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GROWTH AND YIELD RESPONSES OF PEARL MILLET (*PENNISETUM GLAUCUM* [L.] R.BR.) IRRIGATED WITH TREATED EFFLUENT FROM WASTE STABILIZATION PONDS

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Abstract

Shortage of fresh water is a worldwide problem, particularly in the tropics. Treated wastewater can be utilized not only as irrigation water but also to serves as a liquid fertilizer. The effect of treated effluent from waste stabilization ponds and equivalent basal fertilizer on growth, yield and nutritive quality of pearl millet (*Pennisetum glaucum* [L.] R.Br.) was investigated under field conditions. The N, P and K levels in treated effluent were monitored over the entire experimental period. Treated effluent significantly increased plant height, number of leaves, leaf area index and the dry matter yield per hectare. By contrast, basal fertilizer did not significantly improve these parameters. Among the nutritive characteristics, only crude protein content was markedly increased by the effluent. Other nutritive qualities remained uninfluenced by both treated effluent and the basal fertilizer. The study demonstrated that treated effluent can be successfully used for unrestricted irrigation in the water deficient tropical and subtropical areas thereby saving huge quantities of fresh water.

Introduction

Fresh water scarcity is a common problem in arid and semi arid regions of the world. The problem becomes further acute in the countries having agri-based economy. Treated wastewater is being widely used for unrestricted irrigation in many continues to overcome the problems of water shortage (Bouwer & Idelovitch, 1987; Feigin *et al.,* 1991; Al-Jaloud *et al.,* 1995; Vazquez-Montiel *et al.,* 1996; Al-Rashed & Sherif, 2000; Mohammad & Mazahreh 2003; Oron, *et al.,* 2007; Aghtape, *et al.,* 2011).

The use of treated wastewater can provide multiple benefits. However, its use requires effective treatment to protect public health and environment at an affordable cost (Sipala *et al.,* 2003; Anderson *et al.,* 2001; Agunwamba, 2001; Asano & Levine, 1996; Marcos do Monte *et al.,* 1996; Asano *et al.,* 1992).

Treatment of wastewater using waste stabilization ponds (WSP) technology is widely used all over the world particularly in those countries which cannot afford the luxury of sophisticated biomechanical systems of wastewater treatment (Khan *et al.,* 2010, Khan *et al.,* 2009; Khan *et al.,* 2008; Khan & Khan, 2007; Alcalde *et al.,* 2003; Mara & Pearson, 1998). The technology provides low operation and maintenance cost with effective pathogen removal which has made WSP technology as a treatment of choice in many parts of the world (Alcalde, 2003; Mara & Pearson, 1998; Khan & Ahmed, 1992; Mara, 1987).

In Pakistan scientific work on WSP technology is very scanty, and the commercial exploitation has not been initaited so far through which the treated wastewater can be converted into economic asset rather than an economic burden (Khan & Khan, 2007; Khan *et al.,* 2010; Khan *et al.,* 2009; Khan *et al.,* 2008).

Pearl millet (*Pennisetum glaucum* [L.] R.Br.) is an important summer cereal crops grown throughout Pakistan. It requires relatively low irrigation owing to its short growing season. Therefore, it can even be grown in those areas where water is a limiting factor for crop growth (Faridullah *et al.,* 2010; Baltensperger, 2002). It is very well adopted to dry and hot climates therefore it is mostly grown in rainfed areas of Pakistan (Mahmood & Qureshi, 1984). In Pakistan production of all species of millets is about 190,000 tons of which 92% is that of pearl millet (Maqsood & Ali, 2007).

The nutritional quality of pearl millet is poor however, its green fodder is used as a feed for live stock all over the country (Faridullah *et al.,* 2010). Taller varieties in general produced more fodder yield than the short ones (Akmal *et al.,* 2002).

The present study was designed to explore the potential of treated effluent from WSP for the growth of pearl millet. The study demonstrated that the effluent can be efficiently used for the commercial production of pearl millet even in the areas where droughts cause frequent failure of many other crops.

Materials and Methods

Technical details of ponds: The two waste stabilization ponds used in the present study are available at Karachi University Campus that was constructed in consultation with Institute of Environmental Studies, University of Karachi. The technical details are given in Table 1.

The ponds are trapezoidal in shape of equal dimensions and are lined with concrete at the bottom as well as the sides. The ponds are connected in series and the outlet is available at a depth of 1.8 m. The primary ponds are connected with the influent sump which receives the raw domestic waste water through underground sewerage line of Karachi Water and Sewerage Board. The secondary pond is likewise connected with the effluent sump.

