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Influence of short-term irrigation of textile mill wastewater on the growth of chickpea cultivars

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The effect of textile mill wastewater on germination, delay index, physiological growth parameters, and plant pigments of two cultivars of chickpea was studied. The aim of this study was to evaluate the suitability of textile mill wastewater (treated and untreated) at different concentrations (0, 6.25, 12.5, 25, 50, 75, and 100%) for irrigational purposes. The textile effluent did not show any inhibitory effect on seed germination at a lower concentration (6.25%). The other reported plant parameters (delay index, root length, shoot length, dry weight, chlorophyll, and carotenoid) also followed a similar trend. Seeds germinated in 100% effluents but did not survive for longer periods. It has also been concluded that the effect of the textile effluent is cultivar-specific, and due care should be taken before using the textile mill wastewater for irrigation purposes.

Keywords: Textile mill wastewater; Chickpea cultivars; Germination (%); Delay index; Plant biomass; Plant pigments

1. Introduction

Wastewater generation is an inevitable consequence of industrialization. Wastewaters contain various toxic salts, acids, dissolved gases, heavy metals, pesticides, persistent organic pollutants, etc. If these wastewaters are disposed in water bodies, they may deteriorate the quality of water, making it unfit for various uses. The textile industry is considered a major polluter of the environment. The textile industry consumes a large amount of water in different operations like de-sizing, scoring, bleaching, as well as dyeing, printing, and finishing operations. The resultant effluents of all these processes are a major cause of water pollution. India has a large network of textile industries of varying capacity. The combined wastewater volume from Indian textile mills lies in the range of 86–247 l, with an average of 172 l kg^{-1} of cloth produced. This wastewater is characterized by high BOD, COD, sodium, and other dissolved solids as well as micronutrients and heavy metals.

Laboratory-scale experiments have shown [1] that PBW-373 wheat cultivar was more sensitive than WH-147 and PBW-343. The germination of kidney bean (*Phaseolus aureus*) and

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lady's finger (*Abelmoschus esculentus*) seeds was adversely affected when 75 and 100% concentrations of the textile effluent were used as compared with control (water), whereas there was no effect up to 50% concentration [2]. Bengal gram (*Cicer arietinum*) seed germination was adversely affected in textile effluent concentrations as low as 5% [3]. But unlike the aforementioned crops, 50% diluted textile effluent increased the seed germination, total sugars, starch, reducing sugars, and chlorophyll compared to the control (distilled water) for groundnut seedlings. These studies showed that the effects of an industrial effluent vary from crop to crop. Thus, it is essential to study the effect of industrial effluents on individual crops before their disposal in agricultural fields. Dongale and Savant [4] found a significantly higher yield of sugar cane and increase in available N content in soil (300 kg N ha^{-1}) with the applied spent wash and also reported that it was a good source of potassium for sorghum. Ahmad *et al.* [5] have reported that sugar-cane growth was better when irrigated with treated wastewater from an oil refinery than the control (groundwater). The soil receiving wastewater did not show any changes in physico-chemical characteristics. The soil accumulated all the heavy metals, but the sugar cane accumulated Ni, Pb, and Zn only, which had values that were much lower than the permissible limits.

In India, the abundance of soils with a low organic matter content favours the use of industrial wastewaters containing organic matter as an organic amendment and nutrient supply to soil.

Chickpea is a winter crop in India, but different cultivars are used in different regions depending upon soil type, local climate, and irrigation facilities. In the present study, an attempt has been made to assess the effects of untreated (UTE) and treated (TE) textile effluents irrigation on seed germination and growth performance of two different cultivars of chickpea at different effluent concentrations in laboratory and pot culture experiments.

2. Materials and methods

The effect of textile effluents was studied on two varieties of Chickpea (*Cicer arietinum* L.), namely *Haryana channa* No. 1 and *Haryana channa* No. 3. The seeds were procured from the certified local seed supplier. The textile effluents (untreated (UTE) and treated (TE)) were collected in pre-cleaned containers from a textile mill located near Hisar (Haryana), India. Various physico-chemical characteristics of both the effluents were analysed using standard methods [6]. The effluents were refrigerated at 4 °C during the storage period to avoid changing any of its characteristics.

