at 5% or 1% level using Duncan Multiple Comparison Test

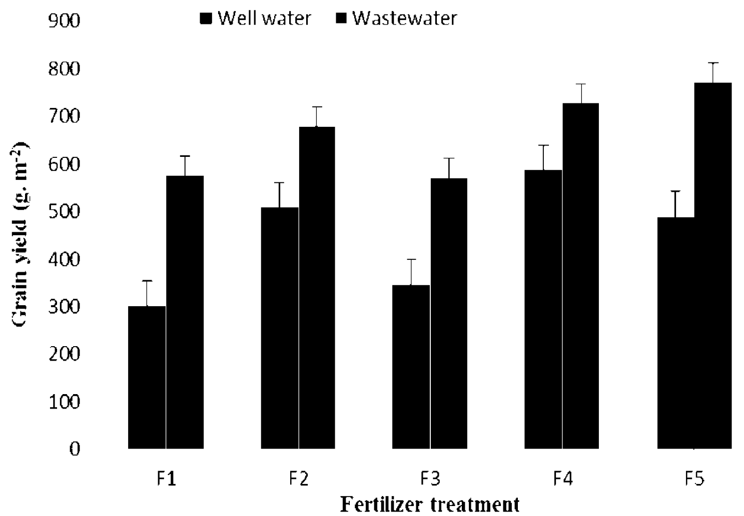

Fig. 1: The interaction effects between fertilizer and irrigation on grain yield

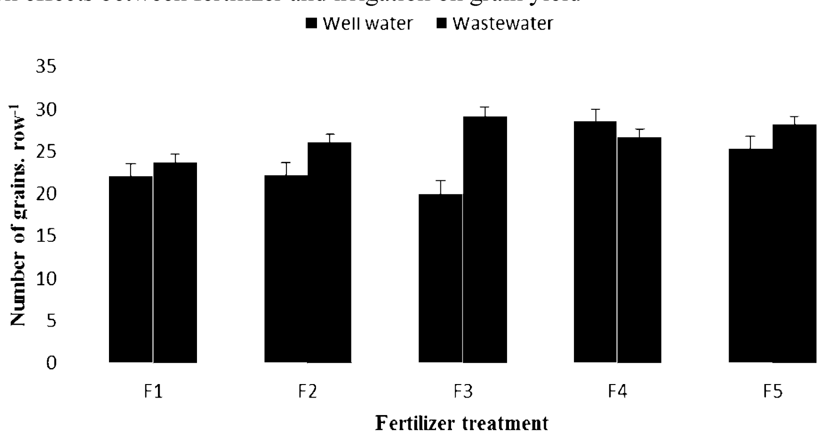

Fig. 2: The interaction effects between fertilizer and irrigation on number of grains per row

Data presented in Table 4 indicated that manure and fertilizer treatments induced an increase in the yield components significantly over control. The maximum of all yield components was observed in F_4 (NPK=350, 200, 100 kg ha^{-1}). Awad [16] concluded that using nitrogen fertilizer significantly increased head diameter, 100 seed weight and seed yield as well as oil yields of corn. Also, Aowad and Mohamed [17] demonstrated that application mineral nitrogen alone had more influence on yield and its components than applying farm yard manure as an organic source.

The irrigation × fertilizer interaction only at the number of grain per ear and row per ear was significant (Table 3). The highest number of grains per ear obtained from W_2F_3 treatment (Fig. 2). This result illustrates that animal manure can be a beneficial source of major nutrients when applied at optimum rates and can influence the temporal dynamic of nutrient availability [18] and increase water use efficiency of crops [19] through it's effect on physical and chemical properties of soil. Zhang *et al.* [20] found that adequate supply of organic wastes with chemical fertilizers improve the wheat crop properties. In case of row per ear, W_2F_5 treatment has the highest amount than other treatments (Fig. 3).

Seed Quality: The protein content of the grains significantly affected by the wastewater treatment applied as shown in Table 5. Results presented in Table 6 revealed that wastewater treatment caused an increase in the protein percentage in corn grains compared to well water. Protein content was 8.4% higher in plants that irrigated with wastewater in compare with plants irrigated with well water. This effect might be due to essential nutrients (especially N) in municipal wastewater that used for protein synthesis. Effects of treated sewage effluent irrigation on increase the protein content in ryegrass [21], wheat [22] and forage corn [23] were observed.

