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Concentration-Dependent Phytotoxic Effects of Textile Effluent on Seed Germination and Early Seedling Development of *Luffa cylindrica* and *Lagenaria siceraria*

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ABSTRACT

Unregulated discharge of industrial wastewater poses severe ecological threats to agricultural ecosystems, particularly in peri-urban farming zones adjacent to textile manufacturing hubs. This study evaluates the phytotoxic impacts of untreated and diluted textile industry effluent on the germination kinetics and early seedling vigor of two economically vital cucurbitaceous crops: *Luffa cylindrica* (sponge gourd) and *Lagenaria siceraria* (bottle gourd). Laboratory bioassays were conducted using a Completely Randomized Design (CRD) with five treatment regimens: T0 (Control - 100% distilled water), T1 (25% effluent + 75% distilled water), T2 (50% effluent + 50% distilled water), T3 (75% effluent + 25% distilled water), and T4 (100% raw effluent). Physicochemical analysis revealed elevated levels of TDS (3,520 mg/L), Electrical Conductivity (2,822 µS/cm), COD (380 mg/L), and BOD (132 mg/L), exceeding Bureau of Indian Standards (BIS) permissible limits. Exposure to higher effluent concentrations (T3 and T4) severely inhibited seed germination, plumule extension, and radicle elongation in both species. *Luffa cylindrica* exhibited higher germination resilience (52.0% at T4) compared to *Lagenaria siceraria* (45.0% at T4). Moderate dilution (T1: 25%) maintained performance comparable to the control, demonstrating that diluted wastewater may be repurposed for restricted agricultural applications after suitable pre-treatment.

Introduction

The continuous growth of the global population, combined with increasing industrialization and urbanization, has intensified the pressure on available freshwater resources. In many regions, the demand for water is growing faster than its sustainable supply, creating serious concerns for public health, environmental stability, and socioeconomic development. Consequently, researchers are increasingly exploring efficient approaches to water conservation, wastewater treatment, and the reuse of treated wastewater. The management of wastewater has become a major challenge for municipal authorities, particularly in densely populated urban areas where land availability for conventional treatment and disposal facilities is limited. However, wastewater should not be viewed solely as an environmental burden. When appropriately treated, it can serve as an alternative water resource and may provide valuable nutrients for agricultural applications. Therefore, wastewater management requires an integrated approach that considers both the environmental risks associated with wastewater discharge and it's potential for beneficial reuse. Industrial development in emerging economies has significantly elevated environmental contamination, with freshwater resources bearing the heaviest pollution burden (Bharagava *et al*., 2020).

The dye manufacturing sector represents an important component of India's industrial economy. Historical estimates indicate that India produced approximately 64,000 tonnes of dyes, accounting for nearly 6.6% of global production at the time of the reported assessment. The Indian dye industry manufactures a wide range of dyes and dye intermediates, including direct dyes, acid dyes, reactive dyes, and pigments. However, the chemical composition, purity, toxicological characteristics, and environmental behaviour of certain commercially used dyes have not always been adequately documented. Despite these concerns, dyes are extensively utilized in several industrial sectors, including textiles, leather processing, paints, and selected food-related applications. Among these sectors, the textile industry has historically accounted for a substantial proportion of domestic dye consumption, making textile wastewater an important area of environmental research. Industrial hubs like Sanganer in Jaipur, Rajasthan, generate millions of liters of complex, synthetic-colored wastewater daily, frequently discharged into surface drains or open lands without complete remediation (Mehta & Bhardwaj, 2012; Kurmi *et al*., 2023).Central pollution control board has listed the dye and dye intermediates industry as one of the heavily polluting industries (CPCB1990).

In Rajasthan, textile printing and dyeing activities contribute significantly to the regional economy. Sanganer, situated approximately 15 km south of Jaipur, is widely recognized for its traditional textile printing industry and the production of brightly coloured fabrics, including garments, bed sheets, curtains, and other textile materials. A considerable proportion of the products manufactured in this region is supplied to national and international markets. Historical descriptions of the area report a geographical extent of approximately 635.5 km², with about 12.9 km² classified as urban land, although these figures should be verified against the relevant geographical and administrative records. Numerous textile-processing establishments operate within the urban industrial zone, and historical estimates have reported approximately 500 block-printing and screen-printing units in Sanganer. The concentration of these activities makes the region particularly relevant for investigating the environmental consequences of dyeing and printing operations, especially the generation and disposal of coloured wastewater. Among major industrial polluters, the textile

dyeing and finishing sector is recognized as one of the most water-intensive and chemically hazardous industries (Ministry of Environment, Forest and Climate Change [MoEFCC], India).