2.1 *Experimental design*

For germination tests, 10 seeds of each chickpea cultivar were placed in sterilized glass Petri dishes of uniform size lined with two filter paper discs. These filter discs were then moistened with 5 ml of distilled water for control and with the same quantity of various concentrations of the textile effluent (6.25, 12.5, 25.0, 50.0, 75.0, and 100%) in distilled water. The Petri dishes were incubated at 18 ± 1 °C in an incubator. Germination was recorded daily at a fixed hour, and the emergence of the radicle was taken as a criterion of germination. All the experiments were carried out in triplicate, and the results were averaged.

Germination time, defined as the time taken for 60% germination, was worked out for studied chickpea cultivars under different effluent concentrations.

Delay index (DI), a normalized parameter, was calculated to compare the performance of different chickpea cultivars under different effluent concentrations as given below:

$$\mathrm{DI} = \frac{X}{Y},$$

where DI = delay index; X = delay in germination time over control (no effluent); and Y = germination time for control.

For observing seedling growth, five 7-d-old seedlings were picked from each of the sets, and the lengths of the root and shoot were recorded. Plants at the termination of experiment were collected, and their roots and stems along with leaves were separated and dried at 65 °C in a hot-air oven for 24 h. Their dry weights were recorded.

2.2 *Pot-culture experiment*

Pots of 15 cm (diameter) × 14 cm (height) size were filled with equal amounts of sandy loam soil of medium fertility, and 10 seeds of *Haryana Channa* No. 3 chickpea cultivar were sown in each pot. The pots were irrigated with selected concentrations (6.25, 12.5, 25, 50, 75, and 100%) of textile effluents. For each treatment, 100 ml of each of these was applied to the respective pot at 7 d intervals, throughout the study period. After germination seeds were thinned to five seedlings per pot in all the pots. The chlorophyll and carotenoid content of the plants were measured. The chlorophyll content was estimated by extracting fresh leaves with 80% acetone and after centrifugation at 4000 rpm for 20 min, measuring the colour intensity of the extract at 445, 645, and 663 nm. The formulae of Arnon [7] were used to calculate the chlorophyll *a* and chlorophyll *b* contents and that of Ikan [8] for the carotenoid content. Each treatment had three replications. A control set, irrigated with distilled water, was also maintained for comparison.

The data in this study were analysed using the SPSS package, and all the values are presented as the mean ± SE. Student's t-tests were used to compare the data between the control (distilled water) and other effluent concentrations. The probability levels used for statistical significance were $P < 0.05$ for the tests.

3. Results and discussion

Chickpea is grown in tropical, sub-tropical, and temperate regions. The south-eastern part of Turkey adjoining Syria has been recognized as the possible centre of origin of chickpea [9]. Chickpea is valued for its nutritive seeds with a high protein content, 25.3–28.9%, after de-hulling [10]. Chickpea seeds are eaten fresh as a green vegetable, dried, fried, roasted, and boiled, and also as a snack, sweet, and as a condiment; seeds are ground, and the flour can be used in soup and dhal, and to make bread. Animal feed is another use of chickpea in many developing countries. Chickpea is commonly grown by farmers in the Haryana state of India. Chickpea prefers dry conditions, but at some locations the irrigation of chickpea using industrial wastewater was observed. In the present investigation, the impact of textile industry effluent in various concentrations (0, 6.25, 12.5, 25, 50, 75, and 100%) on seed germination (%), delay index, shoot length, root length, dry weight, and chlorophyll content of two chickpea cultivars (*Cicer arietinum* L.) viz. *Haryana channa* No. 1 and *Haryana channa* No. 3. has been explored.

The physico-chemical characteristics of untreated and treated forms of the effluent are shown in table 1. Treated effluent was muddy grey in colour. Untreated effluent was brownish black

Table 1. Physico-chemical characteristics of textile effluents.

