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IRRIGATION OF SORGHUM CROP WITH WASTE STABILIZATION POND EFFLUENT: GROWTH AND YIELD RESPONSES

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Abstract

The effect of treated wastewater and equivalent basal fertilizer on growth, yield and nutrient quality of sorghum (*Sorghum bicolor* (L.) Moench) was investigated under field conditions. Treated wastewater significantly increased plant height, stem thickness, number of grain/panicle, grain weight/panicle and 1000 grain weight of sorghum, while basal fertilizer only elevated grain weight/panicle compared to controls. Among the nutrient quality parameters only total sugar content was significantly increased by the treated wastewater over the controls. Other nutrient quality parameters including crude proteins, nitrogen free extract, ether extract and crude ash remained unchanged following the treatments. These results are discussed in the light of previous studies and the potential of wastewater resource in irrigated agriculture is discussed.

Introduction

The treated wastewater is widely used for unrestricted irrigation all over the world. Treated waste water is not only available as a water source for agriculture but also provides a wide variety of nutrients which enhance crop growth and yield. (Vazquez-Montiel *et al.,* 1996; Al-Jaloud *et al.,* 1995; Feigin *et al.,* 1991; Bouwer & Idelovitch 1987). Soil application of treated wastewater as water and nutrients source for agricultural irrigation represents a low cost alternative for wastewater treatment (Asano *et al.,* 1996), particularly applicable in dry and humid regions. 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). Crop irrigation with treated wastewater constitutes an ecologically sound method for the disposal of effluent into the environment (Toze, 2006).

Wastewater treatment using waste stabilization ponds (WSP) is widely used all over the world especially in tropical and subtropical countries (Khan *et al.,* 2008; Khan *et al., 2009*; Alcalde *et al.,* 2003, Mara & Pearson, 1998). However, very little work has been done so far on economical exploitation of WSP effluent in Pakistan. Treated wastewater proves to be an economic asset rather than economic burden and helps in the improvement of environmental quality (Khan *et al.,* 2008, 2009; Khan & Khan 2007; Fonseca *et al.,* 2007; Papadopoulos & Savvides 2003; Asano & Levine 1996; Marcos do Monte *et al.,* 1996; Feigin *et al.,* 1991).

Sorghum (*Sorghum bicolar* (L.) Moench) is widely used for food and fodder all over the world and is considered as fifth most important cereal crop after wheat, maize, rice and barley. Sorghum is cultivated in 100 countries out of which 59% of world sorghum area is in Africa whereas, Asian countries occupy 25%, Asia alone contributes 45% of world sorghum production. In most of the countries it is used primarily as animal feed, but in Africa and India it is used and grown as a food crop, where it is a staple food for millions of people (Mehmood *et al.,* 2008). Sorghum has about the same nutritive quality as corn for domestic animals (Alam *et al.,* 2001). It has the ability to tolerate and survive under adverse conditions of intermittent and continuing drought (Channappagoudar *et al.,* 2007: Duarte *et al.,* 2000;

Owuama, 1997). Sorghum has also received considerable attention during the last years as an alternative source for energy production (Sakellariou *et al.,* (2007).

In Pakistan, sorghum is cultivated on an area of 0.39 million hectare with a total yield of 593 kg/ha (Anon., 1980; Alam *et al*., 2001). Sorghum in Pakistan is cultivated both as irrigated and rain fed crop in summer. Mostly tall varieties are sown for fodder production while dwarf varieties are cultivated for grain production that can resist drought and hot weather. It can be grown successfully throughout the country both under irrigated and rain fed conditions. Naeem *et al.,* (2002) demonstrated that variety Tandojam (F-9603) can be used for highest green fodder yield.

The fodder yield however, hardly reaches to 50-60 tons against the potential of 50-100 tons per hectare (Nabi *et al*., 2006).The lower yield is attributed mainly due to cultivation on marginal lands, low fertilizer use and shortage of good quality seed. In fact, the potential of sorghum for food and fodder has never been given due importance in the country even though it is more environmental friendly from agronomic standpoint with low N and water requirement. It is with this aim that the present investigation was undertaken to explore the potential of treated wastewater from waste stabilization ponds for the growth and yield of sorghum.

Materials and Methods

Technical details of ponds: The technical details of the WSP at Karachi University Campus (KUC) are shown in Table 1 as reported earlier, (Khan *et al.,* 2008; Khan & Ahmad, 1992).

