Open Access, Peer Reviewed, Referred Research Journal

Print & Online available on https://jbsd.in
ISSN: 2229-3469 (Print); ISSN: 2231-024X (Online)

Research Article

"Chlorella vulgaris and Novel Plant Science Trends: Towards a Green Future in Environmental Biotechnology"

Aasawari M. Shenwai[1] and Viraj D. Chabke[2]

[*1]Department of Botany, Satish Pradhan Dnyanasadhana College, Thane, Maharastra, India,
[2]Department of Botany, R. P. Gogate and R. V. Jogalekar College, Adv. N.V. Joshi Road, Near Ratnagiri District Court, Ratnagiri, Maharashtra.

*Email: aasawarishenwai22@gmail.com

Article Info

Received: 22-09-2025,
Revised: 05-12-2025,
Accepted: 15-12-2025

Keywords: Plant sciences, biofertilizers, phytoremediation, indoor plants, microalgae, biochar, environmental sustainability.

Abstract

Plant sciences are undergoing rapid transformation due to advances in biotechnology, sustainable agriculture, and ecological engineering. The present study investigated new plant-based approaches for addressing environmental challenges, including biofertilizers, phytoremediation, indoor plants for air purification, microalgal carbon sequestration, and biochar application. Experimental trials demonstrated that biofertilizers enhanced crop yield and soil microbial activity, phytoremediation significantly reduced heavy metal concentration, and indoor plants effectively removed volatile organic compounds (VOCs). Microalgae showed high biomass productivity and carbon capture efficiency, while biochar improved soil fertility and long-term carbon storage. Results confirmed that integrated plant-based strategies offer multi-dimensional benefits for climate change mitigation, sustainable agriculture, and ecological restoration. Future applications of plant sciences in circular economy models are discussed.

INTRODUCTION

The 21st century has witnessed unprecedented environmental challenges, including climate change, soil degradation, and declining air and water quality. Plant sciences have emerged as a multidisciplinary field contributing solutions through innovations in sustainable agriculture, ecosystem restoration, and bioresource utilization. Traditional approaches in agriculture and forestry are increasingly being complemented by plant-based technologies designed to mitigate anthropogenic impacts.

Recent research has demonstrated the potential of biofertilizers to reduce dependence on chemical fertilizers while improving soil fertility. Similarly, phytoremediation has gained recognition as a low-cost, eco-friendly technology for soil and water decontamination. Indoor plants are now being recognized not only for their aesthetic appeal but also for their capacity to remove air pollutants. Advances in algal biotechnology have opened new opportunities for carbon capture, wastewater treatment, and biofuel production. Additionally, biochar application in soil has shown promise in carbon sequestration and soil rehabilitation.

This study presents experimental findings and integrative analysis on these emerging trends, with emphasis on their role in addressing global sustainability challenges.

Materials and Methods

Data Sources

Experimental trials were conducted on biofertilizers, phytoremediation, indoor plants, microalgae, and biochar applications under controlled and field conditions. Secondary literature from peer-reviewed journals (2018–2024) and international reports (FAO, IPCC, UNEP) was used for validation.

Experimental Setup

Biofertilizers: Rice (*Oryza sativa*) and pigeon pea (*Cajanus cajan*) were grown under three treatments: 100% synthetic fertilizer, 50% synthetic + biofertilizer, and 100% biofertilizer (Azotobacter + mycorrhizal consortium). Grain yield, microbial biomass, and soil organic carbon were monitored.

Phytoremediation: Pot trials were performed with *Vetiveria zizanioides* and *Phragmites australis* in Pb-contaminated soil (250 ppm). Lead accumulation in roots and shoots was measured after 90 days.

Indoor Plants: *Chlorophytum comosum*, *Sansevieria trifasciata*, and *Aloe vera* were exposed to VOCs (benzene, toluene, formaldehyde) in sealed chambers. VOC concentrations were measured after 24, 48, and 72 hours using gas chromatography.

Microalgae: *Chlorella vulgaris* was cultured in photobioreactors with CO_2-enriched aeration. Biomass productivity and CO_2 uptake rates were calculated.

Biochar: Biochar was applied at 5 t/ha in degraded soils. Soil pH, cation exchange capacity, and organic carbon content were analyzed after one cropping season.

Data Analysis

Descriptive statistics and comparative analysis with published data were employed. Results were expressed as means with standard deviations.

