Journal of Environmental Biology
p-ISSN: 0254-8704 • e-ISSN: 2394-0379 • CODEN: JEBIDP

JEB®

Original Research Paper
Volume 46 Issue 4 July 2025 pp. 473-482
DOI: http://doi.org/10.22438/jeb/46/4/MRN-5543

J. Environ. Biol., 2025
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Journal website : www.jeb.co.in ★ E-mail : editor@jeb.co.in

Influence of wastewater irrigation on nutrient profiles and heavy metal accumulation in warm-season turf grasses

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Received: 12 September 2024 **Revised:** 18 December 2024 **Accepted:** 01 April 2025

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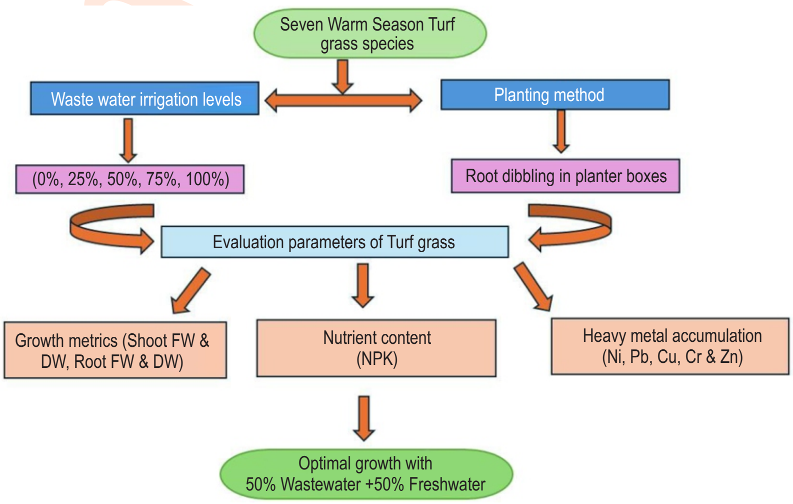
Abstract

Aim: The study aimed to evaluate the performance of warm-season turf grasses under different levels of wastewater irrigation, focusing on the growth parameters and heavy metal accumulation.

Methodology: The research was conducted at the Division of Floriculture and Landscaping, ICAR- Indian Agricultural Research Institute, New Delhi, during 2022-23. Seven turf grass species were assessed under varying wastewater irrigation levels *viz.,* T_1 (Control), T_2 (100% wastewater), T_3 (75% wastewater+25% freshwater), T_4 (50% wastewater + 50% freshwater) and T_5 (25% wastewater + 75% freshwater). Growth metrics, biomass parameters, NPK content in the grass species were estimated. Additionally, the accumulation of heavy metals (Ni, Pb, Cu, Cr and Zn) were estimated in treated and control plants.

Results: *Stenotaphrum secundatum* showed the highest fresh shoot and root weight gain under 50% wastewater irrigation, while the highest nitrogen and potassium content was recorded in *Zoysia japonica*. Heavy metal accumulation was most pronounced in 100% wastewater, particularly in *Zoysia japonica* for chromium and *Cynodon dactylon* var. Tif Dwarf – 419 for nickel, lead and copper.



Interpretation: The study concludes that a 50:50 mix of wastewater and freshwater is optimal for warm-season turf grass growth, balancing plant development with minimal environmental risks. This mixture reduces freshwater use, supports sustainable water management, and enables turf grass to aid in phytoremediation of heavy metal-contaminated soils. However, higher wastewater concentrations elevated heavy metal accumulation, posing ecological and food chain risks.

Key words: Biomass, Heavy metals, Sustainability, Turf grasses, Wastewater

Triveni Enterprises (Educational Services Set-up)

How to cite: Balaji, N., S.S. Sindhu, M.K. Singh, B. Singh, D.S. Gurjar, R. Pandey, Sarika, R. Jain and A.K. Tiwari: Influence of wastewater irrigation on nutrient profiles and heavy metal accumulation in warm-season turf grasses. *J. Environ. Biol.,* **46,** 473-482 (2025).

Introduction

Turf grasses, members of family *Poaceae,* serve both aesthetic and recreational purposes, primarily achieved through regular mowing (Janakiram *et al.,* 2015). The turf grasses are used worldwide in airports, cemeteries, churches, commercial buildings, residential lawns, parks, school grounds, universities, athletic fields, football grounds and golf courses, *etc.* Beyond visual and recreational appeal, turf grasses provide environmental benefits, including soil erosion prevention, enhanced water infiltration and pollutant reduction. Turf coverage plays a pivotal role in various ecosystem services as they grow; they capture carbon dioxide through photosynthesis, converting it into organic matter that is stored in their tissues and roots for many years and improve soil texture. Turf grasses contribute to a healthier urban environment by minimizing dust and mud in residential, commercial and industrial areas. In India, warm season grasses are widely used where dense turf is desired, moreover these are adapted to tropical and warm climate and have good density, texture, wear tolerance drought and heat tolerance with minimal cost and low water inputs (Monteiro, 2017).

They establish quickly and spread rapidly due to lateral branches and stolons, covering larger areas in lesser time. The water requirement of turf grasses is high (15-30 lit m^2 $week^{-1}$) due to shallow root system, high evaporation rate, intensive growth and maintenance (Turgeon and Kaminski, 2019). Water scarcity in urban areas, particularly in developing nations like India, has intensified the strain on freshwater resources due to population growth and increased wastewater production from residential, commercial and industrial sectors (Qian and Mecham, 2005). To address this challenge, many cities have adopted the use of wastewater for irrigating green spaces like lawns and parks. This sustainable approach conserves freshwater, improves soil fertility, and supports sustainable water management (Gan *et al.,* 2006). Wastewater offers benefits such as enhanced nitrogen uptake, reduced groundwater contamination, and cost-effective irrigation due to the proximity of wastewater sources and has become an increasingly viable option in water-scarce regions (Lal *et al.,* 2015).

While it presents a sustainable approach to water reuse, wastewater irrigation can have mixed effects on both nutrient availability and heavy metal accumulation in these grasses. Wastewater is rich in essential nutrients such as nitrogen, phosphorus and potassium, which are critical for turfgrass growth and overall health. These nutrients, when applied through irrigation, can enhance soil fertility, improve turf quality, and reduce the need for synthetic fertilizers. Wastewater irrigation provides a sustainable option for water use in maintaining warm-season turf grasses by supplying essential nutrients. However, it also presents the challenge of managing heavy metal accumulation. This study aims to evaluate the performance of different warm-season turf grasses species with wastewater irrigation under Delhi NCR conditions by analyzing biomass parameters, nutrient content and heavy metal accumulation.