Sample collection and processing: Samples of effluent were collected periodically from June to December 2002 on monthly basis and were analyzed for the following parameters to determine the ponds performance. The parameters examined included 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 (TCC). These parameters were determined in accordance with (American Public Health Association; APHA, 2005.). Phosphate phosphorus was determined by ascorbic acid method (Fogg & Wilkinson 1958).

Field experiment: The soil chosen for the cultivation of sorghum was sandy loam. Twelve plots were developed, each measuring $225m^2$.The treatments used were fresh water (A) which represents the control, fresh water with basal fertilizer (0. 28 kg K_2SO_4 0.094 kg $CaHPO_4$ H_2O; 0.80 kg Urea per plot) (B) WSP effluent (C). The three treatments were randomized within each block in a randomized complete block design. The seeds of sorghum variety Tandojam (Received from Pakistan Agriculture Research Council, Karachi University Campus) were sown in 6 rows with a distance of 2.5 feet between the rows and two feet between the seeds in July, 2002. The plots were irrigated four times during the entire study period. Plots A and B were irrigated with fresh water while plot C was irrigated with WSP effluent. The crop was once sprayed with malathion for the control of shoot fly and stem borer. The vegetative growth was recorded by following the increase in plant height, number of leaves per plant, leaf area index, stem thickness, number of grain /panicle, grain weight/panicle and 1000 grain weight. Additionally, nutrient quality of crop was determined by using the following parameters; crude protein (4.204 AOAC, 1980), crude fiber (4.601 AOAC, 1980) Nitrogen free extract (FAO, 2004) Ether extract (4.5.02 AOAC, 1980) and crude ash (FAO, 2004) that were determined by the methods described in AOAC (1980) while total reducing sugars in the extracted stalk juice were estimated by Nelson's modified Somogy's method (Nelson, 1944).

Table 1. Technical data of waste stabilization pond system at the KUC.

S. No.	Parameters	Characteristics
1.	Pond area (bottom)	98 m^2
2.	Pond area (WSP)	184 m^2
3.	Pond area (average)	130 m^2
4.	Outlet for effluent	1.0, 1.3, 1.5 m
5.	Influent sump capacity	13630 L
6.	Effluent sump capacity	5455 L
7.	Service tank capacity	3068 L
8.	Pond volume at 1.5m depth	198,625 L
9.	Average total retention time	14.7 days
10.	Total average hydraulic load	27000L
11.	Total average BOD_5 load	500 Kg/ha.d

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

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

Ponds performance efficiency: Data of ponds performance taken during 6 months of this study were averaged (%) on monthly basis and are presented in Table 2. The parameters used to characterize the performance of WSP were BOD_5, COD, TKN, NH_3-N, PO_4-P and TCC.

The BOD_5 data represents highly improved efficiency of WSP at KUC where about more than 80% BOD_5 and COD were removed during treatment in WSP. This is consistent with the previous investigations (Khan & Khan 2007; Khan *et al.*, 2008, 2009; Khan & Ahmad, 1992). However, Mara (1987) reported that maximum design permissible organic loading at 25°C is 350 kg/ha.d whereas in present case it is 500 kg/ha.d. Dalu & Ndamba (2003) reported 50% reduction in BOD level when influent and effluent levels were compared in duckweed *(Lemna)* WSP.

The performance of WSP with respect to nutrient parameters was also found satisfactory. The average NH_3-N removal efficiency was found to be 34% while TKN was 56% respectively. These results corroborate the findings of Khan & Ahmad (1992) and Khan & Khan (2007). In fact, ammonia nitrogen removal is difficult and slow in wastewater treatment systems dependent on biological activity except when a long retention time is given allowing autotrophs to grow utilizing inorganic nitrogen. The monthly average removal efficiency of PO_4-P during treatment was 44%.The removal rate of PO_4-P in P-4 could be correlated with the development of algal blooms and high dissolved oxygen concentration.

The coliforms removal form the WSP is primarily a function of climatological parameters including high temperature (Brazily & Kott, 1989) and the penetration of U.V. light through the water column (Curtis *et al.*, 1994). In addition, high pH values and sedimentation would also have accentuated effect on the removal of coliforms. Fernandez *et al.*, (1992) reported that through such a system it is possible to eliminate up to 99.99% of microorganisms of public health importance. The coliform removal efficiency of WSP ranged between 71-98% with a mean removal efficiency of 82%.

