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GROWTH, YIELD AND NUTRIENT CONTENT OF SUNFLOWER (*HELIANTHUS ANNUUS* L.) USING TREATED WASTEWATER FROM WASTE STABILIZATION PONDS

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Abstract

The effect of treated wastewater and equivalent basal fertilizer on growth parameters, chlorophyll and nutrient contents of sunflower was examined. Fresh water with basal fertilizer and treated wastewater significantly increased plant height compared to controls (fresh water) at vegetative stage. Leaf area was significantly increased over the controls by both basal fertilizer and the treated wastewater. Moisture content of leaves and the chlorophyll a and b contents remained unchanged by the treatments. The capitulum diameter, number of seeds/plant, total seed weight/plant as well as 100 seed weight were substantially increased by the treated wastewater. Irrigation with wastewater significantly increased the concentrations of Na, Ca and Mg in sunflower leaves. The level of micronutrient Mn was also elevated in roots. Nutrient levels in other plant parts remained unchanged.

Introduction

Pakistan is one of the countries facing chronic shortage of water since the last two decades. The scarcity of water puts tremendous pressure on the agri-based economy of the country. At the same time untreated wastewater is being commonly used for agriculture, which is responsible for a variety of environmental health problems in the country (Khan *et al*., 2001). The situation is becoming more alarming due to the fact that only a limited number of wastewater treatment plants exist in the country which frequently remain overloaded or under loaded (Khan & Ahmad, 1992). Treated wastewater may prove a potential economic asset by contribution to the water resources and the expansion of irrigated agriculture. It provides solution to the problem associated with indiscriminate disposal, thereby protecting environment and public health (Fonseca *et al.,* 2007; Papadopoulos & Savvides, 2003; Asano & Levine, 1996; Marcos do Monte *et al.,* 1996; Feigin *et al.,* 1991).

The waste stabilization ponds (WSP) offer less expensive and reliable alternative approach to expensive biomechanical systems of wastewater treatment specially in tropical and subtropical regions (Curtis & Mara, 1994; Mra & Pearson, 1998; Alcalde *et al.,* 2003; Ensink *et al.,* 2007). The treated wastewater from WSP can be successfully exploited for irrigated agriculture (Asano *et al.,* 1996), to save the quantity of fresh water and achieve economic benefits in terms of nutrients such as nitrogen, phosphorus and potassium.

The application of treated wastewater to the soil plant system may mitigate the scarcity of water resources and the discharge of nutrients to water bodies by using soil and plants as natural filters (Pollice *et al.,* 2004). In addition, crop irrigation with treated wastewater constitutes ecologically sound method for its disposal to the environment (Toze, 2006). However, the choice of crops for treated wastewater irrigation is the principal factor for the suitability of effluent irrigation because certain crops can be irrigated without negative implications on yield (Fonseca *et al*., 2007; Bouwer & Idelovitch, 1987).

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Sunflower is a valuable oil crop from the economic and ornamental viewpoint. Its seed is commonly used as a vegetable oil in many parts of the world including Pakistan. Although it is a high yielding, high oil crop, its contribution to the domestic production of edible oil in Pakistan is only 13.4% (Shah *et al.*, 2005). The economic potential of this important crop has never been successfully exploited and as a result its cultivated area has declined from 325082ha in 2005 to 323067 ha in 2006-2007 while the production slightly increased for 348275 tones in 2005-2006 to 407224 tones in 2006-2007 (Anon., 2007). Sincere efforts should be made to further increase the sunflower production and to explore new areas for its cultivation as it is drought resistant and can be best fitted in the existing cropping system without any major change (Shah *et al.*, 2005; Meo *et al.*, 2000).

The present study was undertaken to examine if the treated effluent from WSP can be used as an alternative to inorganic fertilizer for the growth and yield of sunflower crop.

Materials and Methods

Technical details of ponds: The general layout of the four waste stabilization ponds (WSP) used in the present investigation has been provided in an earlier publication (Khan *et al*., 2008).