Materials and Methods

The present study was conducted at the Division of Floriculture and Landscaping, Indian Agricultural Research Institute, New Delhi during 2022-23. Seven warm-season turf grass species *viz.,* S_1- Zoysia grass (*Zoysia japonica*), S_2-Bermuda grass (*Cynodon dactylon* var. Tif dwarf-419), S_3-Centipede grass (*Eremochloa ophiuroides*), S_4-Bahia grass (*Paspalum notatum*), S_5-Crowfoot grass (*Dactyloctenium aegyptium*), S6-Seashore paspalum (*Paspalum vaginatum*) and S_7- St. Augustine grass (*Stenotaphrum secundatum*) were carefully selected from the experimental farm of the Division of Floriculture and Landscaping, ICAR-IARI, New Delhi. The turf was transplanted into plastic planters (74x25x25 cm^3), generously filled with a blend of soil, sand and vermicompost in harmonious proportions (2:1:1 v/v). Following the establishment of turf grass, irrigation with wastewater and fresh water were commenced at three-day interval over 90-day duration.

The municipal wastewater, after treatment was sourced from the wastewater treatment plant at ICAR-IARI, New Delhi, and compared with fresh water for different parameters. The pH and EC was measured by the procedure outlined by Jackson (1973). The recorded pH and EC values were 7.55 and 2.12 dSm^{-1} for freshwater and 7.58 and 1.82^{-1} dSm^{-1} for wastewater. The nitrogen content was estimated by Kjeldhal method (Subbaih and Asija, 1956). It was 6.24 mg l^{-1} in freshwater and 26.32 mg l^{-1} in wastewater. Freshwater has a phosphate concentration of 1.22 mg l^{-1}, while in wastewater phosphate content was 4.52 mg l^{-1} (Olsen *et al.,* 1954). Potassium levels were determined using the flame photometer method, as outlined by Jackson (1973) and 4.45 mg l^{-1} potassium content was detected in freshwater while 12.22 mg l^{-1} in wastewater. The total dissolved solids (TDS) in freshwater and wastewater were measured using a handheld multi-parameter analyzer and recorded TDS values were 367 mg l^{-1} for freshwater and 1316 mg l^{-1} for wastewater.

Both BOD and COD were determined by as methods as described in APHA (2023) *viz.,* Winkler method and potassium dichromate method respectively, and were undetectable in freshwater, while wastewater showed 188.56 mg l^{-1} BOD and 356.78 mg l^{-1} COD. The freshwater did not show any detectable BOD and COD, while wastewater had a BOD of 188.56 mg l^{-1} and COD of 356.78 mg l^{-1}. Heavy metals viz., Ni, Pb, Cu, Cr and Zn were analyzed by atomic absorption spectrophotometry (APHA, 2023). Freshwater contained Cr (22.10 µg l^{-1}), Ni (3.52 µg l^{-1}), Cu (3.51 µg l^{-1}) and Zn (8.52 µg l^{-1}), with no detectable Pb. Wastewater contained Cr (52.45 µg l^{-1}), Ni (5.58 µg l^{-1}), Cu (12.16 µg l^{-1}), Zn (85.22 µg l^{-1}), and Pb (6.87 µg l^{-1}). The irrigation was done as per the following treatments: T_1 as Fresh water , T_2 (100% wastewater), T_3 (75% wastewater + 25% freshwater), T_4 (50% wastewater + 50% freshwater) and T_5 (25% wastewater + 75% freshwater). Concomitantly, standard cultural practices, like weeding, hoeing and mowing were executed. The study employed a two-factor completely randomized design (CRD) encompassing

35 treatment combinations viz., S_1T_1- (Zoysia grass irrigated with 100 % Fresh water), S_1T_2-(Zoysia grass irrigated with 100% Waste water), S_1T_3- (Zoysia grass irrigated with 75% Waste water and 25% Fresh water), S_1T_4-(Zoysia grass irrigated with 50 % Waste water and 50 % Fresh water), S_1T_5- (Zoysia grass irrigated with 25 Waste water and 75% Fresh water), S_2T_1- (Bermuda grass irrigated with 100 % Fresh water), S_2T_2 -(Bermuda grass irrigated with 100% Waste water), S_2T_3-(Bermuda grass irrigated with 75% Waste water and 25% Fresh water), S_2T_4-(Bermuda grass irrigated with 50 % Waste water and 50 % Fresh water), S_2T_5- Bermuda grass irrigated with 25 Waste water and 75% Fresh water), S_3T_1- (Centipede grass irrigated with 100 % Fresh water), S_3T_2-(Centipede grass irrigated with 100% Waste water), S_3T_3- (Centipede grass 75% Waste water and25% Fresh water), S_3T_4- Centipede grass irrigated with 50 % Waste water and 50 % Fresh water), S_3T_5-Centipede grass irrigated with 25 Waste water and 75% Fresh water), S_4T_1-(Bahia grass irrigated with 100 % Fresh water), S_4T_2-(Bahia grass irrigated with 100% Waste water), S_4T_3- (Bahia grass 75% Waste water and25% Fresh water), S_4T_4-(Bahia grass irrigated with 50 % Waste water and 50 % Fresh water), S_4T_5-(Bahia grass irrigated with 25 Waste water and 75% Fresh water), S_5T_1-(Crow foot grass irrigated with 100 % Fresh water), S_5T_2-(Crow foot grass irrigated with irrigated with 100% Waste water), S_5T_3-(Crow foot grass irrigated with 75% Waste water and 25% Fresh water), S_5T_4-(Crow foot grass irrigated with irrigated with 50 % Waste water and 50 % Fresh water), S_5T_5-(Crow foot grass irrigated with irrigated with 25 Waste water and 75% Fresh water), S_6T_1-(Seashore Paspalum irrigated with 100 % Fresh water), S_6T_2-(Seashore Paspalum irrigated with 100% Waste water), S_6T_3-(Seashore Paspalum irrigated with 75% Waste water and 25% Fresh water), S_6T_4-(Seashore Paspalum irrigated with 50 % Waste water and 50 % Fresh water), S_6T_5-(Seashore Paspalum irrigated with 25 Waste water and 75% Fresh water), S_7T_1- (St Augustine grass irrigated with 100 % Fresh water), S_7T_2- (St Augustine grass irrigated with 100% Waste water), S_7T_3-(St Augustine grass 75% Waste water and 25% Fresh water), S_7T_4-(St Augustine grass irrigated with 50 % Waste water and 50% Fresh water), S_7T_5-(St Augustine grass irrigated with 25 Waste water and 75% Fresh water) incorporating seven grass species, five irrigation regimes replicated twice.