Collection and analysis of influent and effluent samples: The samples of influent and the effluent were collected periodically twice a month and analysed for the following parameters in accordance with APHA, (Anon., 2005) for organic matter content, total Kjeldahl nitrogen (TKN), potassium, and total phosphate.

Table 1. Technical detail of waste stabilization pond system at Karachi University Campus.

S. No.	Parameters	Characteristics
1.	Pond area (bottom)	$53 m^2$
2.	Pond area (WSP)	$69 m^2$
3.	Pond area (average)	$61 m^2$
4.	Outlet for effluent	1.8m
5.	Influent sump capacity	$203 m^3$
6.	Effluent sump capacity	$67 m^3$
7.	Pond volume at 1.8 m depth	$127 m^3$
8.	Average total retention time	2 days
9.	Total average hydraulic load	$650 m^3$ /day (approx.)
10.	Total average BOD_5 load	250mg/l

(Based on average BOD_5 load of 250 mg/l; Khan and Ahmed 1992; Khan and Khan 2007)

Field experiment: Selection of soil: The soil in which pearl millet was cultivated was sandy loamy with pH 7.8 and maximum water holding capacity of 32%.

Development of experimental plots: In all nine plots were developed each measuring 9.0 m^2. Various treatments were used such as fresh water (A) which represents the control, fresh water with basal fertilizer (0.010 gm/l K_2SO_4; 0.08 gm/l $CaHPO_4$ H_2O; 0.010gm/l g Urea) (B) and WSP effluent (C) . The three treatments were randomized within each of the three blocks in a randomized complete block design.

Sowing of pearl millet: Seeds of pearl millet variety var. NARC-5 (kindly provided by the Agriculture Research Centre, Sindh, Tandojam) were sown in 10 rows with a distance of 30.0 cm between rows while distance between the seeds was 20 cm. The seeds were sown on 2 July 2009 and the crop was harvested in August 31, 2009.The thinning was done manually after 15 days of germination to maintain the desired plant spacing and to avoid competition between plants.

Irrigation of plots: The plots were irrigated only twice with 30 gallons of water per plot. Plots of treatments "A" were irrigated with fresh water those of treatment "B" with fresh water containing basal fertilizer while plots of treatment "C" were irrigated with WSP effluent. This amounts to 0.0027 (approx.) acre inch.

Growth studies: The vegetative growth was recorded by following the increase in plant height, number of leaves per plant, leaf area cm^2, stem thickness and dry matter forage yield. Additionally, nutrient quality of crop (dry matter) was determined by using the following parameters; crude protein (4.204 Anon., 1980), crude fiber (4.601 Anon., 1980) and the total carbohydrate in dry matter was determined by the anthrone reagent method (Cerning & Guilhot, 1973) . Chlorophyll was extracted from fully expanded leaves. Extraction was performed in 80% acetone. The extract was filtered and optical densities were recorded at 663 and 645 nm. Chlorophylls "a" and" b" were estimated in accordance with the procedure of Arnon (1949)

Statistical analysis: Data of individual variables were subjected to two-way analysis of variance ANOVA (Zar, 1999). As a follow up of ANOVA, Duncan's multiple range test was also performed.

Results and Discussion

Effect of NPK on the growth and yield of pearl millet: The treated effluent is rich source of nutrient that can be successfully used for unrestricted irrigation. The analysis of NPK and organic matter contents of liquid fertilizer is given in Table 2. The average concentrations of total nitrogen, phosphate phosphorus, potassium and organic matter in the effluent were 17.2, 3.92, 6.87, 590.88 mg/l respectively. Based on these concentrations of nutrients and the total amount of effluent used for irrigation of pearl millet crop, the total quantities of N, P and K turned out to be 16.36, 2.90 and 5.54 kg/ha respectively.

It can be seen from Table 3 that irrigation of pearl millet with the treated effluent significantly (P at the most 0.05) increased plant height, number of leaves per plant and leaf area while thickness of the stem remained unchanged with Treatment B and C. These vegetative characters are mainly influenced by NPK and organic matter which is adequately available in treated effluent. Infact the treated effluent improved the plant growth. 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 of plants. Agunwamba (2001) also reported elevated mineral content of soils irrigated with wastewater. Overman (1975) reported that the use of secondary municipal effluent for irrigation of pearl millet (*Pennisetun americanum*) can provide adequate nutrients for crop fertility. However, he reported that dry mater content decreased with irrigation rate. Feng *et al.*, (2007) also reported that treated wastewater improves the yield of peral millet.