Table 5: Analysis of variance of treatments effects on seed quality, chlorophyll content and osmotic adjustment compounds as affected by different treatments

S.O.V	df	Seed protein	Seed oil	Chlorophyll	Proline	Carbohydrate
Replication	2	0.0007 ns	0.022 ns	1.27 ns	0.0002 ns	0.024 ns
Irrigation (A)	1	4.026**	0.463**	29.84**	0.014**	0.017 **
Error (A)	2	0.0006	0.024	0.16	0.0007	0.011
Fertilization	4	0.396**	0.097*	13.3**	0.033**	0.014 ns
Irrigation× Fertilization (A×B)	4	0.064*	0.022 ns	3.84*	0.0069*	0.011 ns
Error (B)	16	0.005	0.021	1.33	0.0021	0.022
CV (%)		0.84	4.44	2.86	8.5	6.2

Ns= Non significant; *and ** = Significant at 5% and 1% probability, respectively

Table 6: Mean comparison of seed quality, chlorophyll content and osmotic adjustment compounds as influenced by different treatment treatments

Treatment	Protein (%)	Oil (%)	Chlorophyll (SPAD values)	Proline (µM/g fresh wt.)	Carbohydrate(µg glucose/g fresh wt.)
Irrigation					
W1	8.62b	3.15b	39.32b	0.52b	2.38b
W2	9.35a	3.40a	41.32a	0.56a	2.43a
Fertilization					
F1	8.65e	3.38a	38.93b	0.63a	2.39a
F2	8.99c	3.41a	39.19b	0.55a	2.44a
F3	8.84d	3.28ab	39.69b	0.58ab	2.43a
F4	9.13b	3.19b	42.29a	0.42c	2.43a
F5	9.31a	3.11b	41.50a	0.54b	2.32a

Means of each column designated by the same latter are not significantly different at 5% or 1% level using Duncan Multiple Comparison Test

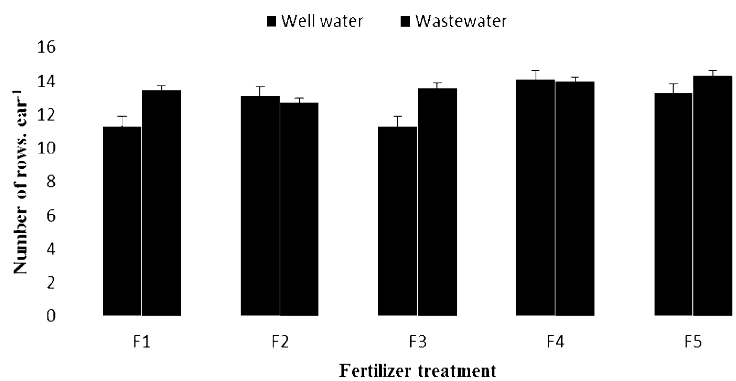

Fig. 3: The interaction effects between fertilizer and irrigation on number of rows per ear.

Data presented in Table 5 showed that protein percentage was significantly affected by fertilizer treatments used. The corn plant that fertilized by F_5 showed the highest value and control showed the lowest value (Table 6). Da Silva *et al*. [24] concluded that nitrogen fertilization had a significant effect on protein content of maize hybrids. Interaction effect between irrigation and fertilizer treatments had a significant influence on protein percentage (Table 5). The maximum level of protein content was recorded from application of treated wastewater and NPK=175, 100, 50 kg ha^{-1} that increased it 19.6% than well water and without fertilizer application (Fig. 4). This result showed that application of wastewater and chemical fertilizer helped in increasing the protein content, which could be related to the adequate supply of nutrients by combination of them.

Results of this study showed that wastewater treatment significantly affected the oil content of the grains (Table 5). It is obvious from the data in Table 6 that the oil content of corn grains significantly increased with wastewater treatment compared to well water. Wastewater induced 7.9% increase in the oil content than well water. Data in Table 5 cleared that fertilizer treatments had a different effect in oil content of the seed. Among the all treatments, F_1 and F_2 had the highest and F_4 had the lowest oil percentage of the seed. Rathke *et al*. [25] found that the highest oil content of oilseed rape (*Brassica napus* L.) was observed in unfertilized plots. Lower content of oil in seeds in chemical fertilizer treatment may be due to a reduced availability of carbohydrates for oil synthesis at high N supply. The negative influence of N fertilizers on the oil content of the seeds was reported by