Parameter	Untreated effluent	Treated effluent
Colour	Brownish black	Muddy grey
pH	9.9	8.2
EC (mmho cm^{-1})	8.13	7.34
Specific gravity	1.01	0.99
Suspended solids (mg l^{-1})	210	128
Total Solids (mg l^{-1})	7333	6786
Total alkalinity (as $CaCO_3$, mg l^{-1})	946	792
Dissolved oxygen (mg l^{-1})	Nil	Nil
BOD (mg l^{-1})	1626	496
COD (mg l^{-1})	2190	960
Total nitrogen (as N) (mg l^{-1})	246	238
Sodium (mg l^{-1})	186	142
Potassium (mg l^{-1})	9	7
Calcium (mg l^{-1})	318	267
Chloride (mg l^{-1})	860	692
Sulphate (mg l^{-1})	381	326
Fluoride (mg l^{-1})	Nil	Nil
Phosphate-P (mg l^{-1})	18	14

in colour, had a deficit in dissolved oxygen, was rich in total solids, total alkalinity, BOD, and COD, and had considerable amounts of total nitrogen, phosphate, chlorides, sulphates, sodium, and calcium. The potassium content was negligible. The magnitude of analysed parameters was lower for treated effluent than for untreated effluent (table 1). The suspended solids and BOD of both effluents exceeded the prescribed Indian disposal standards (100 and 150 mg l^{-1}, respectively).

Germination of both chickpea cultivars was not affected in 6.25, 12.5, and 25.0% concentrations of TE. Channa No. 3 had 100% germination in 6.25, 12.5, 25, and 50% concentration of UTE, whereas seed germination of Channa No. 1 declined at a UTE concentration $>6.25\%$ (table 2). Paliwal *et al.* [11] reported an increase in different growth parameters of *H. binata* seedlings with 25, 50, and 75% sewage water treatments, which revealed that the sewage water significantly influenced growth performances. Excessive salts in the effluent could be responsible for reduced plant growth of *Oriza sativa* at 50, 75, and 100% concentrations [12].

In treated effluent, both varieties had a lower rate of germination than the control. However, germination in Channa No. 3 was 90% germination in $\leq 75\%$ treated effluent. Channa No. 3 showed better germination than Channa No. 1 in both effluents (table 2). Ramana *et al.* [13] studied the effect of distillery effluent on germination of five crops. Among them, tomato had

Table 2. Effect of textile effluents on germination (%) of different chickpea cultivars (after 120 h) ($n = 3$, mean ± SE).

Effluent	Untreated effluent		Treated effluent	
conc. (%)	Channa No. 1	Channa No. 3	Channa No. 1	Channa No. 3
0 (DW)	100.0 ± 0.0a	100.0 ± 0.0a	100.0 ± 0.0a	100.0 ± 0.0a
6.25	100.0 ± 0.0a	100.0 ± 0.0a	86.6 ± 5.8b	90.0 ± 0.0ab
12.5	93.3 ± 5.8a	100.0 ± 0.0a	86.6 ± 5.8b	90.0 ± 0.0ab
25.0	90.0 ± 0.0a	100.0 ± 0.0a	83.3 ± 5.8b	90.0 ± 0.0ab
50.0	83.3 ± 5.8bc	93.3 ± 5.8a	80.0 ± 0.0bc	90.0 ± 0.0ab
75.0	80.0 ± 0.0c	83.3 ± 5.8b	76.6 ± 5.8c	90.0 ± 0.0ab
100	73.3 ± 5.8c	80.0 ± 0.0b	70.0 ± 17.3cd	86.6 ± 5.8b

Note: Values followed by the same letters in a column are not significantly different ($p \leq 0.05$).

Table 3. Effect of textile effluent concentrations on delay index (DI) of different chickpea cultivars.