Table 2. Characteristics of Waste Stabilization Ponds effluent and performance efficiency (%) in relation to temperature, wind velocity and total sunshine hours (2003).

Months (2002)	BOD_5 mg/l	COD mg/l	NH_3-N mg/l	PO_4-P mg/l	TKN mg/l	TCC values Log values
June	258	661	27.4	6.4	41.8	3.16
	42	93	17.6	3.5	16.6	1.02
	(86)	(86)	(36)	(45)	(60)	(98)
July	235	659	25.7	5.9	40.2	4.25
	35	94	16.2	2.7	17.5	1.21
	(85)	(86)	(40)	(54)	(56)	(71)
August	260	536	28.3	5.8	44.5	4.98
	34	82	15.6	2.8	16.8	1.11
	(87)	(85)	(45)	(52)	(60)	(78)
Sept.	272	567	26.4	4.7	41.6	5.16
	43	102	16.6	2.4	18.4	1.03
	(84)	(82)	(37)	(49)	(56)	(80)
October	259	501	25.9	5.6	42.7	6.12
	51	81	18.4	3.3	19.3	1.11
	(80)	(84)	(29)	(41)	(55)	(82)
November	264	548	26.7	6.1	44.4	6.57
	49	173	19.1	3.6	21.8	1.13
	(81)	(68)	(28)	(41)	(51)	(83)
December	255	479	24.8	6.3	42.5	6.69
	52	110	18.6	4.8	20.2	1.16
	(80)	(77)	(25)	(24)	(52)	(83)
	43.71	105	17.44	3.3	18.65	1.11
Min-Max (%)	80-87	68-86	25-45	24-54	51-60	71-98
Mean (%)	83	81	34	44	56	82

Based on the analysis of samples collected thrice in a month and were averaged. Vertically first figure is the influent value, second is the effluent value and figures in parenthesis are ponds percentage efficiency (%).

Effect of NPK on the growth and yield of sorghum: The liquid fertilizer generated from WSP is a rich source of nutrients that could be successfully used for unrestricted irrigation. The NPK analysis and organic matter contents of liquid fertilizer is given in Table 3. The averages concentrations of total nitrogen, phosphate phosphorus, potassium and organic matter in the effluent were 18.65, 3.30, 6.30 and 562 mg/l respectively. Based on these concentrations of nutrients and the total amount of effluent used for irrigation of sorghum crop, the total quantities of N, P and K turned out to be 16.36, 2.90 and 5.54 kg/ha respectively.

The results presented in Table 3 clearly demonstrate that irrigation of sorghum plants with liquid fertilizer (treated effluent) considerably increased plant growth. The increase in plant growth can mainly be attributed to availability of nitrogen and phosphates as they are the critical factors responsible for the improved growth of sorghum. Day & Tucker (1977) also reported high grain yield in sorghum crop irrigated with wastewater. However, Mendoza *et al.*, (2006) reported that when sludge is applied from WSP, it further improved sorghum plant nutrition. Rajput *et al.*, (1983) working with sorghum cultivar Shaheen found that plant height, ear length, ear weight and grain yield increased with N and P application. Similarly, Milam & Hickingbottom (1989), Arya *et al.*, (1997) and Howard & Lessman (1989) also demonstrated that increasing N rate increased grain yield of sorghum.

Table 3. NPK values and organic matter concentration of WSP effluent used for irrigation of sorghum bi color (L Moench) var. Tandojam.

Sample No.	Months (2002)	Total nitrogen (mg/l)	Phosphate-phosphorus (mg/l)	Potassium (mg/l)	Organic matter mg/l
1	June	16.60	3.50	6.10	562
2	July	17.50	2.70	5.75	554
3	August	16.80	2.80	6.28	575
4	Sept.	18.40	2.40	7.13	532
5	October	19.30	3. 30	5.68	625
6	November	21.80	3.60	6.67	517
7	December	20.20	4.80	6.50	632
Average		18.65	3.30	6.30	562
Min-Max		16.60-21.80	2.40-4.80	5.68-71.3	517-632
LSD		± 1.6	± 0.35	± 0.7	± 23