The discharge of dye-containing wastewater is a significant environmental concern because a proportion of the dyes used during manufacturing and textile processing may ultimately enter industrial effluents. Earlier estimates have suggested that approximately 11% of globally produced dyes may be released into the environment through wastewater, with losses attributed to both dye manufacturing and subsequent colouring processes. However, these percentages are dependent on the production methods, dye types, and industrial practices considered and should therefore be interpreted in the context of their original sources. Textile effluents frequently contain intensely coloured compounds and associated processing chemicals that can adversely affect the appearance and quality of receiving water bodies. The persistence of colour can also interfere with light penetration, potentially disturbing photosynthetic activity and ecological processes in aquatic environments. Furthermore, many synthetic dyes exhibit limited biodegradability because of their complex molecular structures and chemical stability. These characteristics can reduce the effectiveness of conventional biological wastewater treatment methods and increase the difficulty of removing colour and associated contaminants. Consequently, the development of effective and environmentally sustainable treatment technologies is essential for reducing the pollution load of textile effluents and promoting the safe reuse of treated wastewater.

Textile effluents are characterized by intense dark coloration, alkaline pH, high Biological Oxygen Demand (BOD), high Chemical Oxygen Demand (COD), elevated Total Dissolved Solids (TDS), and heavy metal traces (Pb, Cd, Cr, Ni) originating from synthetic azo dyes and chemical auxiliaries (Carliell *et al*., 1998; Imtiazuddin & Tiki, 2020). When peri-urban farmers utilize untreated or partially treated industrial runoff for crop irrigation, these contaminants alter soil osmotic balance, impair beneficial soil microbial functions, and bioaccumulate across agricultural food chains (Misra & Dinesh, 1991; Khan & Malik, 2018).

While the phytotoxicity of textile wastewater on staple cereal crops (e.g., Triticum aestivum) and oilseeds (e.g., Brassica juncea) is widely documented (Rashmi *et al*., 2021; Kurmi *et al*., 2023), vegetable crops in the family Cucurbitaceae remain inadequately investigated. Cucurbits like *Luffa cylindrica* (sponge gourd) and *Lagenaria siceraria* (bottle gourd) are extensively cultivated in suburban agricultural belts surrounding industrial centers. These species possess distinct seed coat architectures, larger lipid/protein reserves, and high water demand during initial imbibition, making their sensitivity to osmotic and chemical toxicity unique and critical to evaluate.

Therefore, this study investigates the concentration-dependent phytotoxic effects of textile wastewater from Sanganer, Jaipur, on seed germination dynamics, radicle emergence, and plumule elongation of *Luffa cylindrica* and *Lagenaria siceraria*. The primary goal is to establish critical toxicity thresholds and assess whether controlled dilution can mitigate inhibition for potential agricultural reuse.

Materials and Methods

Collection and Physicochemical Analysis of Effluent

Untreated textile dyeing effluent was collected in pre-sterilized 20-liter high-density polyethylene (HDPE) containers from key industrial discharge points in Sanganer, Jaipur, Rajasthan, India. Physicochemical parameters—including pH, Electrical Conductivity (EC), TDS, BOD, COD, and heavy metal concentrations—were analyzed following standard testing protocols (APHA, 2012).

Seed Selection and Surface Sterilization:

Certified, uniform seeds of *Luffa cylindrica* and *Lagenaria siceraria* were obtained from an authorized local seed supplier. To eliminate seed-borne fungal spores, seeds were surface-sterilized in 0.1% mercuric chloride ($HgCl_2$) solution for 3 minutes, followed by five successive washings with sterile distilled water.

Experimental Setup and Treatments

The bioassay was set up in a Completely Randomized Design (CRD) with three replications under controlled laboratory conditions (25 ± 2 °C, 12-hour light photoperiod). Five treatment regimens were prepared by diluting raw textile effluent with distilled water:

T0 (Control): 100% Distilled Water (0% Effluent)
T1: 25% Textile Effluent + 75% Distilled Water
T2: 50% Textile Effluent + 50% Distilled Water
T3:75% Textile Effluent + 25% Distilled Water
T4: 100% Raw Untreated Textile Effluent

Twenty-five sterilized seeds per crop species were placed in sterile glass Petri dishes (150 × 15 mm) lined with double-layered Whatman No. 1 filter paper discs. Each Petri dish received an initial 10 mL of the respective treatment solution, with equal volumes replenished every 24 hours to maintain constant moisture.