Collection and analysis of sample: The samples of influent and the effluent for pond-3 and pond-4 were collected every month and analysed for the following parameters in accordance with APHA (Anon., 2005): Biochemical oxygen demand (BOD_5), Chemical oxygen demand (COD), Ammonia nitrogen (NH_3-N), Organic matter content, Potassium, total Kjeldahl Nitrogen (TKN), and Total coliforms bacteria (TCC).

Field experiment: During treatment of wastewater through WSP a minimum of 27,000 litres was received daily. Before it was used for irrigation of sunflower field the effluent was subjected to analysis of nitrogen, phosphate and potassium. The soil in which sunflower was cultivated was sandy loam pH 7.6, water holding capacity 34.2 %. In all 12 plots each 256 m^2 were developed in four blocks. To avoid edge effect due to movement of water and dissolved solids, plots were divided from each other by the insertion of polythene sheet to a depth of 30 cm. Various treatments used were fresh water (A) which represents the control, fresh water with basal fertilizer (K_2SO_4=0.015 g/l; $CaHPO_4$. H_2O =0.005 g/l.; urea=0.035g/l) (B) and WSP effluent also called liquid fertilizer (C). Pure NPK applied through basal fertilizer were 3.21 kg/ha N, 1.0 kg/ ha P and 1.4 kg/ha. K. The three treatments were randomized within each of the four blocks in a randomized complete block design.

Seed of variety Suncom-90 provided by Pakistan Agriculture Research Council, Karachi suitable for autumn sowing was used. Seeds were sown on August 2 in 5 rows with a distance of 730 cm between rows and 30-40 cm between the seeds. The plots after sowing were irrigated with 5000 litres of either fresh water, fresh water with basal fertilizer or treated wastewater per plot. Subsequently the plots were irrigated once a week. Care was taken to avoid seed predation by birds such as parakeets.

The vegetative growth was recorded by following the increase in plant height, fresh and dry weight of leaves, water and chlorophyll contents and leaf area. All these parameters were measured at vegetative stage and flowering stage and were replicated five times.

Chlorophyll was extracted from fully expanded leaves using 80% acetone. Four samples one for each replicate was taken for each treatment. The extract was filtered and optical densities were recorded at 663 and 645 nm. Chlorophyll a and b were estimated in accordance with the method of Arnon (1949).

At maturity the nutrient concentrations of N, P, K, Ca, Mg and Mn were determined in seeds leaves, stems and roots as indicator of plant nutrition status. Sub samples of seeds, leaves, stem and roots were wet digested for K, Ca, Mg, Mn and analysed for elemental content using atomic absorption spectrophotometry (Allen *et al.,* 1986), whereas nitrogen and phosphorous were determined as described earlier. Four replicates were taken for each plant part and nutrient. Data were subjected to two-way ANOVA (Zar, 1999). As a follow up of ANOVA Dunnett's t-test and Duncan's multiple range tests were performed.

Results and Discussion

Characteristics of treated effluent: From the climatological data and the ponds performance efficiency for the 6 months (Table 1) it is evident that ponds worked well in terms of high BOD and COD removal. However, nutrients parameters varied with high removal efficiencies during the months of July and August. The organisms of public health importance (TCC) were also reduced drastically during the same period. The results accorded well with previous findings (Khan & Ahmad 1992; Cutis *et al.,* 1994; Dalu & Ndamba 2003; Khan *et al.,* 2008).

Effect of NPK on the growth and yield of sunflower: The averages of total nitrogen, phosphate phosphorus, potassium and organic matter in the effluent were 48.0, 8.0, 16.2 and 118 mg/l (Table 3). Based on these concentrations of nutrients and the total amount of effluent used for irrigation of sunflower crop, the total quantities of N, P and K turned out to be 75, 15 and 25 kg/ha respectively. Similar levels of these macro-nutrients have been demonstrated to be adequate for the growth and yield of sunflower (Bhan, 1977; Pal, 1981). Bange *et al.,* (1997) observed elevated N availability in the soil after irrigation with treated wastewater. However, increased yield has been reported with higher dosages of nitrogen fertilizer (Vivek *et al.,* 1994). Fig. 1 shows various plant growth parameters at vegetative and flowering stages. Fresh water with basal fertilizer (treatment B) and treated wastewater (treatment C) exhibited significant ($p<0.05$) increase in height (at vegetative stage only), while fresh and dry weight of leaves increased significantly ($p<0.05$) over the controls at flowering stage only. Leaf area was significantly (p at the most 0.05) elevated by the treatments over the controls at flowering phase. However, moisture content % and the chlorophylls a and b contents were not altered significantly by either the basal fertilizer or the treated wastewater compared to controls.