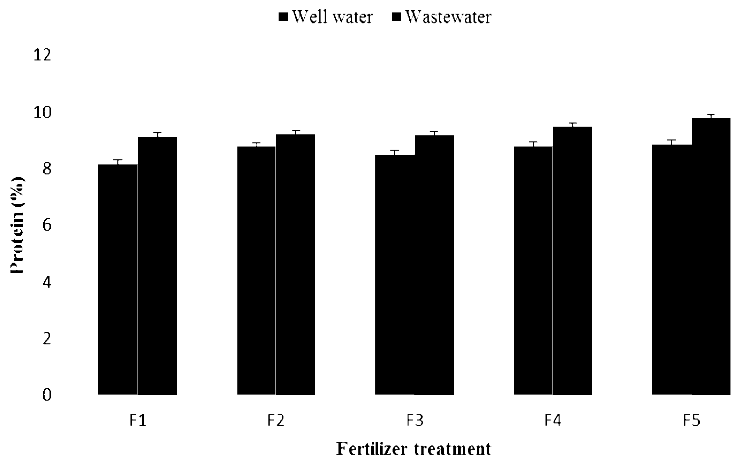

Fig. 4: The interaction effects between fertilizer and irrigation on seed protein.

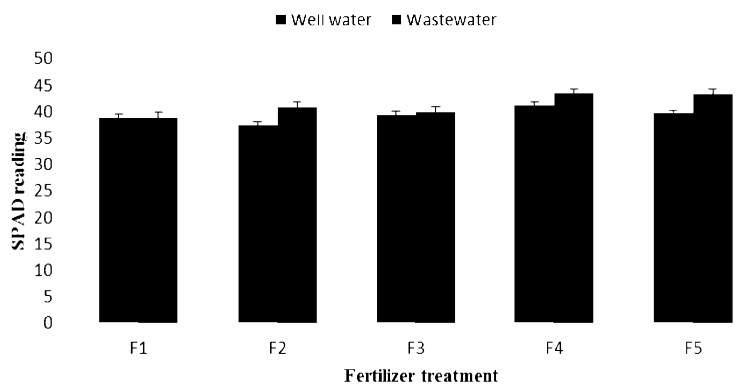

Fig. 5: The interaction effects between fertilizer and irrigation on leaf chlorophyll.

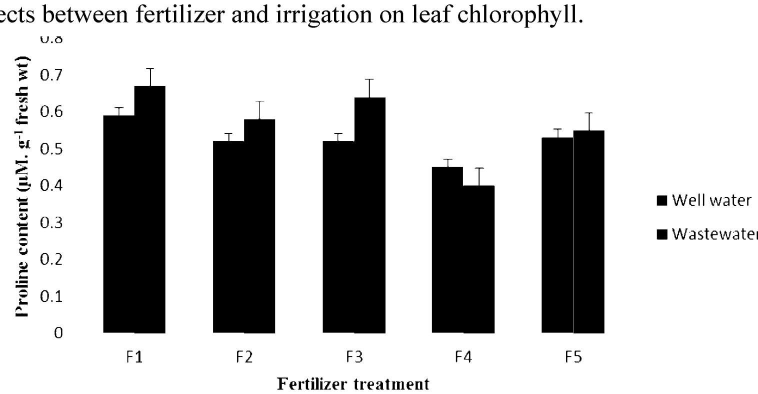

Fig. 6: The interaction effects between fertilizer and irrigation on proline content.

Mason and Brennan, [26] and Cheema *et al.*, [27]. Furthermore, the negative correlation between oil content and protein synthesis is well documented [28, 29].

Interaction effect of irrigation and fertilizer treatments had not any significant influence on oil content of corn seed (Table 5).

Chlorophyll, Proline and Carbohydrate Concentrations: Result showed that chlorophyll content (SPAD readings) significantly increased by applying treated wastewater (Table 5). Data in Table 6 showed that wastewater induced 5.1% increase in the chlorophyll content than well water. Also, chemical fertilizers had significant effects on the chlorophyll content (Table 5). The highest leaf chlorophyll content obtained from F_4 and F_5 and the lowest value recorded from control (Table 6). Promoting effect of inorganic fertilizers on chlorophyll content may be due to this fact that nitrogen is a constituent of chlorophyll. Furthermore, nitrogen is the main constituent of all amino acids in proteins and lipids that acting as a structural compounds of the chloroplast [30]. The interaction effect of irrigation and fertilizer treatments was significant for chlorophyll content (Table 5). Figure 5 show that the highest protein content obtained from W_2F_4.