Growth Measurements and Germination Metrics:

Germination counts (defined as radicle emergence >= 2 mm) were recorded on Day 2, Day 4, and Day 8 post-inoculation. Final Germination Percentage (GP) was calculated using the standard formula by Rehman *et al*. (1998):

Formula: Germination Percentage(%) = Number of germinated seeds / Total seeds sown) × 100 On Day 8, ten representative seedlings were selected randomly from each replicate to measure plumule (shoot) length and radicle (root) length using a calibrated centimeter scale.

Results and Discussion

Physicochemical Characteristics of Effluent

The characterization of raw textile effluent demonstrated significant deviation from safety standards established by the Bureau of Indian Standards (BIS) for agricultural discharge (Table 1).

Table 1: Physicochemical characteristics of industrial textile effluent compared with BIS irrigation standards.

Parameter	Observed Value	BIS Standard Limit Impact	Impact Assessment
Color	70 Hazen	25 Hazen	Photosynthetic blocking& turbidity
Temperature	29.1 °C	50 °C	Within thermal safety limits
pH at 25°C	7.55	5.5 - 9.0	Neutral to slightly alkaline
Conductivity (EC)	2.822 mS/cm	0.300 mS/cm	Severe salinity hazard
Turbidity	288 NTU	| 10 NTU	High suspended solids
Total Dissolved Solids (TDS)	3,520 mg/L	2,100 mg/L	High osmotic pressure hazard
Chemical Oxygen Demand (COD)	380 mg/L	250 mg/L	High chemical pollutant load
Total Hardness ($CaCO_3$)	196 mg/L	500 mg/L	Within permissible bounds
Biological Oxygen Demand (BOD)	132 mg/L	100 mg/L	Elevated organic load
Sodium (Na^+)	245 mg/L	200 mg/L	Sodic stress risk
Potassium (K^+)	46.8 mg/L	12 mg/L |	Nutrient ionic imbalance
Chloride (as Cl^-)	616 mg/L	600 mg/L	Mild toxicity hazard
Chromium (Cr)	BDL (<0.5 µg/L)	100 µg/L	| Below detection limit

Copper (Cu)	0.052 mg/L	3.0 mg/L	Within safe limits

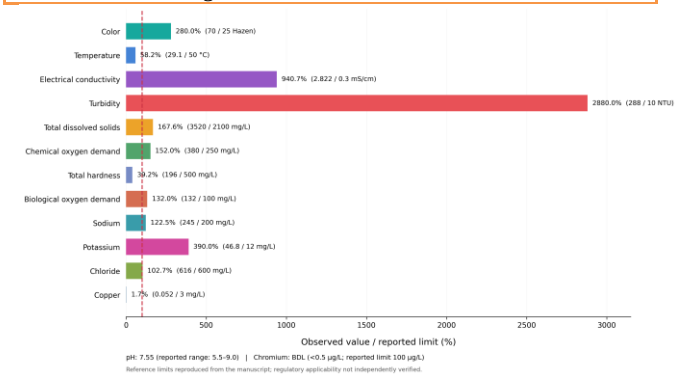

Figure 1 Comparative assessment of the physicochemical characteristics of untreated industrial textile effluent against the reported Bureau of Indian Standards (BIS) reference limits. Coloured bars represent the observed values expressed as percentages of their respective reference limits, highlighting variations in physicochemical parameters and potential environmental concerns associated with textile wastewater.

Germination Response to Effluent Concentration:

Exposure to increasing concentrations of textile wastewater resulted in a significant, dose-dependent decline in germination percentages across both tested cucurbitaceous species (Table 2).

Table 2: Phytotoxic impacts of varying effluent concentrations on seed germination shoot length, and root length at Day 8 (Mean ± SD).

Crop Species	Treatment (Effluent %)	Germination (%)	Shoot Length (cm)	Root Length (cm)
Luffa cylindrica*	T_0 (Control - 0%)	96.00 ± 1.00	5.47 ± 0.15	4.80 ± 0.20
Luffa cylindrica	T_1 (25% Effluent)	95.67 ± 1.15	4.93 ± 0.23	4.67 ± 0.15
Luffa cylindrica	T_2 (50% Effluent)	85.33 ± 2.52	4.60 ± 0.26	4.43 ± 0.21
Luffa cylindrica	T_3 (75% Effluent)	82.00 ± 1.00	4.23 ± 0.32	4.10 ± 0.20
Luffa cylindrica	T_4 (100% Effluent	52.00 ± 2.00	3.93 ± 0.15	3.10 ± 0.10
Lagenaria siceraria	T_0 (Control - 0%)	90.00 ± 1.41	5.10 ± 0.18	4.25 ± 0.12
Lagenaria siceraria	T_1 (25% Effluent)	88.33 ± 1.52	4.75 ± 0.20	4.10 ± 0.15
Lagenaria siceraria	T_2 (50% Effluent	78.00 ± 2.00	4.12 ± 0.22	3.65 ± 0.18
Lagenaria siceraria	T3 (75% Effluent)	62.00 ± 2.50	3.50 ± 0.19	3.05 ± 0.14
Lagenaria siceraria	T_4 (100% Effluent)	45.00 ± 2.08	2.85 ± 0.16	2.10 ± 0.11