Shoot and root fresh weights were determined by harvesting shoots and roots in a designated 100 cm^2 area, followed by weighing. The collected shoots and roots were then dried at 60°C for 72 hr to remove all the moisture, and the dry weights were recorded until a constant weight was obtained. After obtaining the fresh weight or constant dry weight, change in the weight for different treatments was estimated over control by the following formula and was expressed in percentage:

$$\text{Percent change in weight} = \frac{\text{(Fresh or Dry Weight Treatment wise)} - \text{(Fresh or Dry weight in control) (T1)}}{\text{(Fresh or Dry Weight in control) (T1)}} \times 100$$

Estimation of N,P,K content: Nitrogen, phosphorus and potassium contents in turf grass samples were determined by Kjeldahl method Colorimetric method and flame photometry following the procedures established by Subbiah and Asija (1956), Olsen *et al.* (1954) and Jackson (1973).

Heavy metal content: Heavy metal concentrations in turf grass root and shoot were analyzed by Atomic Absorption Spectrophotometry. One gram of dried ground plant sample was mixed with a di-acid (HNO_3 and $HClO_4$) in a 15:1 ratio. After overnight pre-digestion, the samples were digested at 200°C on a hot plate until the appearance of clear vapors. The cooled sample was filtered using Whatman No. 42 filter paper, producing a purified liquid aliquot. This aliquot was then analyzed for Cr, Ni, Pb, Cu, and Zn.

Statistical analysis: Statistical analysis using analysis of variance (ANOVA) was conducted for the data pertaining to physiological and biochemical parameters, following the specified procedures .

Results and Discussion

It is evident from Fig. 1 (A) that the effect of wastewater treatment was significant with respect to change in fresh weight in different species of warm season turf grasses. Among wastewater treatments, the change in weight ranged between-37.55 to 31.03 per cent. The turf grass irrigated with 100% wastewater (T_2) showed poor growth in all the species and the lowest shoot fresh weight (-16.94 to-37.55%) and similar trend was observed in T_3 treatment, however, (T_4) treatment resulted in maximum gain in fresh weight (10.29 to 31.03%). The maximum weight gain (31.03%) was observed in *Stenotaphrum secundatum* (S_7), followed by centipede grass (S_3) and minimum (10.29%) in *Zoysia japonica* (S_1). Interaction data reveals that treatment combination S_7T_4 resulted in maximum gain in shoot fresh weight (31.03%) while maximum shoot dry weight gain (27.47%) in S_3T_4. Similar trend of shoot growth was observed in treatment T_5, but the per cent growth was less (6.81-23.87%) as compared to T_4 treatment. Comparison of different species revealed that the maximum gain in shoot fresh weight (11.88%) was recorded in *Stenotaphrum secundatum* (S_7), followed by centipede grass (S_3) and minimum (6.81%) in *Zoysia japonica* (S_1). Data shown in Fig. 1 (B) revealed that irrespective of species, maximum change in shoot dry weight (-48.14) was observed in grass species treated with T_2 followed by T_3, treatments whereas the maximum positive change in shoot dry weight (27.47%) was observed in turf grass species irrigated with fresh and wastewater in equal proportion. Among different species the, maximum weight gain (2.47%) was observed in centipede grass (S_3), while maximum weight loss (-15.74%) was observed in St. Augustine grass.

Fresh and dry weight of root was significantly affected by treatment and species (Fig. 2). The change in root fresh weight

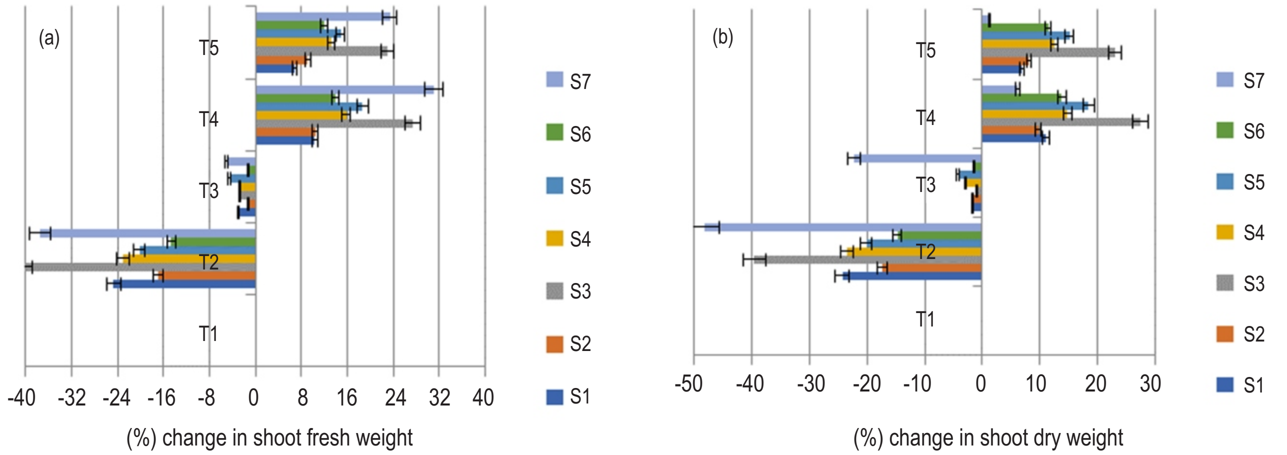


Fig.1: Effect of different levels of wastewater irrigation on per cent change in shoot (a) fresh (b) dry weight on different turf grass species.