	Channa No. 1		Channa No. 3	
Effluent conc. (%)	Untreated effluent	Treated effluent	Untreated effluent	Treated effluent
6.25	1.0	0	0	0
12.50	1.0	0	0	0
25.00	1.0	0	0	0
50	1.0	1.0	0	0
75	1.5	1.5	0	0
100	2.5	2.0	1.0	0

the lowest (29%) germination, and onion had the highest (48%). It was also reported that germination was inhibited in all five crops in ≥50% distillery effluent concentration.

The delay index was higher in Channa No. 1 than in Channa No. 3 (table 3). The delay index was zero for Channa No. 3 in both the effluents at all the concentrations except in 100% UTE. The seeds take up water during germination in order to hydrolyse the stored food material and to activate their enzymatic systems. As absorption takes place by osmosis, the salt content outside the seeds may act as a limiting factor, which might be responsible for the delay in germination [14]. Adriano *et al.* [15] also considered high salt content as a limiting factor for the germination of seeds. The reason for the delay in the germination of seeds when irrigated with 25, 50, 75, and 100% effluent concentration may be attributed to the soil-water relationship to which the seeds were more susceptible during their germination period [16].

The shoot length of Channa No. 1 was significantly reduced when irrigated with >6.25% UTE. In control (distilled water), Channa No. 1 had a shoot length of 15.17 ± 0.78 cm, which was reduced to 6.77 ± 1.50 cm when irrigated with >6.25% UTE (table 4). A further decline in the shoot length was observed as the concentration of effluent was increased (0.70 ± 0.60 cm shoot length in 100% UTE). Shoot length of Channa No. 3 had no effect at ≤25% UTE concentration. A similar trend was observed for root length in Channa No. 1 with a minimum root length of 0.93 ± 0.81 cm at 100% effluent concentration. Channa No. 3 had a higher, but insignificant, root length at 6.25% concentration (21.22 ± 1.67 cm) than the control (20.27 ± 1.85 cm). When treated effluent was used for chickpea irrigation, the variations in root length and shoot length were similar to when untreated effluent was used in irrigation.

The dry weights of Channa No. 1 were adversely affected by both the effluents. When Channa No. 1 was irrigated with 6.25 and 12.5% diluted water, the variations in dry weight were insignificant ($p < 0.05$). However, at ≥25% effluent concentrations, there was a significant decrease in shoot dry weights. The adverse effect of excessive salt in the textile effluent may have been responsible for the reduction in dry biomass at 25, 50, 75, and 100% effluent concentrations. Paliwal *et al.* [11] have reported a decrease in dry weight of *Hardwickia Binata* when irrigated with sewage water at 50, 75, and 100% concentrations. Channa No. 1 had 55.7 ± 3.13 mg of dry weight in 6.25% concentration of TE, which is insignificantly higher than the control (table 5). This increase in yield with textile effluent may be due to the increase in organic matter and macro- and micronutrients present in the effluent. Shoot dry weights of Channa No. 3 also followed a similar trend (table 5). The root biomass was significantly higher in 6.25, 12.5, and 25% concentrations of TE than the control. Channa No. 3 also had an increase in root biomass in 6.25% concentration of both effluents, which decreased significantly in ≥12.5% effluent concentrations (table 5).

The chlorophyll content was affected at higher effluent concentrations. When irrigated with untreated effluent, there was a significant decrease in total chlorophyll content (1.093 ±

Table 4. Effect of textile effluent on shoot and root length of different chickpea cultivars (after 7 d) (in cm) ($n = 3$, mean ± SE).

