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Effect of textile wastewater on growth and yield of wheat (*Triticum aestivum* L.)

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Abstract

Textile wastewater can be a good source of nutrients in addition to meet the crop water requirements in areas facing water shortage problem. The use of untreated industrial wastewater can be hazardous for end users and soil environment due to high concentration of pollutants. The toxic effects of wastewater could be reduced by dilution of these pollutants. A pot trial was conducted to evaluate the suitability of untreated textile wastewater at different dilution levels (0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%) for improving growth, physiology and yield of wheat (Triticum aestivum L.*). Tap water (0 % dilution level) was applied as control treatment. Results showed that textile effluents negatively affected growth and yield of wheat. Maximum reduction in growth, yield, chemical and physiological parameters of wheat was recorded on application of textile wastewater (100% wastewater dilution level). However, on dilution, inhibitory effects of textile wastewater on all measured parameters of wheat were significantly reduced. In addition, effects of 10% and 20% diluted textile effluent on growth and yield of wheat was statistically at par with control. So, it can be concluded that although textile wastewater imparts negative effects on wheat but on dilution it can be used for irrigation of wheat in areas facing water scarcity. However, dyes or their intermediates even in the diluted textile wastewater after entering into food chain may cause harm to human. Such wastewater could be used for biomass production of bioenergy crops and further studies are required to test toxicity impacts of textile wastewater on human through food chain.*

Keywords: Textile effluents, wheat, water scarcity, crop production

Introduction

As a developing country, Pakistan's economy can be characterized as semi-industrialized (GOP, 1991) and contribute about 24% in gross domestic product (GDP) (Kirk and Ehow, 2008). Being one of the major industry in Pakistan's industrial sector, textile industry plays significant role that shares 7.4% in GDP of Pakistan. In Asia, Pakistan is the 8th largest exporter of textile products (Ahmad, 2011). Estimated amount of 1,441,167 m^3 wastewater /day is generated from textile processing units (GOP, 2008). Untreated discharge of this wastewater has not only affected the good quality of drinking water (Kaur *et al*., 2010) but has also caused much damage to environment (soil and water) by adding pollutants (WHO, 2002; Wins and Murgan, 2010; Kaur *et al*., 2010).

Textile wastewater contains heavy load of pollutants, exhibiting high total dissolved solids (TDS), total suspended solids (TSS), and many other organic and inorganic compounds (heavy metals) (Cooper, 1995; Pathak *et al*., 1999; Siddique *et al*., 2010). Presence of these toxic substances limits its application for irrigation purposes (Khan *et al.*, 2003). However, availability of some vital nutrients like copper, zinc, iron, and manganese in textile wastewater (Beghum *et al.*, 2011) may offer a possibility to use it for irrigational purpose after proper treatment (Khan *et al.*, 2011). Ahmad *et al.* (2003) reported that application of sewage water also improves the fertility of soil and increases crop production due to the presence of these nutrients. For this reason, some of the small land holders are using wastewater for irrigation purposes in dry areas (Girsha and Raju, 2008: Shah, 2009).

Direct application of textile effluents may cause inhibitory effect on growth of some plants (Wins and Murgan, 2010), but on dilution can impart positive effects (Rahman *et al*., 2009). It has been reported that dilution of wastewater has significantly increased growth and germination of black gram, green gram, rice, groundnut, sunflower and maize (Elarajan and Bupathi, 2006; Wins and Murgan, 2010). Thus for beneficial cultivation, farmers can use textile effluent for irrigation with lower

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concentrations of effluent like 25% dilution (Kumar *et al.*, 2006). Lead (Pb), Zn, Fe, Mn and Cu contents in rice seedlings were significantly increased on application of textile wastewater in comparison to good quality irrigation water (Beghum *et al.*, 2011). Considering the above points, this study was undertaken to evaluate the effects of different dilutions of textile wastewater on wheat growth and yield with the objective to find out the appropriate level of dilution of textile effluent for improving growth and yield of wheat.