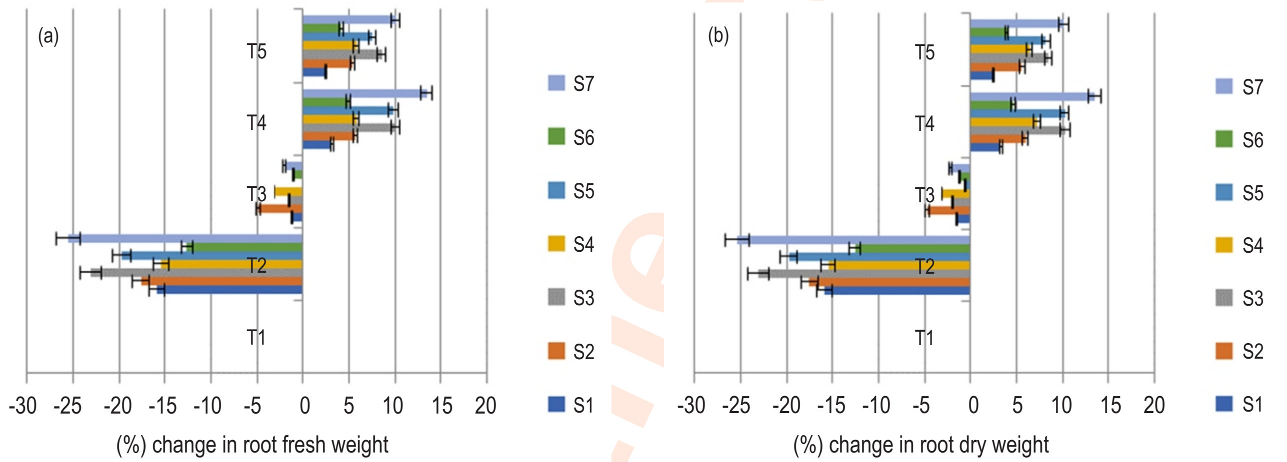


Fig. 2: Effect of different levels of wastewater irrigation on per cent change in root (a) fresh and (b) dry weight on different turf grass species.

varied from -25.34 to 13.51% (Fig. 2 A). T_2 treatment negatively affected the root growth of turf grass species and similar results were obtained with T_3 treatment. The maximum root weight change over control was observed in T_4 and T_5 treated turf grass species. Among different species, *Dactyloctenium aegyptium* (S_5) exhibited the lowest decrease in root fresh weight (-0.48%) while the highest (-2.89%) was recorded in *Zoysia japonica.* Data shown in Fig. 2 (B) revealed that irrespective of species, the maximum change in root dry weight over control (-25.50%) was observed in T_2 followed by T_3 treated grass species, whereas the maximum positive change in root dry weight (13.42%) was observed in turf grass species irrigated with fresh and wastewater in equal proportion. Interaction reveals that maximum gain in root fresh and dry weight (13.51 and 13.42%, respectively) was observed in *Stenotaphrum secundatum* irrigated with 50:50 fresh and waste water (S_7T_4).

Similar to root fresh weight, *Stenotaphrum secundatum* (S_7) exhibited the maximum change in root fresh weight while *Zoysia japonica* (S_1) recorded the lowest among different species. The contrasting root weight changes among species, such as the resilience of *Dactyloctenium aegyptium, Stenotaphrum secundatum* and the higher sensitivity of *Zoysia japonica,* demonstrate variability in tolerance to wastewater irrigation, reinforcing the importance of selecting appropriate turf grass species for specific environmental conditions. The growth of turf species was affected negatively due to the application of 100% wastewater, potentially due to nutrient imbalance suboptimal water quality or the presence of contaminants and toxicity from accumulated salts or heavy metals as evident from the physico-chemical parameters of Fresh and waste water these findings are in line with the reports of Carey and Migliaccio (2009); Mohanty *et al.* (2024) and Tong *et al.* (2022).

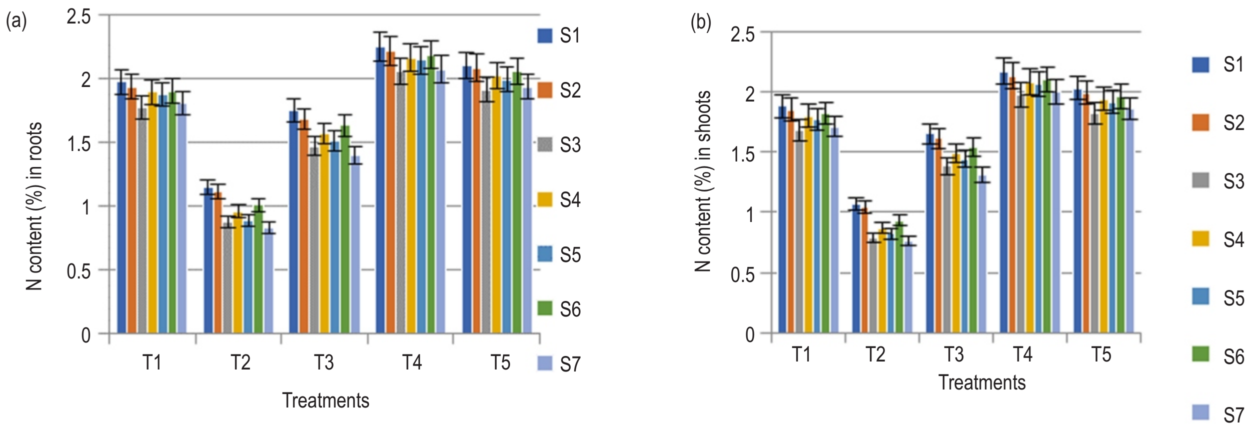


Fig. 3: Effect of different levels of wastewater irrigation on nitrogen concentration (%) in (a) roots and (b) shoots of different turf grass species.

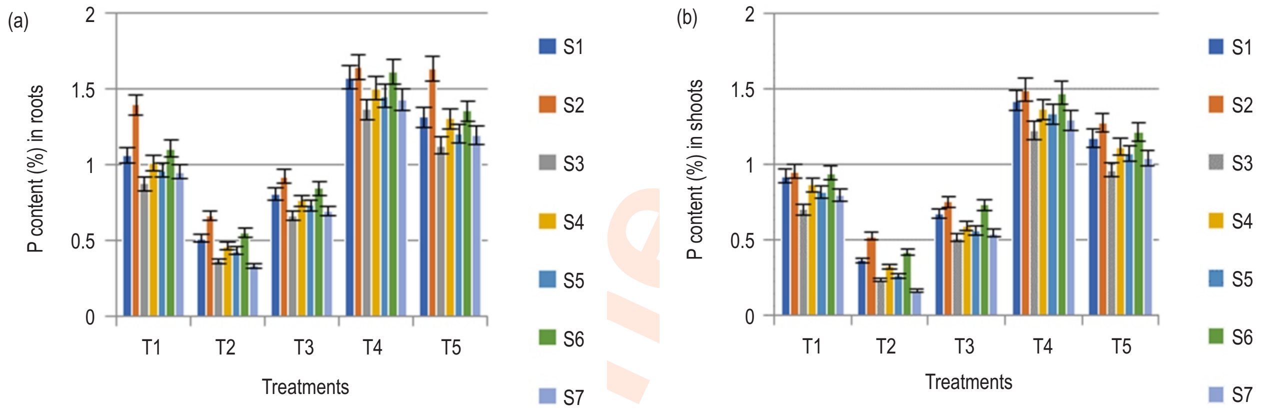


Fig. 4: Effect of different levels of wastewater irrigation on phosphorus concentration (%) in (a) root and (b) shoot of different turf grass species.