Yield parameters of sunflower in response to treatments is presented in Table 3. The capitulum's diameter, number of seeds/plants, total seed weight/plant as well as 100 seed weight were significantly (p at the most 0.05) increased by the treated wastewater over the controls but the basal fertilizer (treatment B) failed to exhibit any significant influence on the yield parameters. Generally, seed weight is regarded as a fairly constant character (Harper *et al.,* 1970) but for the sunflower it exhibited considerable variation. In general, the results corroborate the findings of Tsadilas (1999), Tsadilas & Vakalis (2003) and Khan *et al.,* (2008) who obtained increased yield of maize crop irrigated with treated wastewater.

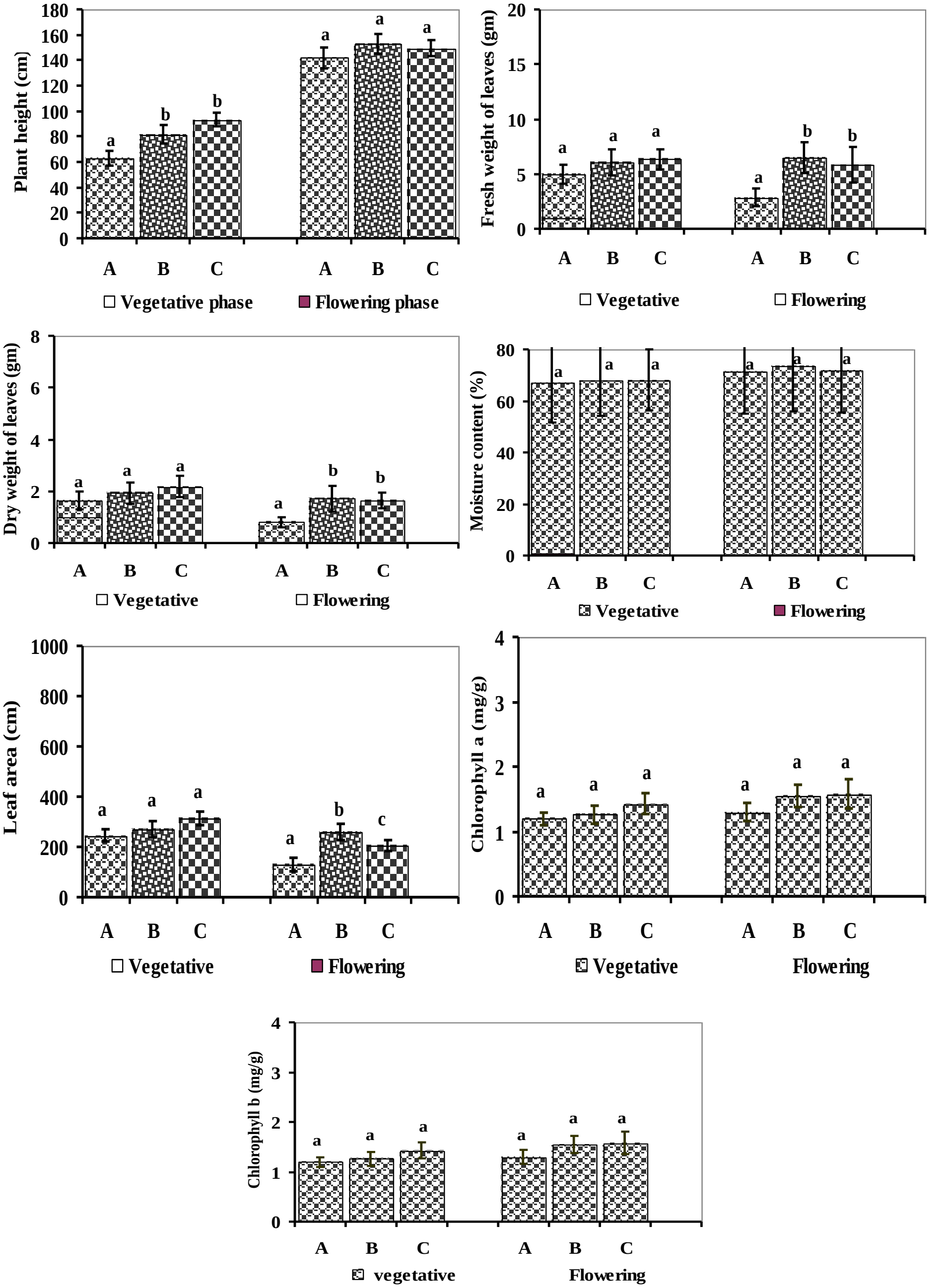

Fig. 1. Effect of treated wastewater on the growth of sunflower plant; A= fresh water (control); B= freshwater plus basal fertilizer urea, $CaHPO_4$,H_2O, K_2SO_4; C= treated wastewater.

Table 2. Quantities of NPK values of effluent collected on different dates for the feeding of sunflower crop.

Sample No.	Dates	Total nitrogen (mg/l)	Phosphate-phosphorus (mg/l)	Potassium (mg/l)	Organic matter (mg/l)
1	23-08- 2000	14.39	2.57	5.60	571
2	30-08- 2000	15.32	3.22	6.70	584
3	07-09- 2000	16.72	3.40	6.88	612
4	14-09- 2000	14.25	4.65	5.10	545
5	20-09- 2000	14.78	2.80	7.00	578
6	27-09- 2000	19.62	2.45	7.67	530
7	06-09- 2000	16.75	2.80	7.56	596
8	06-10-2000	16.48	2.65	6.78	645
9	13-10-2000	40.64	2.58	7.80	672
10	20-10-2000	28.58	4.35	6.85	668