Materials and Methods

Plant material and growth conditions

A pot experiment was conducted to evaluate the effects of different dilutions of textile wastewater on growth and yield of wheat (cv. Fsd-2008). The bulk surface (0-15cm) soil was collected from the Research Area, University of Agriculture, Faisalabad, Pakistan and pre-sowing soil analysis was performed. The soil texture was determined by following the standard protocol (Moodie *et al.*, 1959) while other physico-chemical properties such as pH, electrical conductivity (EC), saturation percentage (SP) and extractable potassium were determined by following the standard methods from U.S. Salinity Lab. Staff (1954). The total nitrogen was determined by the method of Jackson (1962), available phosphorus through the method of Watanabe and Olsen (1965). The physic-chemical properties of soil used in pots are given in (Table 1). Textile effluent was collected from a textile unit located on Sargodha Road, Faisalabad, Pakistan and analyzed for various characteristics (Table 1). Saturation percentage of soil was determined using following formula:

$$SP\ (\%) = \frac{Mass\ of\ wet\ soil - mass\ of\ oved\ dried\ soil}{Mass\ of\ oven\ dried\ soil} \times 100$$

Table 1: Physico-chemical characteristics of textile effluent and soil used for pot trial

Characteristic	Unit	Value	Soil used in Pot trial
Soil Texture class			Sandy clay
pH		8.2	7.7
EC	dS m^{-1}	3.5	1.41
Saturation percentage (SP)	%		33
Total N	%	-	0.05
Available P	mg kg^{-1}	-	3.3
Extractable K	mg kg^{-1}	-	154
BOD*	mg L^{-1}	350	-
COD**	mg L^{-1}	920	-

BOD:* biological oxygen demand, COD:** chemical oxygen demand

Treatment and design of experiment

The experiment was comprised of 11 treatments. Tap water was diluted with textile wastewater up to 100% (0, 10, 20, 30, 40, 50, 60, 70, 80, 90% and 100% dilution levels). While, tap water (0 % dilution level with wastewater) was taken as control treatment. After filling the pots, soil was saturated with tap water before sowing and pots were arranged according to the completely randomized design (CRD). Each treatment was replicated 4 times. At sowing of seeds, all the pots (except control treatment) were irrigated with different dilutions of textile wastewater. After germination, irrigation (500 mL Hoagland solution + 500 mL dilutions of textile wastewater) was done at critical growth stages (crown root initiation, tillering, heading, milky grain formation and dough formation). Hoagland solution and textile wastewater was only source of nutrient to geminated wheat seedlings.

Growth, yield, physiological and chemical parameters of wheat

Crop was harvested at maturity and the data regarding growth, yield, physiological and chemical parameters of wheat were recorded during the growth period and after harvesting. Plant height (cm), spike length (cm) and root length (cm) was recorded using measuring tape. For root sampling, soil was washed away and root samples were thoroughly washed with distilled water. After drying with tissue paper, root mass (g pot^{-1}) of all the replicates of all the treatments was weighed using a measuring balance and average was calculated. Straw yield (g pot^{-1}), 1000 grain weight, grain yield (g pot^{-1}) and harvest index was measured after harvesting.

At active growth stage, parameters regarding gas exchange i.e. photosynthetic rate (µmol CO_2 m^{-2} s^{-1}), transpiration rate (µmol H_2O m^{-2} s^{-1}), stomatal conductance (µmol m^{-2} s^{-1}) and sub-stomatal CO_2 concentration (µmol mol^{-1}) were measured using IRGA (Infrared gas analyzer). Both sides of the top third, fully developed leaf of each plant were measured at the ambient light. Grain and straw samples were digested with sulphuric acid and hydrogen peroxide (Allen *et al.*, 1986) and nitrogen (N), phosphorous (P) and potassium (K) concentration was determined by Kjeldhal method (Jackson, 1962), spectrophotometer (Ashraf *et al*., 1992) and flamephotometer (Jenway PFP-7), respectively.

Statistical analysis

Data collected after the experiment were analyzed statistically using software "Statistix 8.1®" version and means were compared by using LSD test (Steel *et al*., 1997) at 5% probability level.