	Channa No. 1		Channa No. 3	
Effluent conc. (%)	SL	RL	SL	RL
Untreated effluent				
0 (DW)	15.17 ± 0.78a	20.94 ± 1.01a	15.60 ± 0.62a	20.27 ± 1.85a
6.25	6.77 ± 1.50b	13.56 ± 3.94b	14.73 ± 1.42a	21.22 ± 1.67a
12.5	6.27 ± 1.90b	10.53 ± 0.66c	13.93 ± 0.75a	13.01 ± 3.10b
25.0	5.70 ± 0.40b	7.83 ± 0.98d	12.31 ± 1.20a	9.76 ± 0.15c
50.0	4.40 ± 0.36c	3.30 ± 0.20e	6.16 ± 0.50b	8.65 ± 3.03c
75.0	1.33 ± 0.25d	1.70 ± 0.26f	5.33 ± 0.25b	4.80 ± 3.12d
100	0.70 ± 0.60e	0.93 ± 0.81g	2.56 ± 0.41c	3.73 ± 0.49d
Treated effluent				
0 (DW)	15.17 ± 0.78a	20.92 ± 1.01a	15.60 ± 0.62a	20.27 ± 1.85a
6.25	13.80 ± 0.55ab	19.55 ± 1.01a	15.43 ± 0.43a	21.61 ± 0.62a
12.5	12.20 ± 0.55b	17.82 ± 1.81a	13.95 ± 1.89a	20.34 ± 1.99a
25.0	7.36 ± 1.69c	17.73 ± 1.99a	12.02 ± 0.37a	17.62 ± 1.21a
50.0	6.70 ± 0.52c	5.36 ± 1.13b	8.40 ± 0.79b	14.21 ± 2.98b
75.0	3.46 ± 0.45d	4.90 ± 0.81b	6.73 ± 1.19c	9.26 ± 2.47c
100	0.63 ± 0.32e	2.33 ± 0.28c	3.86 ± 0.20d	2.66 ± 0.28d

Note: DW: distilled water. Values followed by the same letters in a column are not significantly different ($p \leq 0.05$). Untreated effluent and treated effluent should be considered separately.

0.058 mg g^{-1} fresh weight in control to 0.379 ± 0.019 mg g^{-1} fresh weight in 100% effluent concentration) in Channa No. 3. But when irrigated with treated effluent, the total chlorophyll content was not significantly less than the control at $\leq$25% concentration (table 6). There was a significant decrease at higher effluent concentrations. The reduction in chlorophyll content may be due to the presence of heavy metals, which interfere with the protochlorophyllide reductase complex, and the synthesis of amino levulinic acid. The carotenoid content also decreased significantly when the concentration of effluent was increased (table 6).

Table 5. Effect of textile effluent on dry weight (after 7 d) of different chickpea cultivars (mg plant^{-1}) ($n = 3$, mean ± SE).

	Channa No. 1		Channa No. 3	
Effluent conc. (%)	Shoot	Root	Shoot	Root
Untreated effluent				
0 (DW)	55.4 ± 4.67a	12.8 ± 2.87a	56.8 ± 5.12a	12.2 ± 2.68a
6.25	53.5 ± 5.32a	14.0 ± 2.13a	55.3 ± 3.19a	12.9 ± 2.53a
12.5	50.2 ± 5.26a	12.5 ± 1.85a	52.1 ± 4.45a	9.5 ± 2.25b
25.0	40.1 ± 5.89b	10.0 ± 2.14b	41.6 ± 3.67b	5.4 ± 2.76c
50.0	15.8 ± 3.16c	9.0 ± 1.23b	18.5 ± 3.87c	5.7 ± 1.84c
75.0	13.3 ± 2.12c	5.1 ± 2.17c	11.3 ± 3.24d	5.1 ± 1.44c
100	4.6 ± 0.55d	3.2 ± 0.96d	4.2 ± 0.63e	3.0 ± 0.37d
Treated effluent				
0 (DW)	55.4 ± 4.67a	12.8 ± 2.87a	56.8 ± 5.12 a	12.2 ± 2.68a
6.25	55.7 ± 3.13a	15.4 ± 2.66b	56.1 ± 3.56a	13.3 ± 3.22a
12.5	52.4 ± 3.24a	14.8 ± 2.11b	54.6 ± 4.15a	10.7 ± 2.46b
25.0	42.9 ± 4.56b	13.3 ± 2.23ba	51.7 ± 3.94a	8.6 ± 1.77c
50.0	33.1 ± 3.18c	9.5 ± 2.54c	34.2 ± 4.31b	6.4 ± 1.43d
75.0	16.9 ± 2.14d	9.3 ± 2.28c	18.7 ± 2.48c	5.1 ± 2.31d
100	5.3 ± 1.12e	3.5 ± 0.45d	7.3 ± 2.34d	3.7 ± 0.58f

Note: DW: distilled water. Values followed by the same letters in a column are not significantly different ($p \leq 0.05$). Untreated effluent and treated effluent should be considered separately.