For *Luffa cylindrica*, maximum germination occurred under T0 (96.00%) and T1 (95.67%), while high effluent concentrations (T3 and T4) suppressed germination down to 82.00% and 52.00%, respectively. *Lagenaria siceraria* displayed higher sensitivity across all treatments, dropping from 90.00% (T0) to 45.00% (T4).

The germination inhibition observed under higher wastewater concentrations is primarily attributed to elevated TDS (3,520 mg/L) and Electrical Conductivity (2.822 mS/cm). High dissolved salt concentrations disturb the osmotic gradient between the aqueous medium and the seed coat, impeding necessary water imbibition required to trigger key hydrolytic enzymes during germination (Prabhakar *et al*., 2004; Kaushik *et al*., 2004).

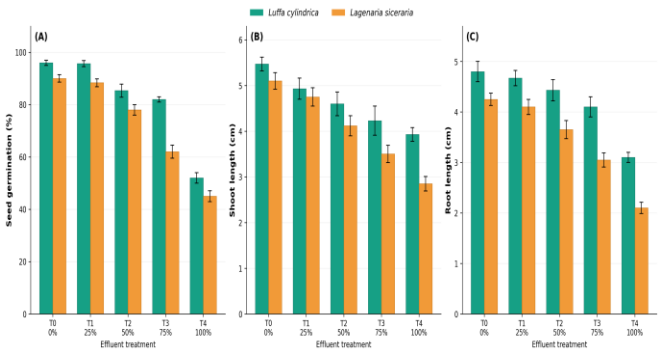

Figure 2 Concentration-dependent effects of industrial textile effluent (0%, 25%, 50%, 75%, and 100%) on (A) seed germination (%), (B) shoot length (cm), and (C) root length (cm) of *Luffa cylindrica* and *Lagenaria siceraria* on Day 8. Bars represent mean values, while error bars indicate standard deviations (mean ± SD; n = 3). Increasing effluent concentrations resulted in progressive inhibition of seed germination and seedling growth in both species, with Lagenaria siceraria exhibiting greater sensitivity.

Seedling Vigor and Elongation Performance

Root and shoot extension demonstrated sensitive responses to effluent toxicity. For *Luffa cylindrica*, radicle length decreased from 4.80 cm (T0) to 3.10 cm (T4), while plumule length declined from 5.47 cm (T0) to 3.93 cm (T4). Similarly, *Lagenaria siceraria* root length was severely restricted, exhibiting a 50.5% reduction under raw effluent (T4) compared to control.

Roots exhibited greater growth inhibition than shoots across all effluent stress treatments. Direct physical contact between emerging root apical meristems and toxic chemical additives, azo dye residues, and heavy metal species inhibits active cell division and cell elongation (Dutta & Boissya, 1996; Malaviya & Sharma, 2011). However, 25% effluent dilution (T1) maintained seedling growth without substantial physiological impairment, indicating that controlled low-concentration applications provide essential mineral ions (K+, Na+) without exceeding osmotic tolerance thresholds (Niroula, 2003; Ali *et al*., 2020).

Conclusion

This study confirms that raw textile industry wastewater from Sanganer, Jaipur, exerts significant phytotoxic stress on seed germination and seedling vigor of *Luffa cylindrica* and *Lagenaria siceraria*. Unrefined effluent (100% raw wastewater) drastically reduces germination success and seedling root-shoot development due to high salinity/EC, high TDS, and elevated oxygen demand (COD/BOD). However, diluting textile wastewater to 25% mitigates toxic effects, supporting seedling development comparable to fresh water controls. Consequently, raw textile wastewater should never be directly used for irrigating vegetable crops, but properly treated and diluted wastewater offers a viable supplementary resource in water-scarce agricultural regions.

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Competing Interests: The authors declare that there are no financial or personal conflicts of interest related to this work.