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

Sample No.	Dates	Total nitrogen (mg/1)	Phosphate-phosphorus (mg/l)	Potassium (mg/l)	Organic matter (mg/l)
1	30-06-2009	13.19	3.52	7.54	651
2	01-07-2009	16.52	2.22	5. 78	673
3	07-07-2009	13.63	5.40	7.22	546
4	14-07-2009	14.75	4.75	6.11	645
5	20-07-2009	12.62	3.12	7.23	578
6	26-07-2009	20.56	3.67	7.11	563
7	01-08-2009	19.87	4.32	7.87	610
8	06-08-2009	18.75	2.57	5.62	587
9	11-08-2009	20.64	3.28	6.75	534
10	19-08-2009	21.64	4.63	7.13	542
11	27-08-2009	15.67	4.22	7.72	561
12	29-08-2009	18.77	5.39	6.58	591
Average		17.21	3.92	6.87	590.08
Min-Max		12.62-21.64	2.22-5.40	5.62-7.87	534-673
Std. Dev		3.21	1.034	0.758	45.86

Table 3. Vegetative characteristics of the pearl millet crop as influenced by fresh water (A) freshwater with basal fertilizer (B) and treated wastewater.

Treatment	Plant height n=6	No. of leaves/ plant n=5	Leaf area (cm^2) n=5	Stem thickness n=5	Dry matter yield (t/ha^{-1}) n=4
Control	188.3 a ± 2.4	8.6a ± 0.8	208 a ± 10.6	0.96 a ± 0.08	14.5 a ± 1.6
Basal fertilizer	194.2 a ± 1.8	8.7a ± 1.2	223 a ± 13.8	0.98 a ± 0.06	15.2 a ± 1.2
Treated effluent	199.6 b ± 1.5	10.2b ± 7	229 b ± 8.6	0.98 a ± 0.09	18.3 b ± 1.8

Mean followed by ± standard error

The yield of pearl millet is low in Pakistan mainly because of outdated varieties (Akmal *et al.,* 2002). It is therefore, important to look for other alternatives which can improve the crop yield. One such alternatives is the treated effluent (treatment C) which provides a good source of N, P and K that can be successfully exploited for the growth of crops of commercial importance (Khan & Khan, 2007; Khan *et al.,* 2008, 2009).

Nutritive quality of pearl millet: Nutrition quality characteristics of treated and control pearl millet shoot are presented in Fig. 1. Among the nutritive characteristics only crude protein content was significantly enhanced ($p<0.05$) with treated effluent compared to controls while crude fiber percentage and total carbohydrate content remained unaltered by the treatments (i.e., Basal fertilizer and Treated effluent). The results are consistent with the findings of Selim (2008) who demonstrated that pearl millet crop irrigated with secondary treated wastewater provides sufficient NPK that can be comparable to the use of chemical fertilizer.

Aghtape *et al*., (2011) reported that irrigation with wastewater effluent significantly improves the nutritive quality of fox tail millet which accords with the present findings.

Increased yield of pearl millet by the treated effluent 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 (Ramirez-Fuentes *et al.,* 2002; Barton *et al*., 2005; Friedel *et al.*, 2006).

Howard & Lessman (1989) and Patil & Sheelavantar (2006) also provided evidence that increase in N application rate increases grain yield of pearl millet. Rego *et al.,* (2003) recommended the use of farm yard manure in commercially important crops in excessive quantities because of long term availability of nutrients. Ayub *et al.,* (2009) observed that the plant height, number of leaves per plant and leaf area of the pearl millet increased significantly by increased level of N application. They also observed that crude protein and ash contents were also increased by N application. It was concluded that millet cultivar 18-by may be fertilized at the rate of 180 kg ha^{-1} of N application. Khan *et al.,* (2004) and Naeem *et al.*, (2003) also applied fertilizer at rates of 60: 60:00 NPK Kg/ha. However, Ayub *et al.,* (2007) reported that 100 kg N/ha gave significantly higher forage yield. This would mean that the availability of N in treated effluent is in sufficient quantity that improves the crop yield of pearl millet. However, N can not alone be the only contributory factor in the treated effluent that improves the yield. This can also be attributed to presence of organic matter that improves the structure and fertility of soil and hence crop yield.