Table 6. Effect of textile effluent plant pigments of Channa No. 3, chickpea cultivar (after 30 d) (mg g^{-1} fresh weight) ($n = 3$, mean ± SE).

Effluent conc. (%)	Chl *a*	Chl *b*	Total Chl	Carotenoid
Untreated effluent				
0 (DW)	0.713 ± 0.054a	0.289 ± 0.017a	1.093 ± 0.058a	1.92 ± 0.054a
6.25	0.694 ± 0.032a	0.278 ± 0.031a	1.054 ± 0.031a	1.87 ± 0.024a
12.5	0.685 ± 0.025a	0.265 ± 0.042a	0.985 ± 0.036a	1.81 ± 0.027b
25.0	0.678 ± 0.034a	0.255 ± 0.036a	0.983 ± 0.031a	1.76 ± 0.025b
50.0	0.432 ± 0.027b	0.218 ± 0.025a	0.659 ± 0.023b	1.31 ± 0.028c
75.0	0.417 ± 0.018b	0.216 ± 0.029a	0.616 ± 0.023b	1.36 ± 0.026c
100	0.213 ± 0.022c	0.131 ± 0.016b	0.379 ± 0.019c	0.84 ± 0.018
Treated effluent				
0 (DW)	0.713 ± 0.054a	0.284 ± 0.017a	1.093 ± 0.058a	1.92 ± 0.054a
6.25	0.728 ± 0.025a	0.278 ± 0.029a	1.135 ± 0.026a	1.96 ± 0.033a
12.5	0.705 ± 0.034a	0.281 ± 0.018a	1.086 ± 0.015a	1.85 ± 0.025a
25.0	0.708 ± 0.036a	0.275 ± 0.023a	1.031 ± 0.031a	1.73 ± 0.038a
50.0	0.615 ± 0.028b	0.232 ± 0.017b	0.879 ± 0.022b	1.45 ± 0.026b
75.0	0.538 ± 0.013c	0.227 ± 0.016b	0.838 ± 0.012b	1.03 ± 0.019b
100	0.314 ± 0.033d	0.201 ± 0.013b	0.604 ± 0.025c	0.87 ± 0.023c

Note: DW: distilled water. Values followed by same letters in a column are not significantly different ($p \leq 0.05$). Untreated effluent and treated effluent should be considered separately.

4. Conclusion

It is evident from the data that the physico-chemical characteristics of the effluents exceeded the prescribed Indian standards. It is therefore obvious that some kind of treatment is necessary to minimize the pollution effects before textile industry effluent is discharged on the land. But disposal of these effluents after proper dilution may be a favourable approach. After dilution, the effluent characteristics come within the prescribed disposal limits, and the pollution load per unit effluent volume is decreased.

The better growth of chickpea cultivars at 6.25% effluent concentration may be due to the growth-promoting effect of nitrogen and other mineral elements present in the effluent [17, 18]. Differential responses of chickpea cultivars to untreated and treated wastewater were noted. The delay index showed a variation for chickpea cultivars as well as for effluent concentration. The use of effluent for irrigation may serve as an additional source of water with fertilizing properties after appropriate dilution. Channa No. 1 was more sensitive to textile-effluent irrigation than Channa No. 3. Irrigation water quality not only affected the growth of crops, but also had long-term effects on soil health, grain quality, fodder quality, and health of consumers. Thus, finally it is suggested that long-term experiments be conducted to explore the effect of textile-mill wastewater on the aspects suggested above before its use for irrigation.

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