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TREATED RESIDENTIAL GREYWATER AND ITS EFFECT ON SHOOT DRY MATTER AND NUTRIENT UPTAKE IN MAIZE (*ZEA MAYS*)

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Abstract

Shortage of freshwater resources and limited fertilizer usage due to cost related issues in agriculture are the basic limiting factors in food production. This study evaluated the effect of greywater application on shoot dry mater and uptake of maize crop. The experiment included five treatments canal water, untreated greywater and treated greywater through reed bed technology using *Cyperus iria*, *Phragmites karka* and *Typha elephantina*, arranged in a randomized complete block design. All the treatments received a basal doze of NPK fertilizer. The soil used in the experiment was silty clay in texture with 55% clay, pH - 7.70, EC - 1.07 dS m^{-1}, $CaCO_3$ - 12.50% organic matter - 0.17%, NO_3-N – 4.60 mg kg^{-1}, NH_4-N – 1.68 mg kg^{-1}, ammonium bicarbonate diethylene triamine penta acetic acid (AB-DTPA) extractable P and K as 0.18 and 270 mg kg^{-1}, respectively. The treated greywater had a highly significant effect on shoot dry matter and N, P and K uptake in maize. The highest contents were found in treatments applied with greywater, treated under reed bed technology using *Cyperus iria* and the lowest in canal water applied treatments. Part of applied fertilizer was supplemented through greywater application.

Key words: Greywater application, Maize, Nitrogen, Phosphorus, Potassium.

Introduction

Inadequate use of chemical fertilizers due to cost related issues, coupled with poor fertility of soils and particularly the scarcity of freshwater resources are big threats to agriculture production (Maqbool *et al*., 2019). The huge quantities of wastewater generated from an over populated country like Pakistan is another concern to environment and a hazard to human health. According to Pakistan Economic Survey (Anon., 2016), the main sources of wastewater generation in Pakistan are rural residential (48%) and urban (25%), while the remaining 16%, 6%, and 5%, respectively are agriculture, industry and commercial based.

Wastewater quality is based on the type and its source. Chemical constituents and heavy metal load is way too high in industrial and municipal wastewater over domestic one (Jenssen & Vrale, 2004). Greywater is the domestic wastewater excluding toilet waste. On an average 65% of domestic wastewater is reported to be greywater (Eriksson *et al*., 2003; Friedler and Hadari, 2006). The nutrient contents (i.e. NPK) and microorganisms hazardous to human health are generally low in treated greywater (Jenssen & Vrale, 2004) and therefore, the wastewater causing environmental pollution can turn into a valuable source of chemical fertilizer in agriculture. Treated greywater use on agricultural lands is a common practice in many countries of the world. It is successfully used on cotton, wheat, maize, sunflower, different vegetables (i.e. okra, tomatoes, spinach, beans, etc.) including fruit trees (Oliver & Hossain, 2016; Fagan, 2015; Mzini & Winter, 2015; Al-Hamaiedeh & Bino, 2010; Rusan *et al.,* 2007 and Day *et al.,* 1981). Generally, these experiments reported an increased growth, leaf nutrient contents with relevant uptake and the productivity due to presence of N, P and K contents in greywater. These studies show either no or low adverse effects on plants. Long term experiments may show salt (Zuma *et al.,* 2009) or heavy metal i.e. Pb and Ni (Rusan *et al.,* 2007) accumulation in soils or high nutrient uptake as in case of tomato (Misra *et al.,* 2009). This is due to high contents of nutrients in greywater. This can be best avoided by diluting the greywater before its application (Day *et al.,* 1981).

A small number of local studies have highlighted the treatment of greywater (Memon *et al.,* 2017; Hayder *et al*., 2015; Mustafa, 2013; Iram *et al.,* 2012 and Aslam *et al*., 2007) however its usage in crops is not a common practice in Pakistan agriculture. The main objective of this study was to introduce and assess treated greywater application in agriculture with maize as a test crop. The details of greywater treatments have been given elsewhere (Memon *et al.,* 2017).

Materials and Methods

This study relates to the use of greywater in agriculture, rather than its treatment, which has been detailed in a separate study (Memon *et al.,* 2017). The greywater used in this experiment was collected from reed bed units planted with *Cyperus iria* (sedge grass), *Phragmites karka* (reed grass) and *Typha elephantina* (reed mace). These units were constructed at Sindh Agriculture University Residential Area, Tandojam, Sindh Pakistan. Greywater from ten houses was treated into these units by discharging 90L per day, thrice a day at an equal interval time. Treated greywater from each of the three units was collected into 1000 ml autoclaved bottles, every third day around 8.00 in the morning. Samples were packed on ice in insulated coolers and transported to the laboratory.