These contrasting responses can be attributed to species-specific physiological traits, including differential water uptake efficiency, nutrient utilization patterns, and varying sensitivities to particular water constituents or pollutants (Wang *et al.,* 2024). However, a balanced irrigation regime (50: 50) can promote healthy root growth, optimizing both biomass production and resource conservation and can be attributed to the presence of essential macro- and micronutrients in the wastewater, which likely facilitated increased nutrient uptake and translocation (Kama *et al.,* 2023). Furthermore, the adequate moisture availability provided by 50% wastewater treatment may have contributed to improved water relations and facilitated nutrient absorption, resulting in higher root fresh and dry weights. The findings corroborate with the previous studies conducted by Naaz and Pandey (2010) in lettuce, Iqbal *et al.* (2015) in chilli and Selahvarzi *et al.* (2022) in C_3 and C_4 grasses, which highlighted the importance of species-specific factors in determining plant responses to wastewater irrigation.

Perusal of data presented in Fig. 3 revealed that T_4 treated turf grass species produced the highest nitrogen content in root (2.15%) and shoot (2.07%), followed by turf grass species irrigated. On the other hand, the lowest nitrogen content in roots (0.98 %) and shoots (0.90 %) was recorded with 100% wastewater application. Among different species, *Zoysia japonica* showed the highest (1.84% and1.76%) nitrogen content in root and shoot respectively, followed by *Cynodon dactylon* var. Tif dwarf–419. In contrast, the lowest nitrogen content was observed in *Stenotaphrum secundatum* and *Eremochloa ophuroides.* The interaction between species and treatments revealed that *Zoysia japonica* treated with 50% wastewater (S_1T_4) produced the highest nitrogen content in roots (2.25%) and shoots (2.17%), followed by *Cynodon dactylon* var. Tif dwarf – 419 with similar water application (S_2T_4), whereas the lowest nitrogen content in both roots and shoots was observed in *Stenotaphrum secundatum* with 100% wastewater application (S_7T_2).

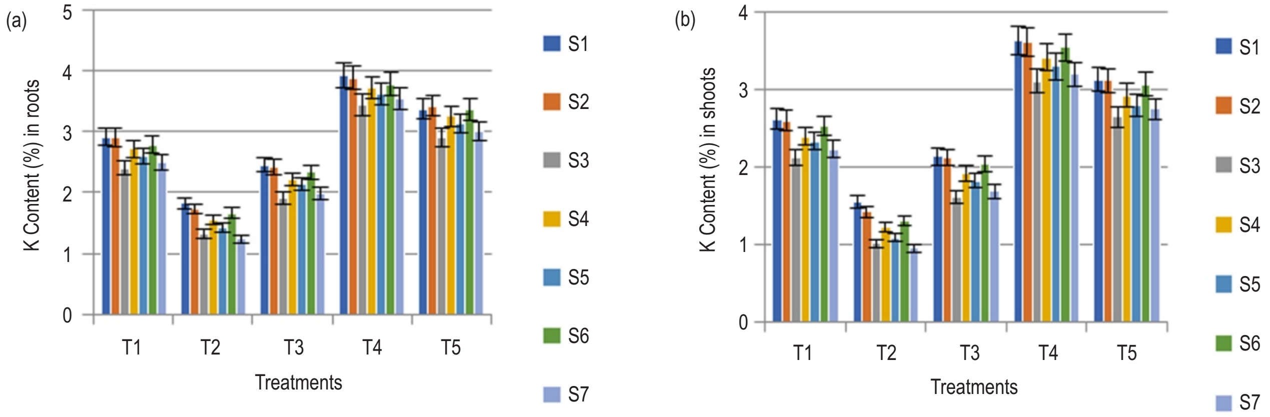


Fig. 5: Effect of different levels of wastewater irrigation on potassium concentration in (a) roots and (b) shoots of different turf grass species.

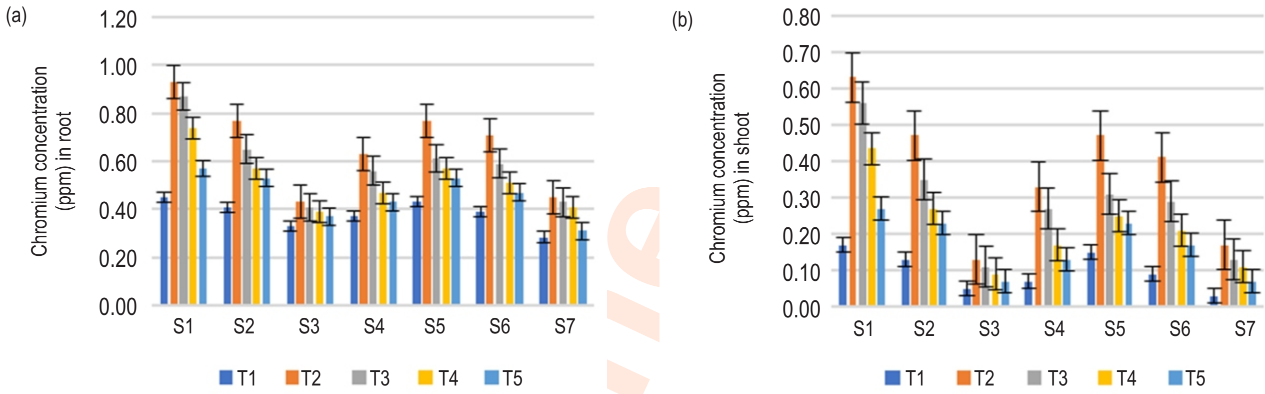


Fig. 6: Effects of different levels of wastewater irrigation on chromium concentration in (a) roots and (b) shoots of different turf grass species.