The results presented in Fig. 2 also show that plant height was significantly ($p<0.05$) greater in treated effluent application compared to fresh water or fresh water with basal fertilizer. In addition, treated effluent also gave significant (P at the most 0.05) number of grain/panicle, increase in grain weight/panicle and 1000 grain weight (Fig. 1). Although seed weight is regarded as a fairly constant character (Harper *et al.,* 1970) but in the present study it displayed marked variability with treatments. However, no significant variation was recorded in leaf area index. Stem thickness was significantly ($p<0.05$) higher with treated effluent compared to either control (fresh water) or fresh water with basal fertilizer (B and C). Howard & Lessman (1989) and Patil & Sheelavantar (2006) also provided evidence that increase in N rate increases grain yield of sorghum. Phalsen *et al*., (2001) reported increased dry weight and leaf area with an increase in N application while potassium had no significant effect. However, Dercas *et al*., (1995) found low nitrogen requirements for sorghum. 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. The treated effluent (Treatment C) provides a good source of N, P and K that can be successfully exploited for the growth of crops of commercial importance (Khan *et al.,* 2008, 2009; Khan & Khan, 2007).

Nutrient quality of Sorghum plant: Nutrient quality characteristics of treated and control sorghum shoot are presented in Fig. 3. Most of the parameters (crude proteins, crude fiber, N-free extract, ether extract, crude ash) were not significantly influenced by the treatments. However, only total sugars were significantly elevated by the wastewater ($p<0.05$).

Increased yield of sorghum 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*., 2006; Barton, *et al*., 2005; 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 of plants. Agunwamba (2001) also reported elevated mineral content of soils irrigated with wastewater.