The analysis of variance (Table 5) revealed that concentrations of two osmotic adjustments include proline and carbohydrate in corn leaves significantly changed in response to wastewater irrigation. The corn plants that irrigated by wastewater showed 7.6% and 2.1% increase in proline and carbohydrate concentrations, respectively (Table 6). Data presented in Table 2 showed that municipal wastewater used in this experiment had a high electrical conductivity (3.2 dS m^{-1}). It is indicated that proline is the important compound in the tolerance of plant cells to salinity by increasing the concentration of osmotic active components in order to equalize the osmotic potential of the cytoplasm [31]. Also, proline is able to minimizing the adverse effect of salinity which is associated with the decrease of Na^+ and Cl^- concentrations in plant tissues [32]. The role of proline in membrane stabilization, protection of proteins from stress-induced damage and detoxification of injurious ions in plants exposed to salt stress had been reported [33, 34]. Cha-Um and Kirdmanee [35] showed that the salinity induced an increase in proline concentration in corn.

The effects of manure and chemical fertilizer on the proline and carbohydrate concentration of corn were summarized in Table 5. Proline and carbohydrate concentration were greater as affected by manure compared with chemical fertilizer. The highest value of carbohydrate content and proline were recorded from F_2 (30 ton ha^{-1} manure) and F_3 (15 ton ha^{-1} manure), respectively.

The interaction effect of irrigation and fertilizer treatments only on proline content was significant (Table 5). Among all treatments, the highest prolin concentration was found in W_2F_3 and the lowest value was recorded from W_2F_4 (Fig. 6).

REFERENCES

1. Oron, G., Y. Demalach., Z. Hoffman and Y. Manor, 1992. Effect of effluent quality and application method on agricultural productivity and environmental control. Water Sci. Technol., 26(7/8): 1593-1601.
2. Arar, A., 1994. Water management and conservation measures under semi-arid and arid conditions, in: Optimization of Water in Agriculture, Proceedings of the Regional Seminar, Amman, Jordan, 21-24 Nov. pp: 177.
3. Vazquezmontiel, O., N.J. Horan and D.D. Mara, 1996. Management of domestic wastewater for reuse in irrigation, Water Sci. Technol., 33(10-11): 355-362.
4. Mohammad, M.J. and N. Mazahreh, 2003. Changes in soil fertility parameters in response to irrigation of forage crops with secondary treated wastewater, Comm. Soil Sci. Plant Anal., 34 (9 and 10): 1281-1294.
5. Yadav, R.K., B. Goyal, R.K. Sharma, S.K. Dubey and P.S. Minhas, 2002. Post-irrigation impact of domestic sewage effluent on composition of soils, crops and ground water-a case study. Environ. Int. 28: 481-486.
6. Rattan, R.K., S.P. Datta, P.K. Chhokar, K. Suribabu and A.K. Singh, 2005. Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater- a case study. Agric. Ecosyst. Environ., 109: 310-322.
7. Palaniswami, C. and U.S. Sree Ramulu, 1994. Effects of continuous irrigation with paper factory effluent on soil properties. J. Indian Soc. Soil Sci., 42: 139-140.
8. Yaryan, K.M., 2000. The effect of treated wastewater and irrigation systems on yield of some field crops. Ms Thesis. Isfahan University of Technology. College of Agriculture, Iran.
9. Kiziloglu, F.M., M. Turanb, U. Sahina, Y. Kuslua and A. Dursunc, 2008. Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (*Brassica olerecea* L. var. botrytis) and red cabbage (*Brassica olerecea* L. var. rubra) grown on calcareous soil in Turkey. Agric. Water Manage., 95(6): 716-724.
10. Day, A.D., J.A. McFadyen, T.C. Tucker and C.B. Cluff, 1979. Commercial production of wheat grain irrigated with municipal waste water and pump water, J. Environ. Qual., 8: 3-8.
11. Rahmani, H.R., 2007. Use of industrial and municipal effluent water in Esfahan province-Iran. Sci. Res. Essay, 2: 84-88.
12. Schlegel, H.G., 1956. Die verwertung organischer sauren durch chlorella in lincht. Planta, 47: 510-514.
13. Bates, L., R. Waldren and I. Teare, 1973. Rapid determination of free proline for water stress studies. Plant and Soil, 39: 205-207.

