

Combining Textile Effluent Wastewater with Organic Fertilizer for Improved Growth and Productivity of Wheat and Soil Health

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Abstract: Water scarcity is a worldwide problem which could be solved by the use of low quality water like textile effluent wastewater. However, this water contains toxic materials like azo dyes, heavy metals, etc. which have severe health hazardous effects after entering the food chains. Application of organic fertilizer with textile effluent wastewater could provide a sustainable solution to this problem as it provides adsorption sites for toxic materials and improves physicochemical and biological properties of soil. So, a pot experiment was conducted under glasshouse conditions using different combinations of textile effluent wastewater and organic fertilizer. The treatments where textile effluent wastewater and organic fertilizer were applied, their remaining NPK doses were fulfilled through chemical fertilizers. In results, treatment with textile effluent water + organic fertilizer @ 800 kg ha⁻¹ (T₆) showed at par results regarding the growth and yield parameters of wheat compared to control (T₁; tap water and recommended doses of NPK). The same treatment caused an increase of 21%, 45%, 90% and 110% in no. of grains spike⁻¹, root length (cm), fresh root and shoot biomass (g), respectively compared to the application of textile effluent water + recommended dose of NPK (T₂). Similarly, NPK contents of straw (190%, 200% and 67%) and grain (45%, 300% and 73%) were significantly improved in textile effluent water + organic fertilizer @ 800 kg ha⁻¹ (T₆) compared to textile effluent water + recommended dose of NPK (T₂), respectively. Moreover, microbial population was 1.5 folds more in textile effluent water + organic fertilizer @ 800 kg ha⁻¹ (T₆) compared to textile effluent water + recommended dose of NPK (T₂). In conclusion, application of textile effluent wastewater along with organic fertilizer could help to mitigate its negative impacts on crop and soil health.

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1. Introduction

Appropriate management of non-renewable and scarce resources is of prime importance around the world. Among these, good quality irrigation water is of utmost importance for today's system of intensive agriculture to feed the ever-increasing population of the world. Timely and adequate availability of water is essential for optimum crop production (Bhatti et al., 2009). The crop water requirement does not fulfill in case of low irrigation water at critical growth stages. Different strategies suggested by scientists and researchers to cope with this emerging issue which include the use of engineering techniques, agronomic practices, education, public awareness and the use of waste

water for irrigation in agriculture sector (UN-Water, 2006). To meet the water crises, use of industrial wastewater is the best alternative, because it is economical, produces in larger quantities and contains nutrients (EPA, 1996).

The textile industry is one of the major industries in Pakistan, which contributes 24% of GDP, 55.6% of exports and 38% of total manufacturing labor. These industries require a lot of water for dyeing, bleaching and printing etc. depending on the process (Kalar et al., 1993). This wastewater when applied to agricultural crops has many environmental and human concerns. These effluents contain various types of pollutants such as reactive, non-reactive soluble and insoluble dyes

which, when applied to the soil constraints, normal growth and production of crops ultimately affects the ground water quality (Cooper, 1995; Khan et al., 2003). It also negatively affects the soil quality and microbial population; ultimately the human health. So, it is the need of the hour to find out the strategies to mitigate the negative impacts of textile wastewater.

Various chemical and biological techniques have been applied, but these were some disadvantages. However, the use organic fertilizers with textile effluents have not been investigated. These have a significant impact on crop yield and quality (Toor et al., 2006). The organic fertilizers not only serve as a source of nutrients (Takashi, 2008) but also provide adsorption sites which might be helpful in the removal of contaminants from the textile wastewater effluent.

Pakistan is an agricultural country, So, for evaluating the combining textile effluent wastewater with organic fertilizer wheat crop was selected. Wheat (*Triticum aestivum* L.) is the most important crop in Pakistan. About 80% of farmers cultivate wheat which covers more than 40% of total cultivated area to achieve total production 235 m metric tons in 2011-12. Pakistan is facing the severe issue of water scarcity i.e., water availability below 1000 m³. These issues are predicted to increase in future. Water is the most important and its timely and adequate availability to crop is essential for crop growth and production (Bhatti et al., 2009).