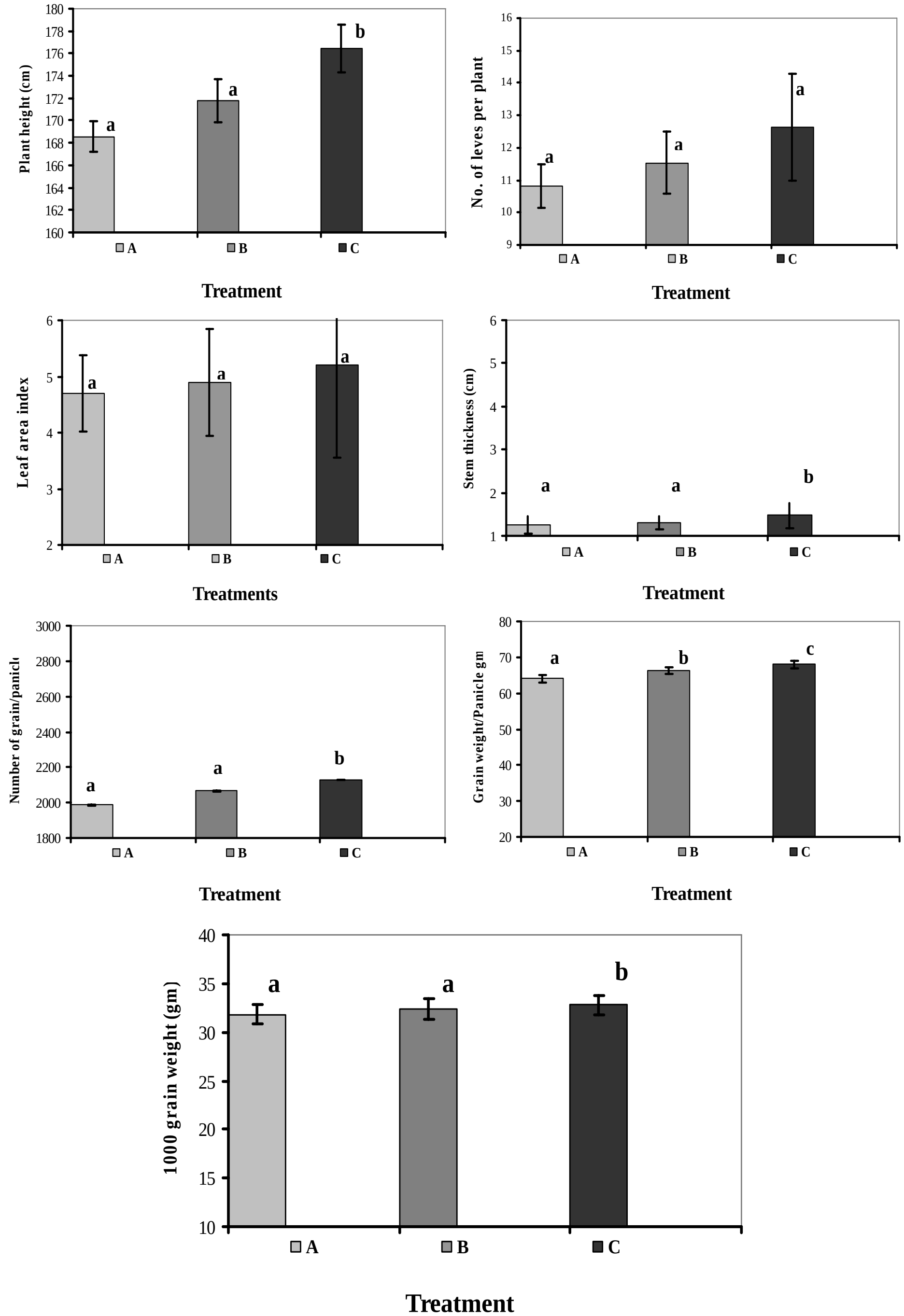

Fig. 2 Growth and yield of *Sorghum bi color* (L.) Moench Var. Tandojam using various treatments A, fresh water; B, Basal fertilizer; C, WSP effluent (Plant height LSD=6.1, No. of leaves LSD=1.6, Leaf area index LSD-1.5, Stem thickness LSD=0.55, No. of grain/panicle LSD= 78, Grain weight/panicle 2.6, 1000 grain weight LSD=1.3.