Results and Discussion

Results revealed that almost all the growth, physiological, chemical and yield parameters of wheat were negatively affected on application of textile wastewater.

Growth parameters

Data in Table 2 have showed that wheat growth has been negatively affected on application of textile wastewater. Maximum reduction in growth parameters of wheat was observed on application of concentrated textile effluent (100% dilution level) as plant height, spike length, root mass and root length of wheat was decreased by up to 17, 22, 68 and 24%, respectively, as compared to control (tap water). However, with dilution of textile wastewater to 50%, its negative effects on plant height, spike length, root mass and root length of wheat plants was reduced by 2, 7, 20 and 8% in comparison with concentrated textile effluent (zero dilution). While, further dilution to 20% showed surprising results, as no significant negative effects on growth of wheat plants were observed. The effect of textile wastewater on dilution level 10, 20 and 30% on growth parameters of wheat was statistically at par with control (Table 2). The reduction in growth parameters at high effluent concentration might be due to the large amount of toxic substances, heavy metals, toxic organic compounds, high BOD and COD (Pathak *et al*., 1999; Robinson *et al*., 2001).

effluent imparts negative effects on growth parameters due to increase in soil salinity and concentration of toxic metals (Jadhav and Savant, 1975). While, on dilution, concentration of toxic elements in wastewater can be reduced (Zalawadia and Raman, 1994; Kumar *et al*., 2006) thus reducing the inhibitory effects on plants (Kumar *et al*., 2006; Rehman *et al*., 2009). This could be the reason of non-inhibitory effect of application of 10%, 20% and 30% diluted textile wastewater. Similar effects of application of diluted wastewater has been reported on winter vegetables (Rehman *et al*., 2009), rice varieties (Mistry and Chatterjee, 2009) and *Arachis hypogea* (Kaushik *et al*., 2005).

Yield Parameters

It was observed that effect of dilution textile wastewater on the yield parameters of the wheat is stimulatory rather inhibitory (Table 3). Results revealed that the plants received concentrated textile effluent showed minimum growth and development as 1000-grain weight, grain yield and straw yield was decreased by on average 50% compared to control. Negative effects of textile waste water on yield parameters of wheat were decreased with gradual decrease dilution level. Minimum reduction in yield parameters of wheat was recorded on application of 20% and 30% diluted textile wastewater. However, the effect of application of 20 and 30% diluted textile wastewater on yield parameters of wheat was statistically at par with control. Although, the effect of 20% diluted textile waste water was superior to others as it increased 1000-grain weight, straw yield and harvest index up to 5, 77 and 35%, respectively, in comparison to control (Table 3). The reduction in yield parameters in response to textile wastewater (at <70% dilution level) application could be

Table 2: Effect of textile wastewater on growth parameters of wheat

Treatments (wastewater dilution level)	Plant height (cm)	Spike length (cm)	Root dry mass (g pot^{-1})	Root length (cm)
Control (tap water)	44.83 ^{bc}	7.47 ^{ab}	3.59 ^{a}	25 ^{b}
10%	47.75 ^{ab} (7)	7.75 ^{a} (4)	3.63 ^{a} (1)	32 ^{a} (28)
20%	53.08 ^{a} (18)	7.83 ^{a} (5)	3.71 ^{a} (3)	32 ^{a} (28)
30%	45.92 ^{bc} (1)	7.58 ^{a} (1)	3.60 ^{a} (0.3)	30 ^{a} (20)
40%	44.92 ^{bc} (0.2)	7.00 ^{ab} (-6)	2.95 ^{b} (-18)	24 ^{b} (-4)
50%	43.92 ^{bcd} (-2)	6.92 ^{ab} (-7)	2.87 ^{b} (-20)	23 ^{b} (-8)
60%	43.67 ^{bcd} (-2)	6.69 ^{ab} (-10)	2.22 ^{c} (-38)	21 ^{bc} (-16)
70%	40.92 ^{cde} (-9)	6.67 ^{ab} (-11)	2.16 ^{c} (-40)	21 ^{bc} (-16)
80%	40.25 ^{cde} (-10)	6.46 ^{ab} (-14)	1.75 ^{d} (-51)	20 ^{bc} (-20)
90%	38.33 ^{de} (-14)	6.37 ^{ab} (-15)	1.27 ^{e} (-65)	19 ^{c} (-24)
100%	37.10 ^{e} (-17)	5.82 ^{b} (-22)	1.13 ^{e} (-68)	19 ^{c} (-24)
LSD at $p < 0.05$	5.01	1.51	0.39	3.22

