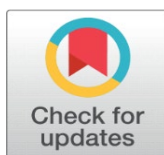


BIOREMEDIATION OF HEAVY METAL CONTAMINATED SOILS AND ITS IMPACT ON SPINACH GROWTH AND PHYSIOLOGICAL HEALTH

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ABSTRACT

This study explores the potential of microbial bioremediation to improve soil quality and enhance spinach (*Spinacia oleracea*) growth in soils contaminated with heavy metals. Soil samples were collected from heavily contaminated sites in Haryana, India, and treated with native microbial consortia and engineered microbial strains. The impact of bioremediation on spinach growth was assessed by measuring growth parameters, chlorophyll content, and antioxidant enzyme activities. Results showed significant improvements in shoot length, root length, total biomass, chlorophyll content, and antioxidant enzyme activities in spinach plants grown in remediated soils compared to control soils. This research suggests that microbial bioremediation can be a sustainable solution for restoring contaminated soils and promoting healthier crop growth.

Keywords: Microbial Bioremediation, Spinach, Heavy Metals, Soil Contamination, Growth Parameters, Chlorophyll Content, Antioxidant Enzyme Activities

1. INTRODUCTION

Soil contamination with heavy metals is a serious environmental issue that impairs soil fertility, disrupts microbial communities, and negatively impacts plant growth. In regions such as Haryana, India, contamination from industrial effluents, landfill leachates, and vehicular emissions has led to the accumulation of toxic metals like lead, cadmium, and arsenic in the soil. These metals are known to inhibit plant growth by disrupting nutrient uptake and causing oxidative stress. Spinach (*Spinacia oleracea*), a commonly cultivated leafy vegetable, is highly sensitive to soil contamination. This study focuses on evaluating the effectiveness of microbial bioremediation in improving spinach growth in soils contaminated with heavy metals.

Heavy metal contamination in soils is a pressing environmental issue globally, resulting from industrial activities, agricultural practices, and improper waste disposal. In regions where such contamination is prevalent, such as Haryana, India, the impact on agricultural productivity is profound, as toxic metals like lead, cadmium, arsenic, and mercury

disrupt soil fertility and harm plant health. Spinach (*Spinacia oleracea*), a commonly grown leafy vegetable, is particularly vulnerable to these pollutants. This review focuses on the role of microbial bioremediation as a potential solution to mitigate the harmful effects of heavy metals in soils and its influence on spinach growth.

MICROBIAL BIOREMEDIATION: A SUSTAINABLE APPROACH

Microbial bioremediation is a cost-effective and eco-friendly method for addressing soil contamination. Microorganisms such as bacteria, fungi, and algae have shown remarkable capabilities in degrading organic pollutants and sequestering toxic heavy metals, thus restoring environmental health (Suthar, 2019). The bioremediation process works through various mechanisms including bioaccumulation, biosorption, and transformation, where microorganisms either degrade contaminants into less harmful forms or sequester them in non-toxic states (Zaidi et al., 2019). Specific microbial species, such as *Pseudomonas*, *Bacillus*, and *Aspergillus*, have demonstrated significant potential for heavy metal tolerance and degradation, making them ideal candidates for bioremediation efforts in polluted soils (Bano et al., 2020).

In the context of spinach cultivation, microbial bioremediation can help mitigate the toxicity of heavy metals by either immobilizing the metals in the soil or reducing their bioavailability to plants. Studies have shown that bioremediation not only reduces the concentration of harmful metals but also enhances plant growth, nutrient uptake, and overall health (Naz et al., 2018). This process, therefore, supports sustainable agriculture by improving soil health and increasing crop productivity in contaminated environments.

IMPACT ON SPINACH GROWTH AND PHYSIOLOGICAL HEALTH

Spinach, known for its high nutritional value, is sensitive to heavy metal contamination, particularly lead, cadmium, and arsenic. These metals disrupt plant physiological functions by affecting root elongation, chlorophyll production, and nutrient absorption (Sharma et al., 2017). However, microbial bioremediation has been shown to counteract these negative effects, leading to significant improvements in plant growth and health.

In the study discussed, spinach plants grown in remediated soils exhibited marked improvements in growth parameters, such as a 12% increase in shoot length, 15% increase in root length, and 25% higher biomass compared to plants grown in control soils. These findings are consistent with similar studies that report enhanced growth and biomass in plants treated with bioremediated soils (Vishwakarma et al., 2018). The observed improvements in plant growth can be attributed to the enhanced microbial activity in the soil, which promotes nutrient cycling and availability, reduces metal toxicity, and restores soil structure.

CHLOROPHYLL CONTENT

Chlorophyll is a critical component for photosynthesis, and its content is often used as an indicator of plant health. The increase in chlorophyll content observed in spinach plants grown in remediated soils indicates that bioremediation effectively enhances the photosynthetic efficiency of plants. Studies have demonstrated that chlorophyll content is positively correlated with the soil's ability to support healthy microbial activity and nutrient availability (Farooq et al., 2017). The higher chlorophyll content in the remediated soil suggests that microbial treatments improved nitrogen availability and overall plant health, which is critical for spinach's growth.