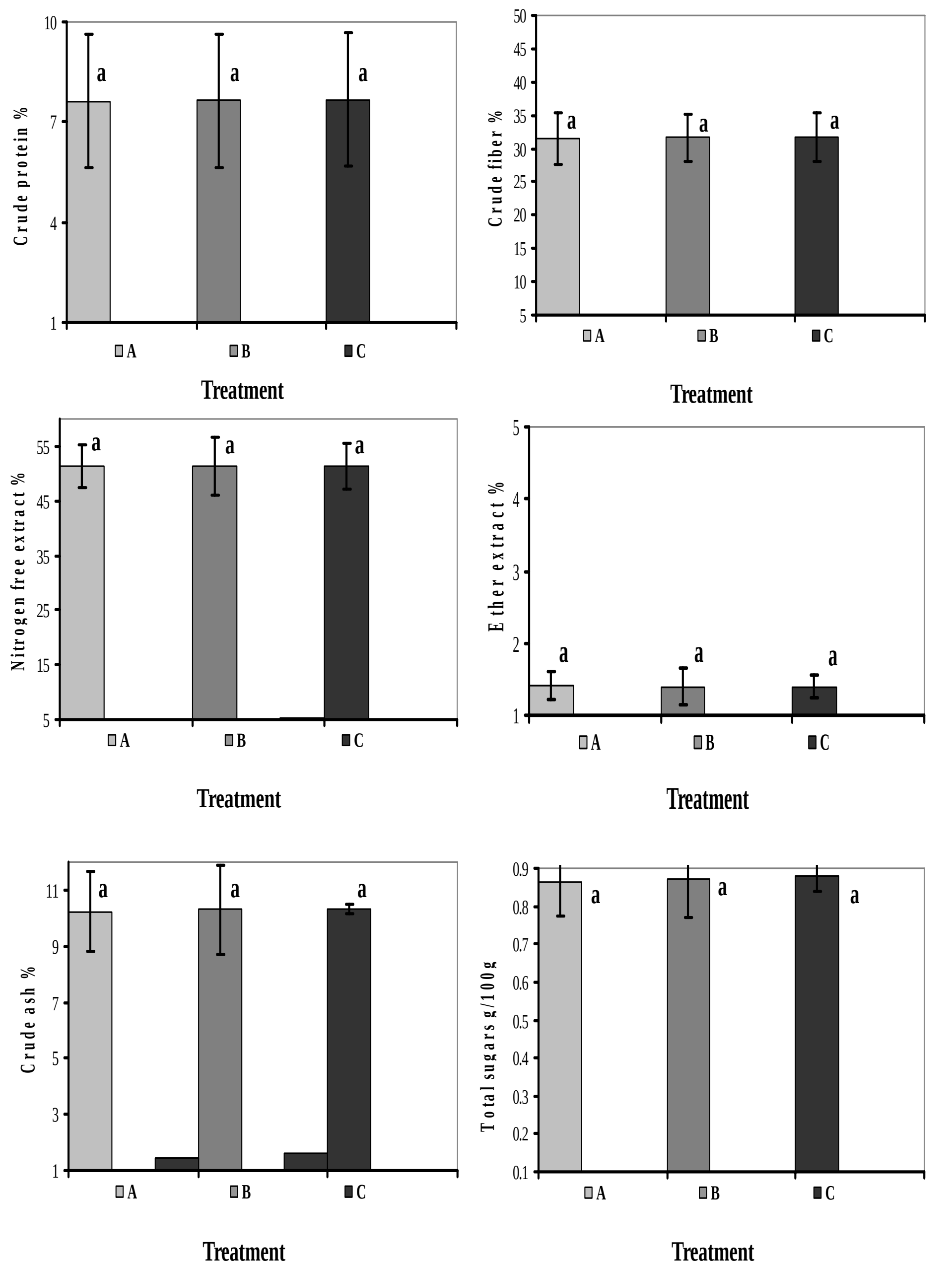

Fig. 3. Nutrient quality of *Sorghum bi color* (L.) Moench var. Tandojam in shots as influenced by respective treatments. Crude proteins % LSD=1.5, Crude fiber% LSD=2.3, Nitrogen free extract % LSD=1.8, Ether extract % LSD=0.3, Crude ash% LSd=2.1, Total sugars LSD=0.15

Conclusions

The study demonstrates that the vegetative growth and yield of sorghum plants can be enhanced by the application of treated wastewater compared to either freshwater or freshwater alongwith the basal fertilizer. However, the nutrient content of various plant parts remains 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 nutrients for plant growth and yield.

References

Agunwamba, J.C. 2001. Analysis of socioeconomic and environmental impacts of waste stabilization and unrestricted wastewater irrigation. Interface with maintenance. *Env. Manag.*, 27: 463-476.

Alam, S., A. Asghar, I.A. Qamas, M. Arshad and S. Salim. 2001. Correlation of economically important trails in *Sorgham bicolar* varieties. *On line Journal of Biological Science*, 1(5): 330-331.

Alcalde, L., G. Oron, L. Gillerman, M. Salgot and Y. Manor. 2003. Removal of faecal coliforms somatic coliphages and F- specific bacteriophages in a stabilization pond and reservoir system in arid regions. *Wat. Sci. Tech*., 3: 177-184.

Al-Jaloud, A.A., G.A.J. Hussian,. Al-Saati and S. Karimulla. 1995. Effect of wastewater irrigation on mineral composition of corn and sorghum plants in a pot experiment. *J. Plant Nutr*., 18: 1677-1692.

Allen, S.E., H.M. Grimshah and A.P. Rowland. 1986. Chemical Analysis. In: *Methods in Plant Ecology*, (Eds.): P.D. Moore, S.B. Chapman. Blackwell Scientific, Oxford, UK, pp. 285-344.

Anonymous. 1980. *Official Methods of Analysis*. Association of Official Analytical Communities. Washington D.C.

Anonymous. 2004. Animal production and health: Assessing quality and safety of animal feed, FAO, Rome.

Anonymous. 2005. Agriculture Statistics of Pakistan, Government of Pakistan. Ministry of food, Agriculture and live stock, Islamabad.

Anonymous. 2005. *Standard Methods for the Examination of Water and Wastewater*. 21st edition. American Public Health Association. Washington DC., USA.

Arya, R.L., K.P. Niranjan and A. Singh 1997. Effect of nitrogen and phosphorus on the productivity of grain sorghum (*Sorghum bicolor*) dolichos (Dolichos) intercropping system. *Indian Jour. Agron*., 42(3): 401-404.

Asano, T. and A.D. Levine. 1996 .Wastewater reclamation and reuse in Japan. Overview and implementation examples. *Water Science and Technology*, 34: 219-226.

Barton, L., L.A. Schipper, G.F. Barkle, M.S. McLeod, N.B. Fitzgerald and. S.P. Pandey. 2005. Land application of domestic effluent onto four soil types: Plant uptake and nutrient leaching. *Journal of Environmental Quality*, 34: 635-643.

Bouwer, H. and E. Idelovitch. 1987. Quality requirements for irrigation with sewage water. *J. Irrig. Drain. Engr.*, 113: 516-535.

Brazily, A. and Y. Kott. 1989. Survival of pathogenic bacteria in elevated temperature oxidation ponds. *Water Science and Technology*, 21: 109-114.