Data are shown as mean of four replicates; **( ) =** % increase from the control; **(-)** = % decrease from the control; Values showing the same letters within the Colum are statistically non-significant with respect to each other (* = significant at $p < 0.05$)

Adverse effects of textile wastewater on root mass might be either due to excessive toxic substances (Bhati and Singh, 2003; Shah, 2009). Similar effects of textile effluent on root mass of *Vigna mungo* (L.) has been reported by Wins and Murgan (2010). Moreover, application of textile due to high level of toxic organic compounds (Dyes) (Nigam *et al*., 2000) and high BOD and COD (Kaur *et al*., 2010). Similar to our results, Egbeeni *et al*. (2009) reported that fruit production in okra was significantly reduced on application of higher concentrations of industrial effluent. While, positive effect on grain and straw yield in response to application of 20% and 10% diluted textile wastewater could be either due to reduced toxic effect of pollutants (Mistry and Chatterjee, 2009) or due to positive effect of beneficial nutrients added from Hoagland solution (Zalawadia and Raman, 1994; Pathak *et al*., 1999; Mistry and Chatterjee, 2009).

Table 3: Effect of textile wastewater on yield parameters of wheat

Treatments (wastewater dilution level)	Grain yield (g pot^{-1})	1000 grain wt. (g)	Straw yield (g pot^{-1})	Harvest index
Control (Tap water)	2.64 ^{a}	0.56 ^{ab}	2.48 ^{cd}	45.4 ^{c}
10%	2.52 ^{a} (-4)	0.58 ^{a} (4)	3.76 ^{ab} (52)	54.5 ^{ab} (20)
20%	2.54 ^{a} (-4)	0.59 ^{a} (5)	4.38 ^{a} (77)	61.4 ^{a} (35)
30%	2.37 ^{ab} (-10)	0.55 ^{ab} (-2)	2.84 ^{bc} (14)	54.1 ^{ab} (19)
40%	2.29 ^{ab} (-13)	0.54 ^{ab} (-4)	2.24 ^{cd} (-10)	43.8 ^{bcd} (-4)
50%	2.20 ^{ab} (-17)	0.53 ^{ab} (-5)	2.21 ^{cd} (-11)	43.7 ^{bcd} (-4)
60%	1.83 ^{abc} (-31)	0.52 ^{abc} (-7)	1.92 ^{cd} (-22)	43.2 ^{bcd} (-5)
70%	1.78 ^{abc} (-32)	0.43 ^{bcd} (-23)	1.71 ^{d} (-31)	42.2 ^{cd} (-7)
80%	1.46 ^{abc} (-45)	0.38 ^{cd} (-32)	1.41 ^{de} (-43)	40.8 ^{cd} (-10)
90%	1.20 ^{c} (-54)	0.33 ^{d} (-41)	1.37 ^{de} (-45)	40.1 ^{cd} (-12)
100%	1.18 ^{c} (-55)	0.30 ^{d} (-46)	1.22 ^{de} (-51)	37.4 ^{d} (-18)
LSD at $p < 0.05$	1.188	0.133	0.991	7.45