For this purpose, a pot study was conducted with the hypothesis that organic fertilizers may mitigate the negative impacts of textile wastewater containing azo-dyes. The objectives of the study include: 1) to find out the best level of organic fertilizer in combination with inorganic fertilizer to mitigate the negative effects of textile effluents on wheat production and soil quality and 2) its effect on soil bacterial populations.

2. Material and methods

A pot experiment was conducted in the glass-house of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad. The soil (0-15cm) was collected from the research area of the Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, air dried, ground and passed through the sieve (2 mm). Later, 8 kg soil was filled in pots (15 cm × 50 cm diameter). Wheat variety Sahar-2006 was used for this pot experiment. Soil sample was analyzed regarding its physicochemical properties following standard procedures (US Salinity Laboratory Staff, 1954) (Table 1).

Table 1 Physicochemical properties of experimental soil.

Properties	Values
Textural class	Sandy loam
pHs	7.72±0.06
ECe (dS m ⁻¹)	1.85±0.07
CEC (cmolc kg ⁻¹)	13.27±0.35
Organic matter (%)	0.68±0.07
Total nitrogen (%)	0.05±0.01
Available P (ppm)	8.33±0.37
Extractable K (ppm)	111.67±3.28

Composting materials consisting of fruit peels and vegetable wastes were collected from the local market of Faisalabad city (longitude 72°0' and 73°45' east and 30°30' and 32°0' north), Pakistan, oven dried (70°C) for 24 hours and ground to fine powder (< 2.0 mm) with the help of electric grinder. The crushed material was subjected to a composting process in a locally fabricated composter (500 kg capacity) and continuously run for seven days. The moisture contents were maintained manually (40% v/w). The temperature rose up from 30°C to 70°C in the composting unit during 2nd and 3rd day of the composting process and then reduced gradually to 30°C after four day process.

Table 2 Chemical analysis of the composted organic fertilizer.

Parameters	Values
Carbon (%)	19.7±0.07
Nitrogen (%)	2.14±0.05
Phosphorus (%)	0.42±0.08
Potassium (%)	1.43±0.15
C:N	9.20±0.31
C:P	46.90±7.35
C:K	13.77±1.13
pH	5.73±0.12

Table 3 Characteristics of textile industry wastewater.

Parameters	Values
pH	9.80±0.12
Biological oxygen demand (BOD) (mg L ⁻¹)	476.7±4.4
Chemical oxygen demand (COD) (mg L ⁻¹)	1021.7±5.2
Total suspended solids (mg L ⁻¹)	321.7±7.3
Total dissolved solids (mg L ⁻¹)	3283.3±8.8
Total nitrogen (mg L ⁻¹)	232.3±4.4
Phosphate (mg L ⁻¹)	16.3±1.4
Potassium (mg L ⁻¹)	7.67±1.4

After 7 days, the organic fertilizer produced was analyzed for various macronutrients and C/N, C/P and C/K ratios were determined (Table 2). Textile wastewater was collected from the outlet of Bashir Textile Printing Mills, Sargodha road, Faisalabad and analyzed for pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS) and total dissolved solids (TDS) following standard procedures (Greenberg et al., 1992) (Table 3). Pots were irrigated with textile wastewater at constant level according to field capacity.

Different combinations of textile effluent water and organic fertilizer were used viz. T₁ = control (tap water + recommended dose of NPK (125, 90 and 60 kg ha⁻¹); T₂ = textile effluent water + recommended dose of NPK; T₃ = textile effluent water + organic fertilizer @ 200 kg ha⁻¹; T₄ = textile effluent water + organic fertilizer @ 400 kg ha⁻¹; T₅ = textile effluent water + organic fertilizer @ 600 kg ha⁻¹; T₆ = textile effluent water + organic fertilizer @ 800 kg ha⁻¹. In treatments T₃-T₆, remaining NPK rates were applied through chemical fertilizers after their deduction from organic fertilizers and effluent water if applied.

Different growth and yield parameters were taken at crop maturity. Plant height, spike and root length were measured with the help of the meter stick. No. of grains per spike were counted manually. Root and shoot biomass were measured using a digital weighing balance.