Channappagoudar, B.B., N.R. Biradar, J.B. Patil and S.M. Hiremath. 2007. Assessment of sweet Sorghum genotype for come yield, juice characters and sugar levels. *Karnataka Journal of Agriculture Science*, 20: 294-296.

Curtis, T.P., D.D. Mara and S.A. Silva. 1992. The effect of sunlight on faecal coliforms in ponds. Implications for research and design. *Wat. Sci. Tech*., 2: 1729-1738.

Curtis, T.P., D.D. Mara, N.G.H Dixo and S.A. Silva. 1994. Light penetration in waste stabilization ponds. *Wat. Res*., 28: 1031-1038.
Dalu, J.M. and J. Ndamba. 2003. Duckweed based wastewater stabilization ponds for wastewater treatment (a low cost technology for small urban areas in Zimbabwe). *Phy. Chem. Earth*., 28: 1147-1160.
Day, A.D. and T.C. Tucker. 1977. Effects of treated municipal wastewater on growth, fiber, protein and amino acid content of sorghum grain. *Jour. Environmental Quality*, 6: 325-327.
Dercas, N., C. Panoutsou, C. Dalianis and C. Sooter. 1995. Sweet Sorghum (*Sorghum bicolor* (L.) Moench). In: *Proceedings of the Eight E.C. conference on response to four irrigation and two nitrogen fertilization rates*. (Eds.): Chartier *et al.,* Biomass for Energy Environment, Agriculture Vol-1. Pergamon Press, UK: 629-639.
Duarte, M.P., A.L. Fermando, H. Guimaraes, V. Amparo L., Alves and J.F. Santos Oliveira. 2000. Study of sweet and fiber sorghum in Portugal. Effect of climatic conditions and sowing date on the final productivity and on quality of biomass In: *Proceeding of the First world Conference on Biomass for Energy and Industry Sevilla*, Spain 5-9, June, 361-364.
Feigin, A., I. Ravina and J. Shalhevet. 1991. *Irrigation with treated sewage effluent*: Management for environmental protection. Berlin Springer-Verlag: pp. 224.
Fernandez, A., C., Tejedor and A. Chordi. 1992. Effect of different factors on the die-off of faecal bacteria in a stabilization pond purification plant. *Wat. Res*., 8: 1093-1098.
Fogg, D. N. and N.T. Wilkinson. 1958. The colorimetric determination of phosphorous. *Analyst*, 83: 406-414.
Fonseca, A.F., U. Herpin, A.M.de Pual, R.L. Victoria and A.J. Melfi. 2007. Agriculture use of treated sewage effluents: Agronomic and environmental implication and perspectives in Brazil. Science Agriculture (Piracicaba, Braz). 24: 194-209.
Friedel, J.K., T. Langer, C. Siebe and K. Stahr. 2006. Effects of long term wastewater irrigation on soil organic matter, soil microbial biomass and its activities in central Mexico. *Biology and Fertility of Soils*, 31: 414-421.
Harper, J.L., P.H. Lovell and K.G. Moore. 1970. Shapes and sizes of seeds. *Ann. Rev. Ecol. Sys*., 1: 327-356.
Howard, D.D. and G.M. Lessman. 1989. Effect of nitrogen rate, source and time of application for no tillage grain sorghum. *Tannesse Farn and Homl Science*, 151-17.
Khan, M.A. and S.I. Ahmad. 1992. Performance evaluation of waste stabilization ponds in subtropical region. *Water Science and Technology*, 26: 1717-1728.
Khan, M.A., S.S. Shaukat and M.A. Khan. 2008. Economic benefits from irrigation of maize with treated effluent of waste stabilization pond. *Pak. J. Bot*., 40(3): 1091-1098.
Khan, M.A., S.S. Shaukat and M.A. Khan. 2009. Growth, yield and nutrient content of sunflower (*Helianthus annus* L.) using treated wastewater from waste stabilization ponds. *Pak. J. Bot*., 41(3): 1391-1399.
Mara, D.D. 1987. Waste stabilization ponds; Problems and controversies. *Wat. Qual. Int*., 1: 20-22.
Mara, D.D. and H.W. Pearson. 1998. *Design Manual for Waste Stabilization Ponds in Mediterranean Countries*. European Investment Bank. Mediterranean Environmental Technical Assistance Programme. Lagoon Technology International Leeds, UK.
Marcos do Monte, M.H., Angelakis and A.N.T. Asano. 1996. Necessity and basis for establishment European guidelines for reclaimed wastewater in the Mediterranean region. *Wat. Sci. Technol*., 33: 303-316.
Mehmood, S., A. Bashir, A. Ahmad, Z. Akram, N. Jabeen and M. Gulfraz. 2008 Molecular characterization of regional *Sorghum bicolor* varieties from Pakistan. *Pak. J. Bot*., 40: 2015-2021.
Mekki, A., A. Dhoub and S. Sayadi, 2006. Changes in microbial and soil properties following amendment with treated and untreated olive mill wastewater. *Microbiol. Res.,* 16: 93-101.
Mendoza, J., G. Tatiana, C. Gabriala and S.M. Nilsa. 2006. Metal availability and uptak by sorghum plants grown in soil amended with sludge from different treatments. *Chenosphere*, 65: 2304-23012.