Table 4: Effect of textile wastewater on physiological parameters of wheat

Treatments (wastewater dilution level)	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})	Transpiration rate (µmol H_2O m^{-2} s^{-1})	Stomatal conductance (µmol m^{-2} s^{-1})	Sub-stomatal CO_2-conc. (µmol mol^{-1})
Control (Tap water)	6.54 ^{a}	3.9 ^{ab}	0.12 ^{a}	322 ^{a}
10%	4.81 ^{abc} (-26)	3.58 ^{ab} (-8)	0.09 ^{abc} (-25)	294.7 ^{abc} (-8)
20%	6.33 ^{ab} (-3)	4.58 ^{a} (17)	0.11 ^{ab} (-8)	309.3 ^{ab} (-4)
30%	4.37 ^{abc} (-33)	3.41 ^{bc} (-12)	0.09 ^{abc} (-25)	281.8 ^{abc} (-12)
40%	4.33 ^{abc} (-34)	3.33 ^{bc} (-15)	0.08 ^{abc} (-33)	278.8 ^{abc} (-13)
50%	4.30 ^{abc} (-34)	3.31 ^{bc} (-15)	0.08 ^{abc} (-33)	273.3 ^{abc} (-15)
60%	3.83 ^{abc} (-41)	3.18 ^{bc} (-18)	0.07 ^{cde} (-42)	270.3 ^{abc} (-16)
70%	3.46 ^{bc} (-47)	3.00 ^{bc} (-23)	0.07 ^{cde} (-42)	253.3 ^{bcd} (-21)
80%	3.18 ^{bc} (-51)	2.71 ^{c} (-30)	0.06 ^{cde} (-50)	249.7 ^{cd} (-24)
90%	2.32 ^{c} (-64)	2.66 ^{c} (-32)	0.05 ^{de} (-58)	244.3 ^{cd} (-22)
100%	2.26 ^{c} (-65)	2.50 ^{c} (-36)	0.04 ^{e} (-67)	204.3 ^{d} (-36)
LSD at $p < 0.05$	3.113	1.009	0.039	57.85

Data are shown as mean of four replicates; **()** = % increase from the control; **(-)** = % decrease from the control; Values showing the same letters within the Colum are statistically non-significant with respect to each other (* = significant at $p < 0.05$)

Physiological parameters

It was revealed from the data (Table 4) that application of textile wastewater at various dilutions negatively affected all measured physiological parameters. Maximum photosynthetic rate (6.54 µmol CO_2 m^{-2} s^{-1}), transpiration rate (3.90 µmol H_2O m^{-2} s^{-1}), stomatal conductance (0.12 µmol m^{-2} s^{-1}) and sub-stomatal CO_2 concentration (322.0 µmol mol^{-1}) was recorded in plants receiving good quality irrigation water. These parameters were linearly decreased with gradual increase in concentration of textile effluents. Maximum reduction in photosynthetic rate (65%), transpiration rate (36%), stomatal conductance (67%) and sub-stomatal cavity CO_2-concentration (36%) was observed on application of textile effluent at its highest concentration. However, inhibitory effect of 20% diluted textile wastewater on photosynthetic rate, stomatal conductance and sub-stomatal CO_2-concentration was negligible compared to other treatments. Moreover, textile wastewater application at this level showed stimulatory effect on transpiration rate of wheat plants. Negative effects of textile wastewater (>20% dilution level) could be due to salinity problem caused by un-judicial use of effluents and may impart negative effects on physiological parameters of plants (Ramana *et al.,* 2002). Similar to our results, Bhati and Singh, (2003) and Kaushik *et al.* (2005) described that textile wastewater negatively affect physiological parameters of plants, but at lower concentration shows no or minor inhibitory effects on physiological parameters of plants.

textile effluents increase nutrient concentration in soil so the plant can uptake more nutrients. These results are in line with findings of Molahoseini (2003).