The dried and ground material of grains and the stalk was digested according to the method of Wolf (1982). Nitrogen was determined from the plant filtrate using Kjeldhal method (Jackson, 1962). The phosphorus contents were determined by spectrophotometer using standard curve (Richards et al., 1954). The Barton reagent was prepared as described by Ashraf et al. (1992). Potassium was determined by flame photometer (Richards et al., 1954).

The effect of different combinations of textile effluent water and organic fertilizer on microbial enumeration (culturable bacteria, N-fixers and P-solubilizers) was observed after the harvest of the crop in the pots. One to two grams rhizospheric soil from each pot was taken and placed in 100 ml sterile saline solution. The solution was shaken for 30 minutes at 200 rpm.

Table 4 Effect of different combination of textile effluent water and organic fertilizer on spike length (cm), plant height (cm), number of grains spike⁻¹, root length (cm), fresh root and shoot biomass (g) of wheat.

Treatments	Spike length (cm)	Plant Height (cm)	No. of grains spike ⁻¹	Root length (cm)	Fresh root biomass (g)	Fresh shoot biomass (g)
T ₁	23.9 a* (0)†	60.9 a (0)	57.8 a (0)	13.5 a (0)	12.9 a (0)	21.8 a (0)
T ₂	12.9 e (46)	46.4 b (24)	47.0 c (19)	8.8 d (34)	6.8 c (47)	10.1 d (54)
T ₃	15.5 d (35)	52.0 ab (15)	50.0 bc(13)	9.7 cd (28)	8.9 bc(31)	13.6 c (37)
T ₄	16.9 d (29)	55.0 ab(10)	52.2 a-c (10)	10.7 bc(21)	10.1 ab (22)	16.4 bc(25)
T ₅	19.1 c (20)	58.2 a (4)	55.1 ab(5)	12.8 ab(5)	11.6 ab(10)	18.1 b (17)
T ₆	22.9 b (4)	60.4 a (1)	56.9 a (2)	12.8 ab(6)	12.9 a (0)	21.2 a (2)

*Means followed by the same letters are not statistically different at $P < 0.05$ according to least significance difference (LSD) test.

† () indicates percent decrease from the control.

Where T₁ = Control (tap water + recommended dose of NPK (125, 90 and 60 kg/ha); T₂ = textile effluent water + recommended dose of NPK; T₃ = textile effluent water + organic fertilizer @ 200 kg/ha; T₄ = textile effluent water + organic fertilizer @ 400 kg/ha; T₅ = textile effluent water + organic fertilizer @ 600 kg/ha; T₆ = textile effluent water + organic fertilizer @ 800 kg/ha

Note: In treatments T₃-T₆, remaining NPK rates were applied using chemical fertilizers after their deduction from organic fertilizers and effluent water if applied.

Table 5 Effect of different combination of textile effluent water and organic fertilizer on nitrogen, phosphorus and potassium in straw and grains of wheat.

Treatments	N Concentration (%)		K Concentration (%)		P Concentration (%)	
	Straw	Grain	Straw	Grain	Straw	Grain
T ₁	2.03 a* (0)†	2.13 a (0)	0.83 a (0)	0.76 a (0)	0.24 a (0)	0.37 a (0)
T ₂	0.53 d (74)	1.27 d (41)	0.44 d (47)	0.34 d (56)	0.07 d (72)	0.08 d (79)
T ₃	0.69 d (66)	1.42 c (34)	0.45 c (46)	0.43 c (43)	0.10 c (58)	0.10 c (73)
T ₄	1.10 bc (46)	1.54 bc (28)	0.55 b (34)	0.48 c (37)	0.10 c (58)	0.12 c (67)
T ₅	1.27 b (37)	1.65 b (23)	0.76 a (9)	0.68 b (11)	0.15 b (39)	0.25 b (32)
T ₆	1.54 a (24)	1.84 b (14)	0.72ab (14)	0.59 a (23)	0.21 a (12)	0.32 a (12)

*Means followed by the same letters are not statistically different at $P < 0.05$ according to least significance difference (LSD) test.

† () indicates percent decrease from the control.

Where T₁ = control (tap water + recommended dose of NPK (125, 90 and 60 kg ha⁻¹); T₂ = textile effluent water + recommended dose of NPK; T₃ = textile effluent water + organic fertilizer @ 200 kg ha⁻¹; T₄ = textile effluent water + organic fertilizer @ 400 kg ha⁻¹; T₅ = textile effluent water + organic fertilizer @ 600 kg ha⁻¹; T₆ = textile effluent water + organic fertilizer @ 800 kg ha⁻¹.