Bulk surface soil (0-15 cm) was collected from Latif Experimental Farm, Sindh Agriculture University Tandojam, located in the southern (25º25'35.60″N, 68º32'35.76″E, elevation 25 m) part of Pakistan. Soil was dried in shade, debris were removed and ground and passed through 2 mm sieve. A small portion of soil was reserved for analysis. A 5 kg quantity was placed in each 15 plastic pots to represent five treatments i.e. canal water, untreated greywater, and treated greywater from reed beds planted with each *Cyperus iria*, *Phragmites karka* and *Typha elephantine*. The experiment was arranged in a randomized complete block design with three replications. The crop received half N, and full P and K of the recommended rate (150-80-60 kg N-P_2O_5-K_2O ha^{-1}) during soil preparation, while the other half of N was applied after 30 days of sowing. Two maize seeds of Akbar variety were sown in the center and in cross position of each pot, which after germination were thinned to four plants. All the pots were irrigated as per treatment details and followed the recommended irrigation requirement and agronomic practices. To provide similar environment to all the plants, pots were rotated every third day.

Maize plants were harvested after six weeks. Shoot dry matter yield was recorded, and the plants were dried, ground and preserved for nutrient analysis. Canal water and spentwash samples were analyzed for electrical conductivity, pH, biological oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), NH_4-N, NO_3-N, and total P and K as described under AWWA, APHA and WEF (1998). Soil samples in addition to electrical conductivity, pH, NH_4-N and NO_3-N were tested for texture, $CaCO_3$, organic matter content and available P and K (Estefan *et al.,* 2013). While, plant samples were tested for total N, P and K and respective nutrient uptakes were calculated as a product of shoot dry matter and relevant nutrient concentration (Memon *et al.,* 2017). All the data was subjected to analysis of variance and those significant were used for comparison of means ($LSD_{0.05}$) using Statistix 8.1.

Results

Soil and greywater characteristics: The experimental soil was silty clay in texture with pH - 7.70, electrical conductivity - 1.07 dS m^{-1}, $CaCO_3$ - 12.50% and organic matter - 0.17%. Available N (NH_4-N and NO_3-N), P and K were correspondingly 1.68, 4.60, 0.18 and 270 mg kg^{-1}. The characteristics of greywater are presented in Table 1. Electrical conductivity (except under *Phragmites karka*), pH and TDS values were within respective prescribed limits of 0.7-3.0 dS m^{-1}, 6-9, 3500 mg L^{-1} as described by Anon., (1985) and NEQS (1997) for irrigation . As for plant available nutrients, NO_3-N being the major form of N in treated greywater was under slight to moderate category of 5.0-30 mg L^{-1} and P was below the prescribed limit of 15 mg L^{-1}. There are no suggested limits for K in irrigation water.

Pot experiment: Maximum height of maize plants was achieved under greywater applied treatments and minimum under canal water application (Fig. 1a). Among treated greywater treatments, maize plants were taller under *Cyperus iria* (50.69 cm), followed by *Typha elephantina* (47.74 cm) and *Phragmites karka* (46.11 cm) treatments. However, the plant height achieved with untreated greywater (47.48 cm) was statistically at par with the plant height by *Typha elephantina* (47.74 cm) and canal water (44.73 cm). Plant height was increased by 13.3% with *Cyperus iria*, 6.7% with *Typha elephantine* and only 3.1% with *Phragmites karka* treated greywater treatments over canal water (Table 2). Comparatively, the increase in plant height over untreated greywater was either very small (i.e. *Cyperus iria* - 6.8% and *Typha elephantina* - 0.55%) or there was no increase as in case of *Phragmites karka* (-2.9).

Table 1. Characteristics of greywater used in maize experiment.

Parameter	Untreated greywater	Treated greywater		
		Cyperusiria	*Phragmites karka*	*Typha elephantina*
EC (dS m^{-1})	2.25	2.33	4.36	2.47
pH	8.33	8.11	7.46	7.98
TSS (mg L^{-1})	0.03	0.07	0.27	0.06
TDS (mg L^{-1})	1421	1442	1999	1546
NO_3-N (mg L^{-1})	14.6	16.8	15.6	15.2
Soluble P (mg L^{-1})	0.702	0.562	0.800	0.393
Soluble K (mg L^{-1})	49.13	63.07	70.33	73.37

Table 2. Percent change in plant height, dry matter and nutrient uptake of maize in treatments applied with treated greywater.