Conclusion

From the results, it can be inferred that concentrated textile wastewater is heavily loaded with pollutants which negatively affect plant growth and yield by interfering with nutrient uptake and physiological process. However, on dilution, toxic effects of textile wastewater are reduced. Moreover, on 20% dilution, its effect on growth, yield,

Table 5: Effect of textile wastewater on chemical composition of wheat grains and straw

Treatments (wastewater dilution level)	Nitrogen (%)		Phosphorous (%)		Potassium (%)	
	Grains	Straw	Grains	Straw	Grains	Straw
Control (Tap water)	2.05 ^{ab}	0.66 ^{c}	0.33 ^{bc}	0.25 ^{bc}	0.76 ^{a}	0.91 ^{a}
10%	2.15 ^{a} (5)	0.57 ^{c} (-16)	0.42 ^{a} (27)	0.22 ^{c} (-12)	0.91 ^{a} (20)	0.81 ^{b} (-12)
20%	2.15 ^{a} (5)	0.86 ^{ab} (30)	0.42 ^{a} (27)	0.24 ^{bc} (-4)	0.92 ^{a} (21)	0.77 ^{ab} (-15)
30%	1.98 ^{ab} (-3)	0.81 ^{bc} (23)	0.41 ^{a} (24)	0.15 ^{c} (-40)	0.89 ^{a} (17)	0.82 ^{ab} (-10)
40%	1.98 ^{ab} (-3)	1.13 ^{a} (71)	0.38 ^{ab} (15)	0.30 ^{ab} (20)	0.88 ^{a} (16)	0.90 ^{ab} (-1)
50%	1.96 ^{ab} (-4)	0.79 ^{b} (20)	0.35 ^{b} (6)	0.22 ^{bc} (-14)	0.87 ^{a} (14)	0.85 ^{ab} (-6)
60%	1.86 ^{ab} (-9)	0.95 ^{ab} (44)	0.33 ^{bc} (0)	0.31 ^{ab} (24)	0.87 ^{a} (14)	0.96 ^{a} (5)
70%	1.66 ^{ab} (-19)	0.92 ^{ab} (39)	0.33 ^{bc} (0)	0.34 ^{ab} (36)	0.87 ^{a} (14)	0.84 ^{ab} (-8)
80%	1.64 ^{ab} (-20)	0.88 ^{ab} (33)	0.32 ^{bc} (-3)	0.38 ^{a} (52)	0.84 ^{a} (10)	0.88 ^{ab} (-3)
90%	1.55 ^{b} (-24)	0.92 ^{ab} (39)	0.30 ^{cd} (-9)	0.29 ^{ab} (16)	0.82 ^{a} (8)	0.84 ^{ab} (-8)
100%	1.49 ^{bc} (-27)	0.91 ^{ab} (37)	0.27 ^{d} (-18)	0.21 ^{bc} (-16)	0.79 ^{a} (4)	0.82 ^{ab} (-10)
LSD at $p < 0.05$	0.56	0.27	0.04	0.099	0.15	0.91

Data are shown as mean of four replicates; **( )** = % increase from the control; **(-)** = % decrease from the control; Values showing the same letters within the Colum are statistically non-significant with respect to each other (* = significant at $p < 0.05$)

Chemical parameters

Nitrogen and phosphorous contents in grains of wheat was negatively affected by application of textile effluents at higher concentration. However, on dilution, its effect on composition of grains and straw was positive rather negative (Table 5). Application of 100% textile wastewater reduced nitrogen and phosphorous contents in grains by 27 and 18%, respectively, compared to control (tape water). On increasing dilution level, inhibitory effects of textile effluents were linearly reduced. In addition, application of 10% and 20% diluted textile wastewater significantly increased N and P contents in grains compared to control. Effect of different dilutions on K contents in grains was statistically non-significant. Highly erratic effects of dilution of textile wastewater were observed on N, P and K contents in straw of wheat crop. In general, increase in concentration of textile effluents resulted in increase in N and P contents in wheat straw. The possible reason is that on application of concentrated textile effluents, root mass is negatively affected (Wins and Murgan, 2010) and in return nutrient uptake is reduced. While, application of diluted

physiological and chemical parameters could be stimulatory rather inhibitory. On the basis of this study, it can be concluded that the diluted textile wastewater can be used to meet the water requirements that can also improve growth and yield of wheat plants. However, further field investigations are needed to confirm its potential on wheat plants under natural soil environment. Moreover, concentration of mobility index of heavy metals from soil to roots, roots to shoots and from shoot to grains need to be investigated.

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