References

Ali, S. A., Parveen, N., & Raju, M. H. (2020). On the analysis of certain biochemical parameters of carps cultured in domestic sewage oxidation ponds. Bioscience Biotechnology Research Communications, 13(4), 2311–2318. https://doi.org/10.21786/bbrc/13.4/102

APHA. (2012). Standard Methods for the Examination of Water and Wastewater (22nd ed.). American Public Health Association, Washington, DC, USA.

Bafana, A., Devi, S. S., & Chakrabarti, T. (2011). Azo dyes: past, present and the future. Environmental Reviews, 19, 350–370. https://doi.org/10.1139/a11-018

Bharagava, R. N., Saxena, G., & Mulla, S. I. (2020). Introduction to industrial wastes containing organic and inorganic pollutants and bioremediation approaches for environmental management. In Bioremediation of Industrial Waste for Environmental Safety (pp. 1–18). Springer, New York, NY. https://doi.org/10.1007/978-981-13-1891-7_1

Carliell, C. M., Barclay, S. J., Shaw, C., Kucka, A. D., Buckley, C. A., & Senior, E. (1998). The effect of salts used in textile dyeing on microbial decolourisation of a reactive azo dye. Environmental Technology, 19(11), 1133–1137. https://doi.org/10.1080/09593331908616772

Dutta, S. K., & Boissya, C. L. (1996). Effect of paper effluent on germination of rice seed (Oryza sativa L. var. Masuri) and growth behaviour of its seedlings. Journal of Industrial Pollution Control, 12(2), 123–128.

Imtiazuddin, S. M., & Tiki, A. (2020). Textile azo dyes: Significance, ecological, health, and safety issues. Pakistan Journal of Chemistry, 10(1–4), 35–38. https://doi.org/10.15228/2020.v10.i01-4.p05

Kaushik, A., Kadyan, B. R., & Kaushik, C. P. (2004). Sugar mill effluent effects on growth, photosynthetic pigments and nutrient uptake in wheat seedlings in aqueous vs. soil medium. Water, Air, and Soil Pollution, 154(1), 3 https://doi.org/10.1023/B:WATE.0000022927.84227.05

Khan, S., & Malik, A. (2018). Toxicity evaluation of textile effluents and role of native soil bacterium in biodegradation of a textile dye. Environmental Science and Pollution Research, 25(5), 4446–4458. https://doi.org/10.1007/s11356-017-0783-7

Kurmi, K. P., Singh, S., Tailor, S. P., & Chaudhary, A. K. (2023). Effect of textile effluent on seed germination and early growth of wheat (Triticum aestivum L.) and mustard (Brassica juncea L.). Current Journal of Applied Science and Technology, 42(9), 1–5. https://doi.org/10.9734/cjast/2023/v42i94089

Malaviya, P., & Sharma, A. (2011). Impact of distillery effluent on germination behavior of Brassica napus L. Journal of Environmental Biology, 32(1), 91–94.

Mehta, A., & Bhardwaj, N. (2012). Phytotoxic effect of industrial effluents on seed germination and seedling growth of Vigna radiata and Cicer arietinum Global Journal of Bio-Science and Biotechnology, 1(1), 11–15.

Misra, S. G., & Dinesh, D. (1991). Soil Pollution. Ashing Publishing House, New Delhi.

Naveenraj,V., Prabakaran, K., & Kulanthaivel, P. (2021). Treatment of contaminated wastewater from textile industry: A review. IOP Conference Series: Materials Science and Engineering, 1055, 012031. https://doi.org/10.1088/1757-899X/1055/1/012031

Niroula, B. (2003). Comparative effects of industrial effluents and sub-metropolitan sewage of Biratnagar on germination and seedling growth of rice and black gram. Our Nature, 1(1), 10–14. https://doi.org/10.3126/on.v1i1.296

Prabhakar, P. S., *et al*. (2004). Impact of fertilizer factory effluent on seed germination, seedling growth and chlorophyll content of gram (Cicer arietinum). Journal of Environmental Biology, 27(1), 153–156.

Rashmi, V., & Tiwari, A. (2021). Effect of industrial effluent on wheat crop. Agricultural Research Journal, 58(1), 45–50. https://doi.org/10.5958/2395-146X.2021.00007.X

Rehman, S., Harris, P. J. C., & Bourne, W. F. (1998). Effect of pre-sowing treatment with calcium salts on seed germination of Acacia species. Journal of Plant Nutrition, 21(2), 277–285. https://doi.org/10.1080/01904169809365403