14. Erfani, A., G.H. Haghnia and A. Alizadeh, 2001. Effect of irrigation by treated wastewater on the yield and quality of tomato. J. Agricultural Sci. and Technol., 15(1): 65-70.
15. Hussain, G., A.A. Al-Jaloud and S. Karimulla, 1996. Effect of treated effluent irrigation and nitrogen on yield and nitrogen use efficiency of wheat. Agricultural Water Management, 30: 175-184.
16. Awad, M.M.M., 2004. Effect of nitrogen fertilization, farmyard manure and biofertilizers on yield and yield components of some sunflower hybrids in north delta region. PhD. Thesis, Agron. Dept., Fac. of Agric., Kafr El-sheikh, Tanta Univ., Egypt.
17. Aowad, M.M. and A.A.A. Mohamed, 2009. The effect of bio, organic and mineral fertilization on productivity of sunflower seed and oil yields. J. Agric. Res. Kafrelsheikh Univ., 35(4): 1013-1027.
18. Paul, T.T.W. and E.G. Beauchamp, 1993. Nitrogen availability for corn in soils amended with urea, cattle slurry and solid composted manure. Canadian J. Soil Sci., 73(3): 253-266.
19. Carter, D.C., D. Harris, J.B. Youngquist and N. Persaud, 1992. Soil properties, crop water use and cereal yield in Botswana after addition of mulch and manure. Field Crops Res., 30(1): 97-109.
20. Zhang, M., D. Heaney, E. Solberg and B. Heriquez, 2000. The effect of MSW (municipal solid waste) compost on metal uptake and yield of wheat, barley and canola in less productive farming soils of Alberta. Compost Sci. and Utilization, 8: 224-35.
21. Quin, B.F. and P.H. Woods, 1978. Surface irrigation of pasture with treated sewage effluent. I. Nutrient status of soil and pastures. New Zealand J. Agricultural Res., 21: 419-426.
22. Day, A.D., A. Rahman, F.R.H. Katterman and V. Jensen, 1974. Effects of treated municipal wastewater and commercial fertilizer on growth, fiber, acid-soluble nucleotides, protein and amino acid content in wheat hay. J. Environ. Quality, 3: 17-19.
23. Mohammad, M.J. and M. Ayadi, 2004. Forage yield and nutrient uptake as influenced by secondary treated wastewater. J. Plant Nutrition, 27: 351-364.
24. Da Silva, P.R.F., M.L. Strieder., R.P. Da Silva Coser, L. Rambo, L.S.G. Argenta, E.L. Forsthofer and A.A. Da Silva, 2005. Grain yield and kernel crude protein content increases of maize hybrids with late nitrogen side-dressing. Sci. Agric., 6(5): 487-492.
25. Rathke, G.W., O. Christen and W. Diepenbrock, 2004. Effects of nitrogen source and rate on productivity and quality of winter oilseed rape (*Brassica napus* L.) grown in different crop rotations. Field Crops Res., 94: 103-113.
26. Mason, M.G. and R.F. Brennan, 1998. Comparison of growth response and nitrogen uptake by canola and wheat following application of nitrogen fertilizer. J. Plant Nutr., 21(7): 1483-1499.
27. Cheema, M.A., M.A. Malik, A. Hussain, S.H. Shah and S.M.A. Basra, 2001. Effects of time and rate of nitrogen and phosphorus application on the growth and the seed and oil yields of canola (*Brassica napus* L.). J. Agron. Crop. Sci., 186: 103-110.
28. Brennan, R.F., M.G. Mason and G.H. Walton, 2000. Effect of nitrogen fertilizer on the concentrations of oil and protein in Canola (*Brassica napus* L.) seed. J. Plant Nutr., 23(3): 339-348.
29. Hao, X., C. Chang and G.J. Travis, 2004. Short communication: effect of long-term cattle manure application on relations between nitrogen and oil content in canola seed. J. Plant Nutr. Soil Sci., 167: 214-215.
30. Arisha, H.M. and A. Bradisi, 1999. Effect of mineral fertilizers and organic fertilizers on growth, yield and quality of potato under sandy soil conditions. Zagazig J. Agric. Res., 26: 391-405.
31. Watad, A., L. Reinhold and M. Lerner, 1983. Comparison between a stable NaCl selected Nicotine cell line and the wild type, Na^+, K^+ and proline pools as a function of salinity. Plant Physiol., 73: 624-629.
32. Nessim, M.G., M.A. Hussein and A.A. Moussa, 2008. The effects of irrigation water salinity, potassium nitrate fertilization, proline spraying and leaching fraction on the growth and chemical composition of corn grown in calcareous soil. International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 2008. pp: 787-803.
33. Verma, D.P.S., 1999, Osmotic stress tolerance in plants: Role of proline and sulfur metabolisms. In molecular responses to cold, drought, heat and salt stress in higher plants, Shinozaki, K. and K. Yamaguchi-Shinozaki, eds (Austin, TX: R.G. Landers). pp: 153-168.

34. Ashraf, M. and M.R. Foolad, 2007. Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environ. Exp. Bot., 59: 206-216.

35. Cha-um, S. and C. Kirdmanee, 2009. Effect of salt stress on proline accumulation, photosynthetic ability and growth characters in two maize cultivars. Pak. J. Bot., 41: 87-98.