11	27-10-2000	22.44	4.48	6.65	597
Average		19.99	3.26	6.78	590.7
Min-Max		14.25-40.64	2.45-4. 65	5.10-7.80	530-672

Table 3. Yield of sunflower using treated wastewater from waste stabilization ponds. Means are followed by standard errors.

S. No.	Parameters	Sample size (n)	Treatment		
			A	B	C
1.	Diameter of capitulum	20	14.95a± 1.8	16.75a ±1.4	22.80 b± 2.3
2.	Number of seeds per plant	10	1108.80 a±216	1078.22a±126	1229.46b±178
3.	Total weight of seeds per plant (g)	10	62.40 a ± 3.5	60.27a ± 5.9	72.43 b ± 6.5
4.	Weight of 100 seeds (g)	5	5.65 a ±0-16	5.59a ± 0.18	5.95 b ± 0.12

A= Fresh water (control), B= fresh water plus inorganic fertilizer (Urea, CaHPO4. H2O.K2SO4), C= Effluent (Liquid fertilizer)

Increased yield of sunflower by the wastewater can be attributed to the presence of not only the readily available adequate amounts of N, P and K but also sufficient quantity of organic matter that improves the soil structure and other soil properties related to availability of water and nutrients. It has been reported that the use of treated wastewater also increases the total carbon, total nitrogen concentration along with the microbial activity in soil (Friedel *et al.*, 2000; Ramirez-Fuentes *et al.*, 2002). Mekki *et al.*, (2006) reported that the use of treated wastewater tends to increase the density of soil microorganisms including bacteria, fungi and actinomycetes that helps in nutrient availability to plants. Agunwamba (2001) also reported elevated mineral content of soil irrigated with wastewater.