Note: In treatments T₃-T₆, remaining NPK rates were applied through chemical fertilizers after their deduction from organic fertilizers and effluent water if applied.

A sample of 0.1 ml was plated by spreading in triplicate. Total culturable bacteria, P-solubilizers and N-fixers were cultivated and counted on a nutrient agar, National Botanical Research Institute's Phosphate (NBRIP) medium [Glucose, 10.0 g; Ca₃(PO₄)₂, 5.0 g; MgCl₂.6H₂O, 5.0 g; MgSO₄.7H₂O, 0.25 g; KCl, 0.2 g and (NH₄)₂SO₄, 0.1 g L⁻¹] (Nautiyal, 1999) and on N-free medium (FeCl₃.6H₂O, 0.1 g; K₂HPO₄, 4 g; MgSO₄.7H₂O, 0.5 g; glucose, 20 g; CaCO₃, 2 g and agar, 15 g L⁻¹), respectively. The plates were incubated at 28°C and the microbial colonies were counted after 3-4 days and were expressed as CFU g⁻¹ dry soil.

3. Results & Discussion

The results showed that maximum growth parameters were observed in the treatment where tap water + recommended dose of chemical fertilizer (T₁; control) was applied compared to all other treatments with textile effluent and organic fertilizer @ (200, 400, 600 and 800 kg ha⁻¹). The negative effect of the textile effluent was decreased with increasing levels of organic fertilizer, which promoted the growth of the plants and ultimately the yield and nutrient contents of the plants.

The treatment which received textile effluent + organic fertilizer @ 800 kg ha⁻¹ (T₆) showed at par results with the control in most of the parameters studied. Regarding the nutrient contents of straw and grains, the maximum level of nitrogen, phosphorus and potassium was obtained in the control (tap water + recommended dose of chemical fertilizer) while that of the minimum was observed in the treatment which received textile effluent water and

recommended dose of chemical fertilizer. Similarly, the effect of the application of textile effluent water + organic fertilizer @ 800 kg ha⁻¹ (T₆) produced statistically non-significant results as in case of the control (T₁). NPK contents of the straw (190%, 200% and 67%) and grains (45%, 300% and 73%) were significantly improved in textile effluent water + organic fertilizer @ 800 kg ha⁻¹ (T₆) compared to textile effluent water + recommended dose of NPK (T₂), respectively.

Earlier, it has been found that the application of textile wastewater containing azo dyes for irrigation changed the physicochemical properties of the soil, caused toxicity to the crop plants and animals (Hsueh et al., 2009; Zhang et al., 2004; Zollinger et al., 1987). In our studies, the growth and yield parameters were severely affected by the application textile industrial waste, which might be due to the presence of azo dyes and salts which caused chemical stress to the crop plants (Garg and Priya, 2006; Kaushik et al., 2005).

In order to mitigate the negative effects of the azo dye containing wastewaters, many strategies have been employed such as coagulation, chemical oxidation, electrochemical treatments, membrane technologies, etc., but these are proven to be unsuccessful due to some drawbacks (Deniz et al., 2013). Adsorption through organic amendments such as organic fertilizers could be an alternative strategy to these strategies as it is economical and environment friendly (Deniz et al., 2013).

Table 6. Effect of different combination of textile effluent water and organic fertilizer on N-fixers on N-free medium, P-solubilizes on NBRIP medium and total microbes on nutrient agar medium.