Similar to nitrogen content, T_4 treatment resulted in highest phosphorus content in roots (1.51%) and shoots (1.37%) in all the turf grass species (Fig. 4). On the other hand, the lowest phosphorous content was noted both in roots (0.47%) and shoots (0.47%). Among different species, *Cynodon dactylon* var. Tif dwarf – 419 showed the highest phosphorous content both in roots and shoots (1.25% and 1.00 %). In contrast, the lowest phosphorus content in roots (0.76%) and shoots (0.73%) was observed in *Eremochloa ophuroides.* The interaction between species and treatments revealed that when *Cynodon dactylon* var. Tif dwarf–419 was grown with 50% wastewater (S_2T_4) produced the highest phosphorus content (1.64% and 1.49%) in roots and shoots respectively, which was statistically at par with (S_2T_5 and S_6T_2). However, the lowest phosphorus content (0.33% and 0.16%) was observed in *Stenotaphrum secundatum* with 100% wastewater (S_7T_2) in both roots and shoots, respectively.

Among different irrigation treatments, T_4 treated turf grass species exhibited the highest potassium content in roots (3.69%) and shoots (3.39%), followed by T_5 treatment (Fig. 5). On the other hand, T_2 treated turf grasses recorded the lowest potassium content in roots (1.53%) and shoots (1.22%). Among different species, *Zoysia japonica* showed the highest root and shoot. (2.89% and 2.60%) potassium content, while the lowest potassium content was observed in *Eremochloa ophuroides*. The interaction between species and treatments revealed that the maximum potassium content in roots (3.92%) and shoots (3.62%) was observed in *Zoysia japonica* treated with 50% wastewater (S_1T_4), followed by *Cynodon dactylon* var. Tif dwarf – 419 with 50% wastewater (S_2T_4). The lowest content in both roots and shoots (0.95 and 1.24 %) was observed in *Stenotaphrum secundatum* with 100 % wastewater (S_7T_2). Accumulation of nitrogen, phosphorus and potassium content in both roots and shoots of warm-season turf grasses increased as the concentration of wastewater increase from 25% (T_5) to 50% (T_4). However, accumulation reduced in T_2 and T_3 treated groups compared to the control group. The variations in levels of nitrogen, phosphorus and potassium levels among diverse plant

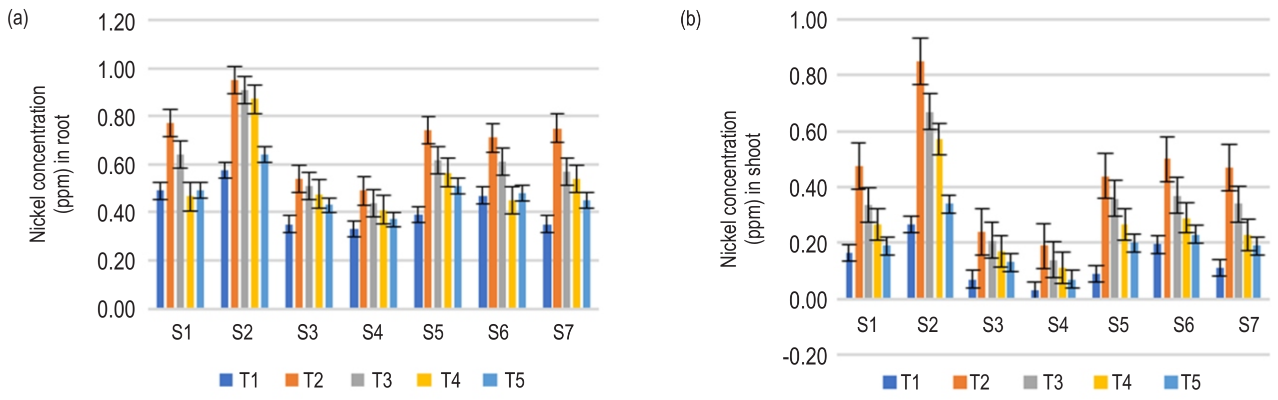


Fig. 7: Effect of different levels of wastewater irrigation on nickel concentration in (a) roots and (b) shoots of different turf grass species.

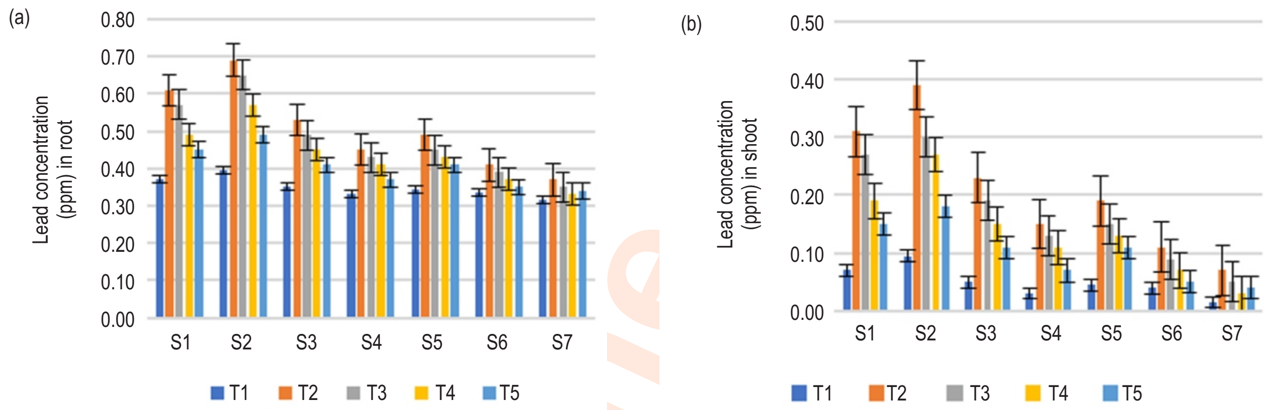


Fig. 8: Effect of different levels of wastewater irrigation on lead concentration in (a) roots and (b) shoots of different turf grass species.