Results and Discussion

Biofertilizers

Application of biofertilizers significantly enhanced soil organic carbon and crop yield compared to control. Increased microbial activity confirmed improved nutrient cycling. These findings align with reports by Kumar et al. (2021), demonstrating long-term sustainability benefits of integrated nutrient management.

Phytoremediation

Vetiveria zizanioides exhibited strong root-based Pb accumulation, while *Phragmites australis* showed moderate shoot uptake. The 45% reduction in soil Pb highlights the feasibility of phytostabilization in contaminated sites. Root accumulation further minimized pollutant transfer into the food chain, consistent with results from Tripathi et al. 2020.

Indoor Plants

Reduction of benzene, toluene, and formaldehyde confirmed that ornamental plants provide ecological services beyond aesthetics. *Chlorophytum comosum* was most effective in benzene removal, while *Sansevieria trifasciata* showed high formaldehyde reduction. These observations validate earlier NASA studies (Wolverton et al., 1989).

Microalgal Carbon Sequestration

Chlorella vulgaris demonstrated efficient biomass productivity and CO_2 uptake, with 35 g CO_2/L sequestered over 14 days. Light intensity was a determining factor, while excessive CO_2 supply inhibited growth. These results are in agreement with Singh & Dhar (2019), highlighting the role of microalgae in industrial carbon capture.

Biochar Application

Application of biochar improved soil fertility, nutrient availability, and organic carbon stocks. The dual role of biochar as a soil amendment and carbon sink supports its utility in climate-smart agriculture. Findings are consistent with Lehmann et al. (2011), confirming its long-term carbon sequestration potential.

Integrated Insights

The combined outcomes indicate that plant-based technologies can address soil, air, and climate challenges simultaneously. Integration of biofertilizers, phytoremediation, indoor plants, microalgae, and biochar applications represents a holistic model for sustainable development.

Conclusion and Future Perspectives

Emerging trends in plant sciences provide effective, eco-friendly alternatives for mitigating global environmental challenges. Biofertilizers reduce dependence on synthetic inputs, phytoremediation offers solutions for heavy metal pollution, indoor plants enhance indoor air quality, microalgae present scalable options for carbon capture, and biochar contributes to soil rehabilitation and carbon storage.

Table 1. Summary of Experimental Results in Emerging Plant Science Applications

Application	**Key Parameter**	**Observation/ Result**	**Impact**
Biofertilizers	Crop yield (rice & pigeon pea)	12–15% increase over control	Reduced fertilizer use, soil health ↑
Phytoremediation	Pb reduction	45% decrease in Pb-contaminated soil	Heavy metal stabilization
Indoor plants	VOC removal	50–70% VOC reduction within 72 h	Improved indoor air quality
Microalgae (*Chlorella*)	Biomass & CO_2 uptake	1.8 g/L/day biomass; 2.4 g/L/day CO_2 uptake	Efficient carbon sequestration
Biochar	Soil fertility & carbon storage	pH ↑ to 6.3, CEC ↑ by 25%, organic C ↑ by 28%	Soil rehabilitation, carbon sink

References

Kumar R, Sharma S, Verma N. 2021. Role of biofertilizers in sustainable agriculture: A review. *Journal of Plant and Soil Science*. **24**(3): 112–123.

Tripathi RD, et al. 2020. Phytoremediation of heavy metal-contaminated soils: Current status and future prospects. *Ecotoxicology and Environmental Safety*. **195**: 110459.

Wolverton BC, Johnson A, Bounds K. 1989. Interior landscape plants for indoor air pollution abatement. NASA Report, Stennis Space Center MS.

Singh J, Dhar DW. 2019. Microalgae in CO_2 sequestration and biofuel production: Opportunities and challenges. *Renewable and Sustainable Energy Reviews*. **105**: 265–279.

Lehmann J, Rillig MC, Thies J, Masiello CA, Hockaday WC, Crowley D. 2011. Biochar effects on soil biota – A review. *Soil Biology and Biochemistry*. **43**(9): 1812–1836.

Singh P, Verma R, Sharma A. 2022. Biofertilizers for sustainable agriculture: Recent advances and applications. *Applied Soil Ecology*. **174**: 104371.

UN DESA. 2022. *World Population Prospects 2022*. United Nations, New York.

Verma S, Patel A, Tiwari R. 2021. Microalgae in carbon capture and utilization: Advances and prospects. *Journal of Applied Phycology*. **33**(5): 2731–2745.