Treatments	N-fixers on N-free medium (CFU mL ⁻¹)	P-solubilizes on NBRIP medium (CFU mL ⁻¹)	Total microbes on nutrient agar medium (CFU mL ⁻¹)
T ₁	1 × 10 ⁷ a* (0)†	11.3 × 10 ⁷ a (0)	21 × 10 ⁷ a (0)
T ₂	2 × 10 ⁷ e (80)	4.0 × 10 ⁷ d (65)	12 × 10 ⁷ e (43)
T ₃	3 × 10 ⁷ de (70)	4.7 × 10 ⁷ cd (59)	14 × 10 ⁷ d (33)
T ₄	4 × 10 ⁷ cd (60)	5.7 × 10 ⁷ cd (50)	15 × 10 ⁷ cd (29)
T ₅	5 × 10 ⁷ c (50)	7.3 × 10 ⁷ bc (35)	16 × 10 ⁷ c (24)
T ₆	8 × 10 ⁷ b (20)	9.3 × 10 ⁷ ab (18)	18 × 10 ⁷ b (14)

*Means followed by the same letters are not statistically different at $P < 0.05$ according to least significance difference (LSD) test.

† () indicates percent decrease from the control.

Where T₁ = Control (tap water + recommended dose of NPK (125, 90 and 60 kg ha⁻¹); T₂ = textile effluent water + recommended dose of NPK; T₃ = textile effluent water + organic fertilizer @ 200 kg ha⁻¹; T₄ = textile effluent water + organic fertilizer @ 400 kg ha⁻¹; T₅ = textile effluent water + organic fertilizer @ 600 kg ha⁻¹; T₆ = textile effluent water + organic fertilizer @ 800 kg ha⁻¹

Note: In all treatments T₃-T₆, remaining NPK rates were applied through chemical fertilizers after their deduction from organic fertilizers and effluent water if applied.

The organic matter serves as a carbon source for the microbes which helps in their survival in the new environment. Moreover, it also provides micro and macro-nutrients for the crops as well as for the microbes containing azoreductase, an enzyme capable of degrading azo dyes through its biotransformation (Ahmad et al., 2008a, b; Fontaine et al., 2003; Reid et al., 2011a, b; Shahzadet al., 2008). Therefore, the application of organic matter is not only beneficial for the crop plants, but also for the microbes which ultimately increase the biotransformation of azo dyes into non-hazardous chemicals (Sinsabaugh et al., 2009).

The addition of organic matter through organic fertilizers provides nutrients for the crop plants which increases the growth and yield and ultimately the nutrient contents (Nannipieri et al., 2012). In our studies, the nutrient contents of the straw and grains were significantly improved which might be due to improved crop growth through the application of organic fertilizer, which served as a source of nutrients and ultimately resulted in increased nutrient contents in straw and grains (Table 5). It might also be due to its role in decreasing soil pH, increasing organic matter contents, cation exchange capacity (CEC) of the soil, and macro and micro nutrient concentration (Chhonkar et al., 2000).

Regarding microbial parameters, the maximum microbes on nutrient agar, NBRIP and N-free media were observed in the case where tap water + recommended dose of chemical fertilizer (control) was applied compared to all other treatments with textile effluent and organic fertilizer @ (200, 400, 600 and 800 kg ha⁻¹). Similarly, in case of the application of textile effluent water + recommended doses of NPK, the minimum numbers of microbes were

observed. Moreover, the effect of the application of tap water + recommended dose of chemical fertilizer (control) and textile effluent water + organic fertilizer @ 800 kg ha⁻¹ (T₆) was statistically non-significant. Moreover, microbial population was 1.5 folds more in textile effluent water + organic fertilizer @ 800 kg ha⁻¹ (T₆) compared to textile effluent water + recommended dose of NPK (T₂).

The organic matter has also been shown to increase the microbial activities of rhizospheric bacteria. In our studies, the microbial enumeration regarding general microbes, N-fixers and P-solubilizes on nutrient agar, N-free medium and on NBRIP media, respectively, was significantly improved with increasing levels of organic fertilizers (Table 6). It might be due to the role of organic fertilizer as a source of carbon and other micro- and macro-nutrients for the microbes which not only increases the microbial biomass and also their activity (Hartl and Erhart, 2005; Oberson and Joner, 2005; Oehlet al., 2004). Similar results were obtained by Lazcano et al. (2013) who also found that integrated fertilizer regimes stimulated microbial growth, altered the structure of soil microbial community and increased enzyme activity relative to inorganic fertilization.

Conclusions

In conclusion, it was clearly found that the application of organic fertilizers could help mitigate the negative impacts of textile effluent water on the crop growth and the microbial population that ultimately increased the yield of wheat. However, further confirmation under natural field conditions are needed to warrant its efficacy.

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