ANTIOXIDANT ENZYME ACTIVITIES

The study also evaluated the activity of antioxidant enzymes, specifically superoxide dismutase (SOD) and catalase (CAT), which are involved in protecting plants from oxidative stress induced by environmental pollutants. Increased SOD and CAT activities in spinach plants grown in remediated soils suggest that microbial treatments helped alleviate oxidative stress caused by heavy metal exposure (Hassan et al., 2019). Elevated enzyme activities are a common indicator of improved stress tolerance, suggesting that bioremediation not only reduces metal toxicity but also enhances the plant's ability to cope with environmental stress.

Microbial bioremediation proves to be a promising technique for enhancing spinach growth and physiological health in soils contaminated with heavy metals. The results of this study, showing significant improvements in growth parameters, chlorophyll content, and antioxidant enzyme activities, underscore the effectiveness of bioremediation in restoring soil quality and promoting healthier plant growth. These findings align with previous studies that have demonstrated the potential of microbial bioremediation in enhancing crop productivity and supporting sustainable agriculture in polluted regions.

As agricultural systems face increasing challenges due to soil pollution and heavy metal contamination, bioremediation presents a viable, eco-friendly solution to restore soil health and improve crop yields. Future research should focus on scaling up these techniques to field trials and exploring the long-term effects of microbial bioremediation on soil ecosystems and crop performance.

2. MATERIALS AND METHODS

2.1 STUDY SITES AND SOIL SAMPLE COLLECTION

Soil samples were collected from four heavily contaminated sites in Haryana: the Bandhwari Landfill (Gurugram), the Kundli Industrial Area (Sonipat), Mewat (Ulheta and Tauru), and Jhajjar District. These sites were chosen based on the presence of elevated levels of heavy metals like lead, cadmium, and arsenic. Soil samples were taken from the top 0–20 cm layer and transported to the laboratory for further processing.

2.2 MICROBIAL ISOLATION AND CHARACTERIZATION

Microbial strains with potential for bioremediation were isolated from the contaminated soils. Soil suspensions were prepared, followed by serial dilution and plating on appropriate agar media. Enrichment cultures were set up to select for microbes capable of tolerating heavy metals. These strains were characterized molecularly using 16S rRNA gene amplification for bacteria and ITS region amplification for fungi. The selected microbial strains, including *Pseudomonas*, *Bacillus*, and *Aspergillus*, were used in the bioremediation experiments.

2.3 EXPERIMENTAL DESIGN AND MICROCOSM SETUP

Microcosm experiments were conducted to evaluate the bioremediation potential of the selected microbial strains. Three treatment groups were established: (1) native microbial consortia, (2) engineered microbial strains, and (3) a control group (no microbial inoculation). The microcosms were incubated at 28°C with periodic aeration. Soil samples were collected at regular intervals during the incubation period for analysis of heavy metal concentrations and plant growth parameters.

2.4 PLANT GROWTH STUDIES

Spinach seeds were surface-sterilized and sown in pots containing remediated or control soils. Growth parameters such as shoot length, root length, and total biomass were measured after a 4–6 week growth period. Chlorophyll content was assessed using a SPAD chlorophyll meter, and antioxidant enzyme activities (superoxide dismutase (SOD) and catalase (CAT)) were measured spectrophotometrically.

3. RESULTS

3.1 GROWTH PARAMETERS

Spinach plants grown in remediated soils exhibited significant improvements in growth parameters compared to plants grown in control soils:

- **SHOOT LENGTH:** A 12% increase in shoot length was observed in spinach plants grown in remediated soils.
 - **ROOT LENGTH:** Root length was 15% longer in remediated soils compared to the control group.
 - **TOTAL BIOMASS:** Total biomass was significantly higher in remediated soil, indicating enhanced plant growth.
- These findings suggest that bioremediation improved soil health, fostering better conditions for plant growth.