Nutrient contents in sunflower plant parts: In general, nitrogen and phosphorus contents were high in seeds (Table 4). Leaves had high Ca, Mg, Mn and K contents. Stems were generally poor in nutrient contents while roots had high K, P and Mg contents. Irrigation with wastewater although slightly increased the concentration of N and Ca over the control but it was non significant. This accords well with the findings of Gadallah (1994) and Bange *et al.*, (1997). The concentration of Mn in root was also significantly elevated ($p<0.05$) in wastewater treatment compared to controls. This corroborates the results of Gadallah (1994). Also, Vazquez-Montiel *et al.*, (1996) found increased level of Mn in maize leaves following irrigation with wastewater.

Table 4. Nutrient contents in the seeds, leaves stem and roots of the sunflower as influenced by fresh water (A) freshwater with basal fertilizer (B) and treated wastewater.

Nutrient % dry weight	Treatments	Plant parts			
		Seed	Leaves	Stem	Root
N	A	2.74 ± 0.25	2.28 ± 0.26	1.46 ± 0.15	1.89 ± 0.14
	B	2.82 ± 0.19	2.34 ± 0.22	1.40 ± 0.12	1.84 ± 0.18
	C	2.83 ± 0.27	2.37 ± 0.20	1.48 ± 0.18	1.83 ± 0.16
P	A	0.46 ± 0.06	0.23 ± 0.05	0.07 ± 0.03	0.32 ± 0.06
	B	0.39 ± 0.04	0.21 ± 0.08	0.07 ± 0.04	0.35 ± 0.04
	C	0.44 ± 0.08	0.25 ± 0.11	0.09 ± 0.03	0.31 ± 0.08
K	A	2.27 ± 0.11	4.65 ± 0.38	5.21 ± 0.48	4.89 ± 0.36
	B	2.35 ± 0.08	4.88 ± 0.21	5.81 ± 0.24	5.21 ± 0.43
	C	2.30 ± 0.12	4.72 ± 0.33	5.65 ± 0.39	5.06 ± 0.52
Ca	A	0.18 ± 0.06	6.36 ± 0.31	1.85 ± 0.23	2.20 ± 0.15
	B	0.22 ± 0.08	6.42 ± 0.25	1.68 ± 0.32	2.08 ± 0.13
	C	0.19 ± 0.11	6.53 ± 0.36	1.77 ± 0.35	2.14 ± 0.19
Mg	A	0.22 ± 0.08	0.68 ± 0.05	0.31 ± 0.08	0.46 ± 0.07
	B	0.25 ± 0.05	0.53 ± 0.08	0.36 ± 0.12	0.49 ± 0.13
	C	0.19 ± 0.07	0.66 ± 0.04	0.38 ± 0.09	0.44 ± 0.06
Mn µg/g	A	77.0 ± 18.0	97.0 ±14.0	45.0 ± 08.0	56.0 ± 8.3
	B	82.0 ± 15.0	92.0 ± 17.0	48.0 ± 06.0	59.0 ± 11.2
	C	63.0 ± 08.0	90.0 ± 12.0	41.0 ± 04.0	73.0 ± 7.5

Interestingly both treatments of basal fertilizer and treated wastewater with one exception did not significantly influence any of the nutrient contents of plant parts. Al-Jaloud *et al.*, (1995) reported elevated concentration of N, Ca, Mg, and Na in leaves of *Sorghum* when the crop was irrigated with wastewater. Moreover, Vazquez-Montiel *et al.*, (1996) found that irrigation of maize (*Zea mays.* L.) with treated wastewater resulted in increase in N, P, K and Mg concentration in leaves. Fonseca *et al.*, (2005 a; 2005b) also obtained similar results in a green house experiment with maize.

Conclusions

The study demonstrates that the vegetative growth and yield of sunflower plants can be enhanced by the application of treated wastewater compared to either freshwater or freshwater along with the basal fertilizer. However, the nutrient content of various plant parts remained generally unchanged following application of treated wastewater.

The economic potential of the treated wastewater has not been fully exploited in Pakistan since it is often regarded as an economic burden. Instead, the treated wastewater can be exploited for irrigated agriculture while simultaneously providing adequate amounts of nutrients for plant growth and yield.

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