species and treatments can be attributed to a combination of factors, including the inherent traits of each plant species, availability of nutrients in treated wastewater, nutrient distribution within plants, genetic diversity and interactions between the nutrients. Short term wastewater application in chrysanthemum significantly enhanced the content of primary nutrients and micronutrients in the soils (Ankit *et al.,* 2023). High concentrations of aggregated macronutrients, micronutrients, and heavy metals as a result of using wastewater can decrease plant yield, disturb photosynthesis, trouble nutrient uptake by plants, decrease enzyme activity, reduce biosynthesis of metabolites, injury cell membranes, and consequently interfere with physiological activities (Hajihashemi *et al.,* 2020, Gurjar *et al.,* 2019; Mohanty *et al.,* 2024). Similar trends were identified in prior studies conducted by Ali *et al.* (2011), Papadopoulos and Stylianou (1988), Mohammad and Mazahreh (2003), Singh and Bhati (2005) and Herpin *et al.* (2007). It is clear from Fig. 6 that out of various treatments, the turf grass species irrigated with 100% treated wastewater produced roots (0.67ppm) and shoots (0.37ppm) with the highest chromium concentration, while turf grasses species irrigated with fresh water (T_1) resulted in lowest concentration in root (0.38 ppm) and shoot (0.10 ppm). Comparison of the species revealed that *Zoysia japonica* (S_1) showed the highest chromium content both in root and shoot (0.71 and 0.41 ppm), while the lowest content was recorded in the roots (0.38 ppm) of *Stenotaphrum secundatum* (S_7) and in the shoot (0.09 ppm) of *Eremochloa ophuroides* (S_3) respectively. It is clear from the Fig.6A and 6B that maximum chromium content in root and shoot (0.93 and 0.63 ppm respectively) was recorded in S_1T_2 treatment combination.

Data presented in Fig. 7 shows that out of various irrigation treatments, the highest nickel concentration was recorded with T_2 treatment in roots and shoots (0.71 and 0.45 ppm). On the other hand, the lowest amount of nickle was recorded both in roots and shoot (0.42 and 0.13 ppm) in control plants. Among different species, the highest nickel concentration

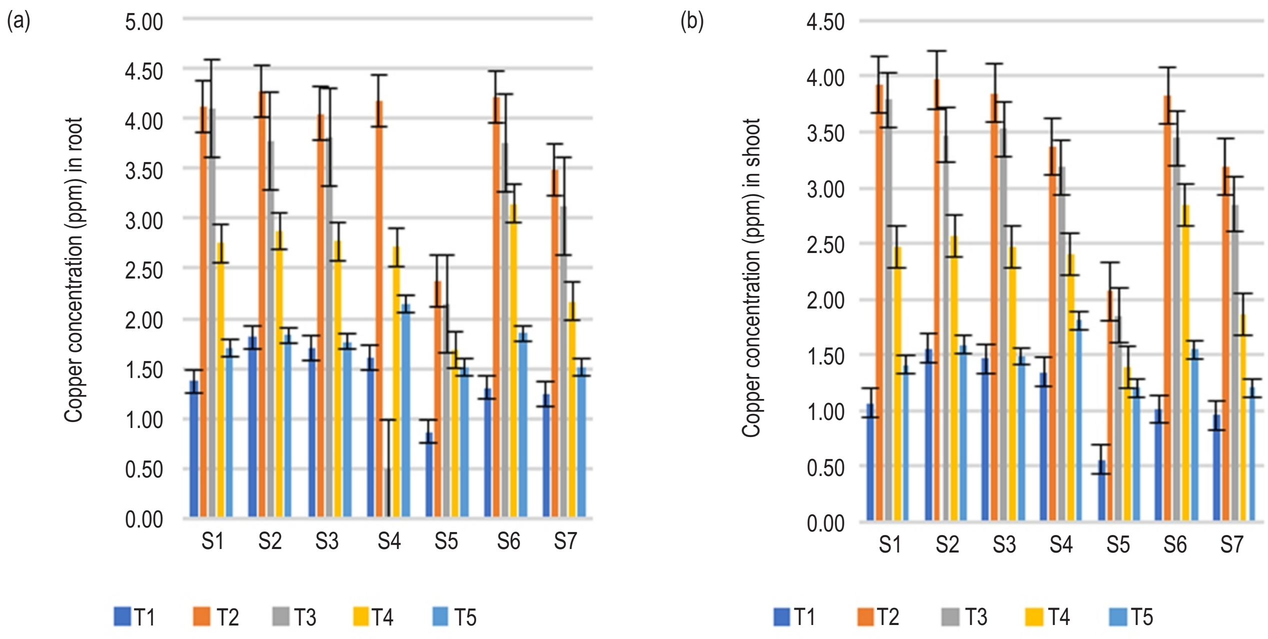


Fig. 9: Effect of different levels of wastewater irrigation on copper concentration in (a) roots and (b) shoots of different turf grass species.

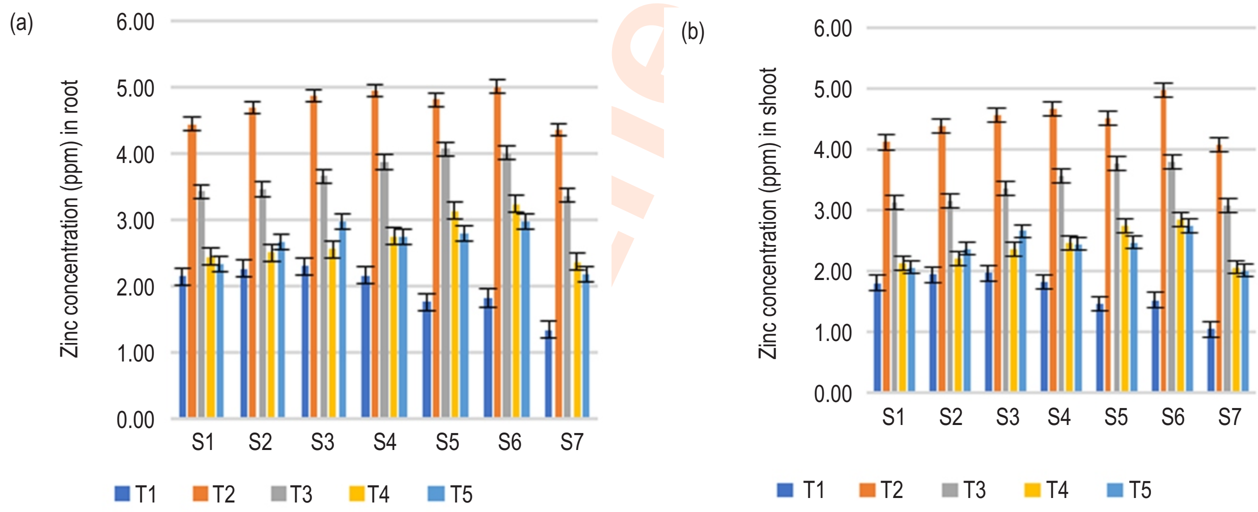


Fig. 10: Effect of different levels of wastewater irrigation on zinc concentration in (a) roots and (b) shoots of different turf grass species.