Treated greywater	Over canal water					Over untreated greywater				
	Plant height	Dry matter	Nutrient uptake			Plant height	Dry matter	Nutrient uptake		
			N	P	K			N	P	K
Cyperus iria	13.3	25.1	163.7	41.7	150.6	6.8	20.6	21.72	13.3	30.5
Phragmites karka	3.1	7.2	111.7	25.0	78.0	-2.9	3.4	-	-	-7.3
Typha elephantina	6.7	13.7	103.3	29.2	150.6	0.55	9.6	-6.2	3.3	30.5

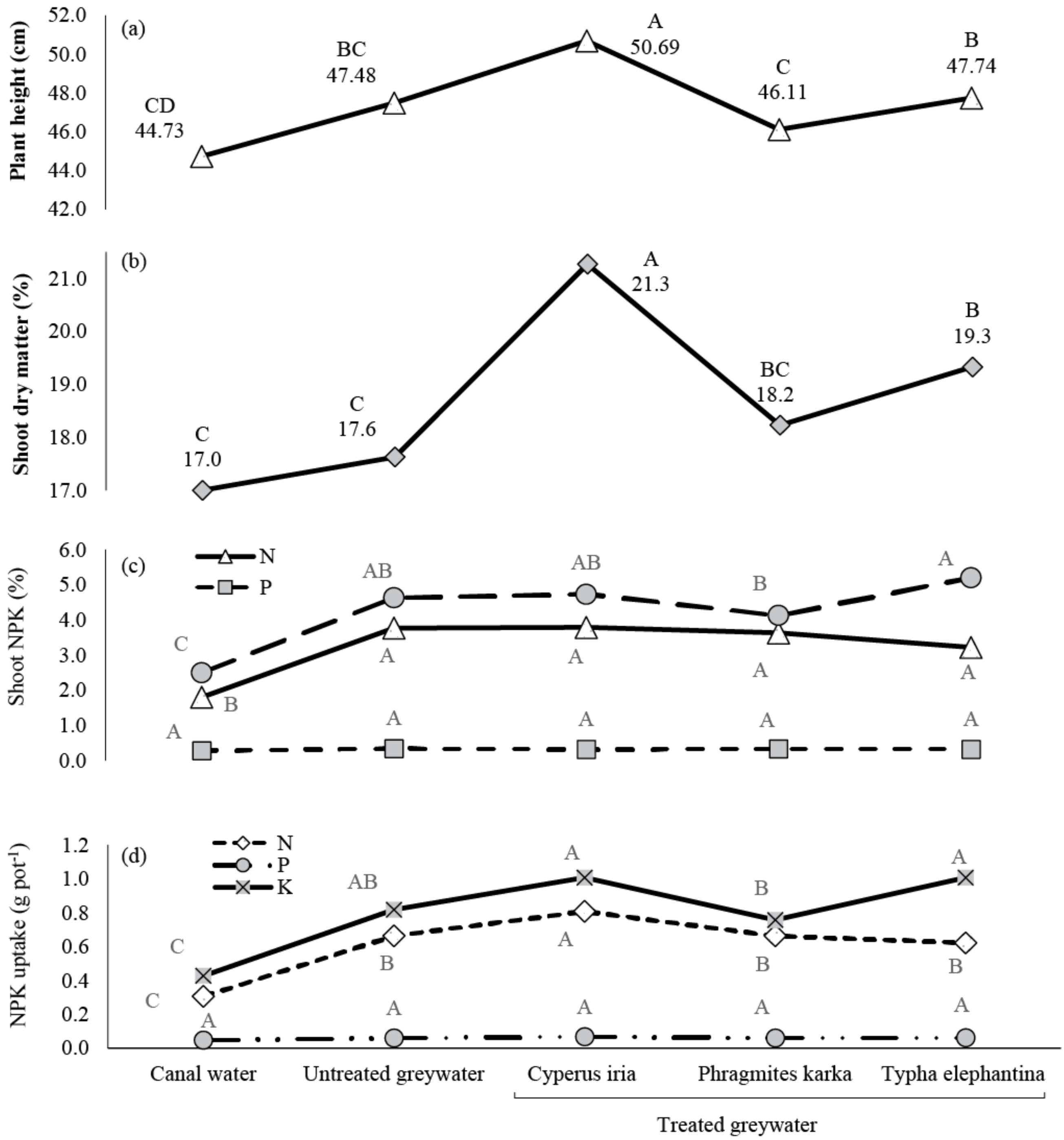

Fig. 1. Effect of greywater on plant height (a), dry matter (b), NPK contents (c) and NPK uptake (d) in maize shoot.

Shoot dry weight followed the same but sharp pattern (Fig. 1b). Dry matter content increased from 17.0 g pot^{-1} under canal water treatment to a maximum of 21.3 g pot^{-1} under *Cyperus iria* treatment with significant change. The dry matter content obtained under *Typha elephantina* (19.3 g pot^{-1}) was similar to the one obtained with *Phragmites karka* (18.2 g pot^{-1}) and so was the case in canal water (17.0 g pot^{-1}) and untreated greywater (17.6 g pot^{-1}) treatments. Shoot dry matter increased by 25.1%, 13.7% and 7.2% over canal water and 20.6%, 9.6% and 3.4% correspondingly under *Cyperus iria*, *Typha elephantina* and *Phragmites karka* treatments (Table 2).