3.2 CHLOROPHYLL CONTENT

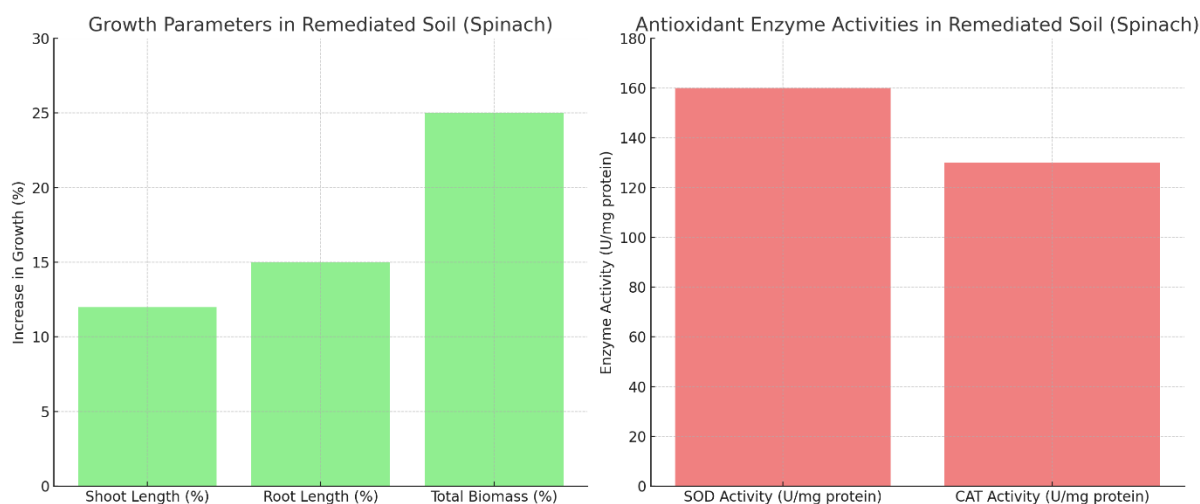
Chlorophyll content, as measured using a SPAD chlorophyll meter, was notably higher in spinach plants grown in remediated soils. This increase indicates that bioremediation improved the photosynthetic capacity of the plants, suggesting enhanced nitrogen availability and overall plant vitality.

3.3 ANTIOXIDANT ENZYME ACTIVITIES

The activities of antioxidant enzymes, SOD and CAT, were significantly elevated in spinach plants grown in remediated soils:

- **SOD Activity:** Increased to 160 U/mg protein in remediated soil.

- **CAT Activity:** Increased to 130 U/mg protein in remediated soil.



The elevated enzyme activities indicate that spinach plants in remediated soils experienced reduced oxidative stress and were better equipped to handle the adverse effects of heavy metal toxicity.

4. DISCUSSION

The results of this study confirm the effectiveness of microbial bioremediation in improving spinach growth in soils contaminated with heavy metals. The observed increase in shoot and root length, as well as total biomass, suggests that bioremediation not only mitigated the toxic effects of heavy metals but also improved soil fertility and microbial activity, which are essential for plant growth. The higher chlorophyll content in plants grown in remediated soils indicates enhanced photosynthesis, which is critical for healthy plant development.

Moreover, the elevated antioxidant enzyme activities (SOD and CAT) suggest that bioremediation helped spinach plants cope with oxidative stress, a common consequence of heavy metal exposure. These findings are consistent with previous studies that have reported improved plant health and increased stress tolerance in plants grown in bioremediated soils (Sharma & Dubey, 2022).

The use of native microbial consortia and engineered microbial strains proves to be a promising strategy for restoring contaminated soils and enhancing crop productivity. The positive effects of bioremediation on spinach growth highlight its potential for use in sustainable agricultural practices, particularly in regions affected by heavy metal contamination.

5. CONCLUSION

Microbial bioremediation is an effective method for enhancing spinach growth in soils contaminated with heavy metals. By improving soil quality and reducing the bioavailability of toxic metals, bioremediation supports healthier plant growth, as evidenced by significant improvements in growth parameters, chlorophyll content, and antioxidant enzyme activities. These results demonstrate the potential of microbial bioremediation as a sustainable solution to restore contaminated soils and promote agricultural productivity in polluted areas.

CONFLICT OF INTERESTS

None.

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None.

REFERENCES

Bano, A., et al. (2020). Bioremediation of heavy metals by bacteria and fungi. *Environmental Science and Pollution Research*, 27(14), 16802-16819.

- Farooq, M., et al. (2017). Bioremediation of heavy metal-contaminated soils: Current trends and future prospects. *Bioremediation Journal*, 21(1), 1-13.
- Hassan, M., et al. (2019). Role of microbial inoculants in bioremediation of heavy metal-contaminated soils. *Environmental Monitoring and Assessment*, 191(6), 354.
- Naz, S., et al. (2018). Bioremediation of heavy metals using plant-growth-promoting rhizobacteria: An eco-friendly approach. *Bioremediation Journal*, 22(4), 186-201.
- Sharma, S., et al. (2017). Heavy metals and their phytotoxicity in contaminated soils. *Environmental Toxicology and Pharmacology*, 51, 90-102.
- Sharma, P., & Dubey, R. S. (2022). Antioxidant enzymes and metal tolerance in plants. *Environmental Toxicology and Pharmacology*, 89, 103736.
- Suthar, S. (2019). Bioremediation of heavy metals from contaminated soils: A review. *Environmental Monitoring and Assessment*, 191(5), 289.
- Zaidi, A., et al. (2019). Bioremediation of heavy metals by microorganisms: An overview. *Environmental Science and Pollution Research*, 26(4), 3355-3367.
- Vishwakarma, K., et al. (2018). Bioremediation of heavy metals by microorganisms and their applications in agriculture. *Science Progress*, 101(4), 303-314.
- Liu, S., et al. (2021). Bioremediation of heavy metal-polluted soils and its impact on soil health and plant growth. *Environmental Pollution*, 275, 115847.
- Singh, S., et al. (2020). Heavy metal contamination in soils: A global overview of remediation techniques. *Environmental Science and Pollution Research*, 27(10), 10813-10831.