was recorded in roots (0.79 ppm) and shoots (0.54 ppm) of *Cynodon dactylon* var. Tif dwarf – 419 (S_2), while the minimum was noted in both root and shoot (0.41 ppm and 0.11 ppm) of *Paspalum notatum* (S_4). Interaction reveals that maximum nickel content in root andshoot (0.95 and 0.85ppm, respectively) was observed in Bermuda grass irrigated with 100% waste water(S_2T_2). Data presented in Fig. 8 A, B shows that the highest concentration of lead in root (0.51 ppm) and shoot (0.21 ppm) was found with T_2 treatment among different turf grass treatments. On the other hand, the lowest concentration in root (0.35 ppm) as well shoot (0.05 ppm) was recorded in control (T_1). Among different species, the highest Pb content (0.56 and 0.25 ppm) was reported in the roots and shoots of *Cynodon dactylonvar*. Tif dwarf – 419 (S_2). In contrast, the lowest (0.34 ppm and 0.04 ppm) lead concentration was observed in the roots and shoots of *Stenotaphrum secundatum* (S_7), respectively. It is clear from the Fig.8 A and 8 B that maximum lead content both in root and shoot (0.69 and 0.39 ppm respectively) was recorded in S_2T_2 treatment combination.

It is evident from data presented in Fig. 9 that different turf grass species irrigated with100% treated wastewater (T_2) recorded the highest copper concentration in roots and shoot (3.81 and 3.46 ppm). On the other hand, the lowest copper concentration in root (1.42 ppm) and shoot (1.14 ppm) was found in T_1 treatment. Treatment combination S_2T_2 recorded maximum copper content in both root and shoot (4.27 and 3.97ppm) respectively. Among different species, *Cynodon dactylon* var. Tif dwarf–419 (S_2) showed the highest concentration of copper both in root and shoot (2.91, and 2.63 ppm). In contrast, the lowest copper content was reported in roots (1.72 ppm) and shoots (1.42 ppm) of *Dactyloctenium aegyptium* (S_5). Turf grasses irrigated with 100% treated wastewater (T_2) produced both roots (4.74 ppm) and shoots with the highest zinc content, while the lowest zinc content (4.47 ppm) in root and shoot (1.98 ppm) was recorded with control treatment. Among different species, *Paspalum vaginatum* (S_6) showed the maximum zinc concentration in roots (3.41 ppm) as well as shoots (3.18 ppm), whereas the lowest zinc concentration (2.73 and 2.46 ppm) was observed in the roots and shoots of *Stenotaphrum secundatum* (S_7). The maximum zinc content was recorded in S_6T_2 treatment combination, both in root and shoots (5.01 and 4.97 ppm respectively). The study demonstrated that irrigating turf grass with wastewater significantly increased the accumulation of heavy metals in different grass species. The maximum concentration of heavy metals was reported in roots and shoots treated with 100% wastewater. Comparison of different species revealed that the highest Cr content was recorded in the roots and shoots of *Zoysia japonica,* whereas the lowest in *Stenotephrum secundatum.* For other metals, including nickel, lead and copper, *Cynodon dactylon* var. Tif Dwarf – 419 exhibited the highest levels in both roots and shoots. These findings indicated that species like *Zoysia japonica* and *Cynodon dactylon* var. Tif Dwarf – 419 have a greater capacity for heavy metal uptake and accumulation, particularly under exposure to high concentrations of wastewater (Tanji *et al.,* 2008; Bedbabis *et al.,* 2014). These grass species have dense and fibrous root systems that increase the surface area for metal absorption. Both species are fast-growing with substantial aboveground and belowground biomass, which facilitates greater accumulation of metalsin plant tissues without immediate phytotoxic effects (Shukla *et al.*, 2011).

The metallic levels observed in grasses could be because of the heavy metals absorbed from the soil and the dose received from plant-adhered dust with the more extensive areas of acid condition influencing the bioavailability of metals (Khan *et al.,* 2007). This trend can be attributed to the direct exposure of root system to wastewater and its potential role as a barrier, limiting the translocation of heavy metals to the aboveground parts (Anjum *et al.,* 2017; Kumari *et al.,* 2021). Interestingly, the maximum Zn content (5.01 ppm) was observed in the roots of *Paspalum vaginatum* under 100% wastewater irrigation, indicating that these species may have a higher affinity for Zn uptake and accumulation compared to other species studied. The observed variations in heavy metal accumulation patterns highlighted the importance of considering plant species-specific responses, wastewater composition, and treatment levels when implementing wastewater irrigation practices.

This study highlights the relevance of using treated wastewater for sustainable urban landscaping and green space management, addressing water scarcity and environmental conservation. A 50:50 mix of wastewater and freshwater was identified as optimal for promoting turf grass growth while mitigating the risks of heavy metal accumulation. *Cynodon dactylon* var. Tif dwarf-419 and *Zoysia japonica* demonstrated exceptional potential for phytoremediation, effectively remediating soils contaminated with nickel, lead, copper and chromium. These findings underscore the dual benefits of wastewater irrigation in biomass production and soil rehabilitation, provided systematic monitoring ensures its long-term agronomic and environmental sustainability.

Acknowledgment

We acknowledge the support provided by the Head of the Division of Floriculture & Landscaping, ICAR-IARI, New Delhi for conducting this research experiment.

Authors' contribution: N. Balaji: Execution of field/laboratory experiments and data collection; **S.S. Sindhu, M.K. Singh:** Conceptualization of research, Designing of the experiments; **B. Singh:** Designing of the experiments, preparation of the manuscript; **D.S. Gurjar, R. Pandey:** Contribution of experimental materials; **Sarika:** Analysis of data and interpretation; **R. Jain:** Preparation of manuscript, data analysis; **A. Tiwari:** Analysis of data and interpretation.

Funding: Not applicable.

Research content: The research content of manuscript is original and has not been published elsewhere.

Ethical approval: The authors have followed and complied with the National/ International Guidelines of relevant and appropriate authority for the use of plants in the experimental study

Conflict of interest: The authors declare that is there is no conflict of interest

Data availability: The data is available with the authors.

Consent to publish: All authors agree to publish the paper in *Journal of Environmental Biology.*

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