Milam, M.R. and K. Hickingbottom. 1989. Influence of row spacing and nitrogen rates on the performance of two grain sorghum cultivar. In: *Sorghum and Millet abstracts*, 14: 25.

Nabi, C.G., M. Riaz and G. Ahmad. 2006. Comparison of some advanced lines of *Sorghum bicolor* (L.) Moench for green fodder/dry matter yields and morph economic parameters. *J. Agriculture Res*., 44(3): 191-196.

Naeem, M., M.S.S. Chauhan, A.H. Khan and S. Salahuddin. 2002. Evaluation of different varieties of Sorghum for gren fooder yield potential. *Asian Jour of Plant Sciences*, 1: 142-143.

Nelson, N. 1944 A photometric adaptation of the Somogyi method for the determination of glucose. *Journal of Biological Chemistry*, 153: 375-380.

Owuama, C.I. 1997. Sorghum, a cereal with larger beer brewing potential. *Word. J. of Microbial and Biotechnol*., 13: 253-260.

Papadopoulos, I and S. Savvides. 2003. Optimization of the use of nitrogen in the treated wastewater reuse for irrigation. *Water Science and Technology*, 3: 217-221.

Patil, S.L. and M.N. Sheelavantar. 2006. Soil water conservation and yield of winter sorghum (*Sorghum bicolor* (L.) Moench) as influenced by tillage, organic materials and nitrogen fertilizer in semiard tropical India. *Soil and Tillage Research*, 89: 246-257.

Phalsen, S., D.E.B. Higgs and A. Suksri. 2001. Effects of nitrogen and potassium fertilizers on growth chemical component and seed yields of forage sorghum (*Sorghum bicolor* L. Moench) growth on Oxic polenstults soil, North East Thailand. *Pakistan Journal of Biological Science*, 4(1): 27-31.

Pollice, A., A. Lopez, G. Laera, P. Rubino and A. Lonigro. 2004. Tertiary filtered municipal wastewater as alternative water source in agriculture a field investigation in Southern Italy. *Science of the Total Environment*, 324. p. 201-210.

Rajput, F.K., A.S. Arain, M.J. Rajput and K.B. Khawaja. 1983. Effect of row spacing and fertilizer levels on the yield and growth of sorghum. *Pak. Jour. Agric. Res*., 4: 166-170.

Ramirez-Fuentes, E., C. Lucho-Constantino, E. Escamilla-Silva and L. Dendooven. 2002. Characteristics and carbon and nitrogen dynamics in soil irrigated with wastewater for different length of time. *Bioresource Technology*, 85: 179-187.

Rego, T.J., V.N. Rao, B. Seeling, G. Pardhasarhadi and J.V.D.K. Rao. 2003. Nutrient balances – a guide to improving sorghum and grand must based dry land cropping system in semi arid tropical India. *Field Crop Research*, 81-53: 68.

Sakellariou, M.M., S. Papalexis, N. Nakos and I.K. Kalavrouziotis. 2007. Effect of modern irrigation methods on growth and energy production of sweet sorghum (Var. Keller) on a dry year in central Greece. *Agric. Water Managt*., 90: 181-189.

Toze, S. 2006. Reuse of effluent water-benefits and risks. *Agric. Wat. Manag*., 80: 147-159.

Vazquez-Montiel, O.N.J. Horan and D.D. Mara. 1996. Management of domestic wastewater for reuse in irrigation. *Wat. Sci. Technol*., 33: 355-362.

Zar, J.H. 1999. Biostatistical Analysis. 4th Ed. Prentice-Hall, Inc. Engelwood Cliffs. N.J. USA

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