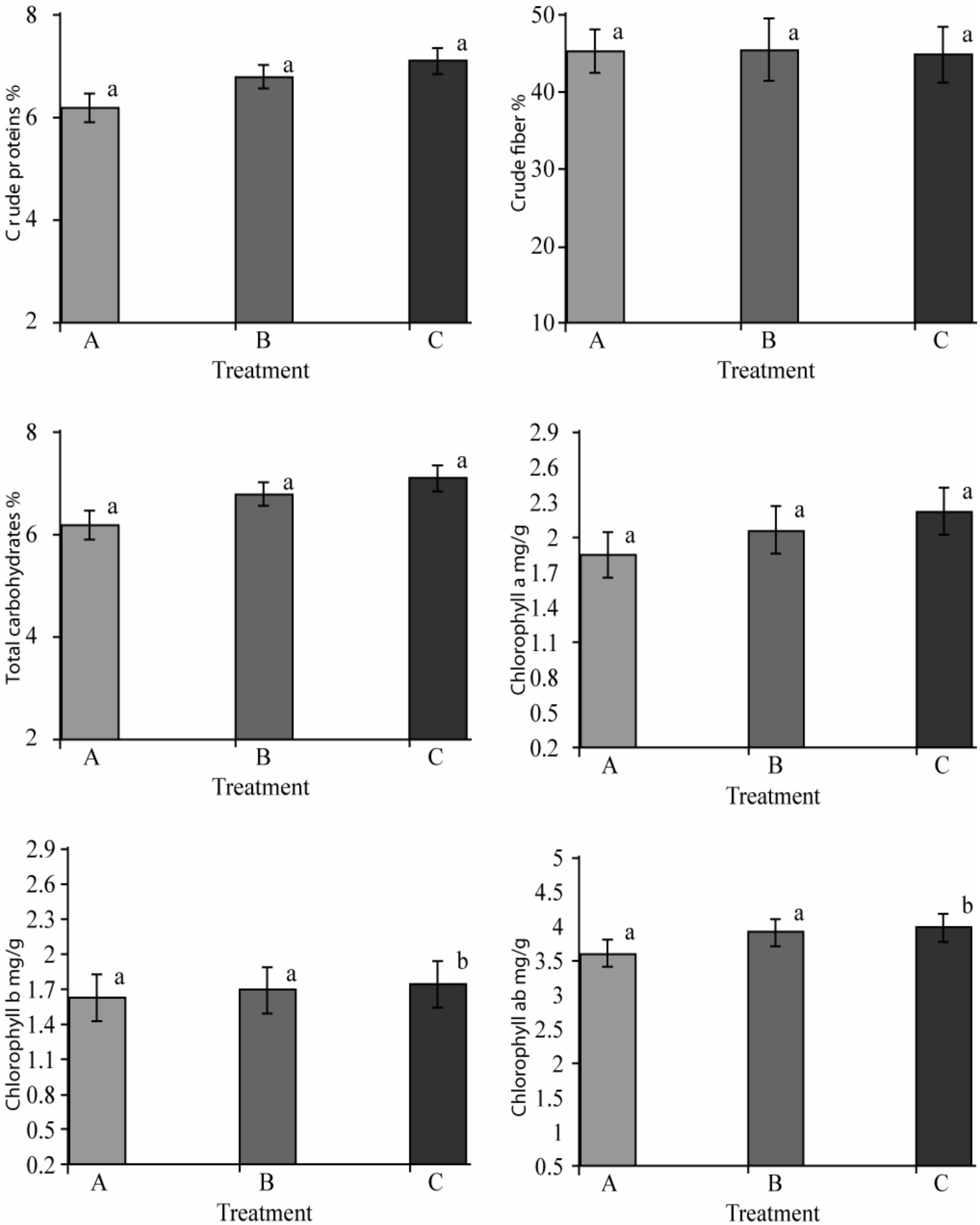

Fig. 1. Nutrient quality of pearl millet in shots as influenced by respective treatments A, Control; B, basal fertilizer; C, treated effluent. (a) Crude proteins %, (b) Crude fiber %, (c) Total `carbohydrates, (d) Chlorophyll a, (e) Chlorophyll b and (f) Chlorophyll a+b.

Conclusions

The study demonstrates that the vegetative growth and forage yield of pearl millet plants can be enhanced by the application of treated effluent compared to either freshwater or freshwater containing basal fertilizer. However, the nutrient content of various plant parts remained unchanged following application of treated effluent. The economic potential of the treated effluent has not been fully appreciated in Pakistan since it is often regarded as an economic burden. Instead, the treated effluent can be exploited for irrigated agriculture while simultaneously providing adequate nutrients for plant growth and yield and saving the expenditure on the input of fertilizer.

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