The N content in maize shoots significantly increased from 1.80% in canal water treatment to a maximum of 3.79% under *Cyperus iria*. However, the N content of treated and untreated greywater treatments was non-significant. Same was true for P under all the treatments including canal water treatment. As for K content, it increased from 2.50% under canal water to 5.20% under *Typha elephantine*, which was statistically similar to the K content of *Cyperus iria* and *T. elephantine* treatments (Fig. 1c). The nutrient uptake (N, P and K) in maize plants was more or less on similar lines (Fig. 1d). Nitrogen uptake increased by 163.7%, 111.7% and 103.3% under *Cyperus iria*, *Phragmites karka and Typha elephantine* treatments compared to the canal water treatment (Table 2). In contrast, the increase in N content over untreated greywater was only 21.72% under *Cyperus iria*. Phosphorus uptake increased by 41.7%, 25.0% and

29.2% over canal water treatment and only by 13.3%, 0% and 3.3% over untreated greywater correspondingly in *Cyperus iria, Phragmites karka and Typha elephantine*. While, K uptake increased to a large extent i.e. 150.6% under *Cyperus iria*, 78% under *Phragmites karka* and 150.6% under *Typha elephantine* over canal water. While, the percent increase in maize uptake by treated greywater (*Cyperus iria*, *Phragmites karka* and *Typha elephantine)* over untreated one, was very small.

Discussion

Maize plants under all the treatments grew well and did not show any toxicity or unusual symptoms. Highest plant height, shoot dry matter, N, P and K content and relevant shoot uptake were generally recorded in treatments under treated greywater application by *Cyperus iria* and lowest by canal water irrigation. A comparison over canal water showed a 13% increase in plant height, 25% in dry matter, 164-42-151% in N-P-K maize uptake, in treatments, where the applied greywater was treated under reedbed technology using *Cyperus iria*. Plant height and shoot dry matter under canal and untreated greywater behaved similarly. Considering the control treatment, the NPK uptake was only 0.31, 0.048 and 0.43 g pot^{-1}. This further illustrated that NPK uptake of 0.50, 0.020 and 0.58 g pot^{-1} was due to greywater application by *Cyperus iria*. The increase in growth parameters as well as uptake is due to nutrient (i.e. NPK) application. The NPK concentration in maize shoot by *Cyperus iria* was 3.79-0.32-4.73%. According to Jones *et al.,* (1991), the N, P and K contents in whole shoot of maize are considered low (<3.5%, <0.3% and <2.5%) , sufficient (3.50-5.00%, 0.30-0.50% and 2.50-4.00%) and high (>5.0%, >0.5% and >4.0%). With this criteria, the canal water had way "low" contents of N, P and K contents but the treated greywater (*Cyperus iria*) was "sufficient" in N (3.79%) and P (0.32%) and "high" in K (4.73%) contents. Eliminating the NPK contents due to fertilizer effect (1.80-0.28-2.50%) and the nutrients already present in soil, 2.00-0.04-2.24% N-P-K was contributed by greywater application. This means that about half of the N and full K can be substituted from greywater, however, due to low P content, a full doze of fertilizer P will be required. Based on the N contents of treated grey water, Al-Brueck and Lammel (2016) also recommended lower rates of N fertilizer application to crops. Plant growth and productivity is generally not affected with greywater application, due to its low NPK contents (Finley *et al.,* 2009). The effect on growth and nutrient content or uptake vary widely depending on the greywater quality and soil type. Plant height and shoot dry matter of maize did not show any significant difference among canal and untreated greywater. The same was reported by Pinto *et al.,* (2010) for growth of silverbeet. Their results also confirmed the lower content of P and to some extent N in maize plant. The lower contents of P might be due to lesser laundry and dishwashing detergent usage. Increase in K content and uptake in maize plants in treated greywater over untreated one is evidenced by Al-Hamaiedeh & Bino (2010) and Travis *et al.,* (2010) for olives and some vegetables.

Conclusion

This study reported that 2.00-0.04-2.24% of N-P-K to maize crop came from greywater application. Considering the overall results about 50% of N and 100% of K requirement of maize crop can be met from the greywater, treated under reed bed technology using *Cyperus iria*. Depending on the greywater quality and crop requirement, the N-P-K% will vary. Nonetheless, it contains significant quantities of N and K and relatively low P contents, which can be used as a value added fertilizer in agriculture. It is suggested that soil properties may also be tested after the harvest of crop.

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