Bioprotective potential of lichen extract (*Pseudevernia furfuracea*) and its stimulating effect on the growth of radish (*Raphanus sativus* L.) and its tolerance to stress induced by cyanobacterial microcystins

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Abstract

Cyanobacterial blooms release toxic Microcystins that contaminate irrigation water and threaten crop safety. This study investigated the protective role of *Pseudevernia furfuracea* lichen extract on *Raphanus sativus* exposed to microcystins in hydroponics. Microcystins reduced growth and induced oxidative stress, while lichen extract improved physiological performance, reduced toxin accumulation, and lowered health risk. Results highlight the potential of lichen-derived biostimulants for sustainable agriculture.

Introduction

Cyanobacteria proliferation is driven by climate change and nutrient influx from agriculture and wastewater. These microorganisms produce microcystins (MCs), toxic compounds that often exceed WHO safety levels in water. In many developing countries, MC-contaminated water is used for irrigation, especially in hydroponic farming. These toxins negatively affect plant growth, induce oxidative stress, accumulate in edible tissues, and may pose risks to human health. Natural biostimulants such as lichen extracts could offer a sustainable strategy to reduce these harmful effects.

Objectifs

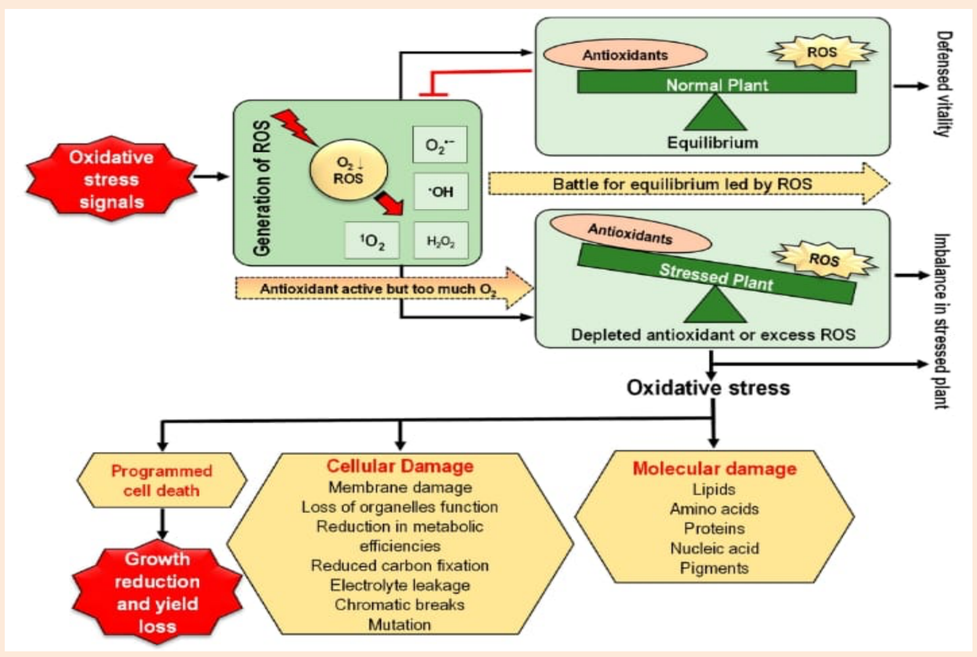
This study aimed to:

- Evaluate the effect of microcystins on radish growth and physiology.
- Assess the biostimulant effect of *Pseudevernia furfuracea* extract.
- Determine its capacity to reduce oxidative stress caused by microcystins.
- Measure microcystin bioaccumulation in roots and leaves.
- Estimate human exposure risk through contaminated radish consumption

Methodology

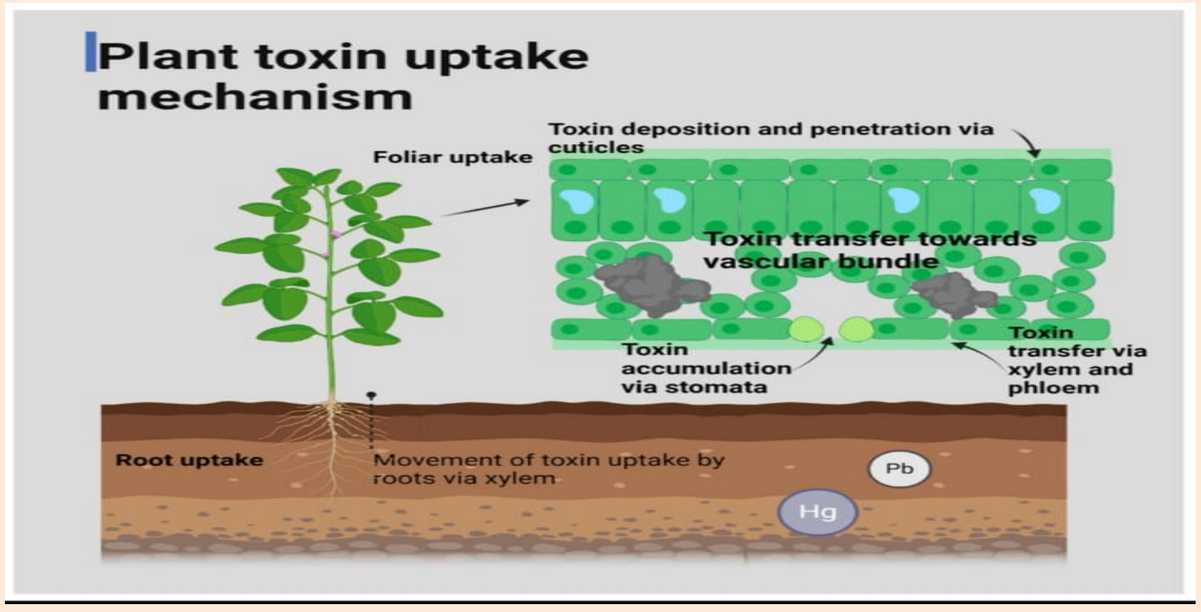
- Plant material: *Raphanus sativus* grown in perlite-filled pots.
- Experimental duration: 45 days.
- Treatments applied:10 and 40 µg/L of microcystins, 0.1 and 1 g/L of *Pseudevernia furfuracea* extract in Individual and combined treatments.
- Parameters analyzed: bioaccumulation, growth performance, chlorophyll and protein content, oxidative stress marker (MDA), sugars, polyphenols, antioxidant enzymes (SOD, CAT, POD), microcystin bioaccumulation, and estimated daily intake (EDI) assessment.

Impact of Microcystin-Induced Stress on Biometric and Biochemical Parameters in Plants

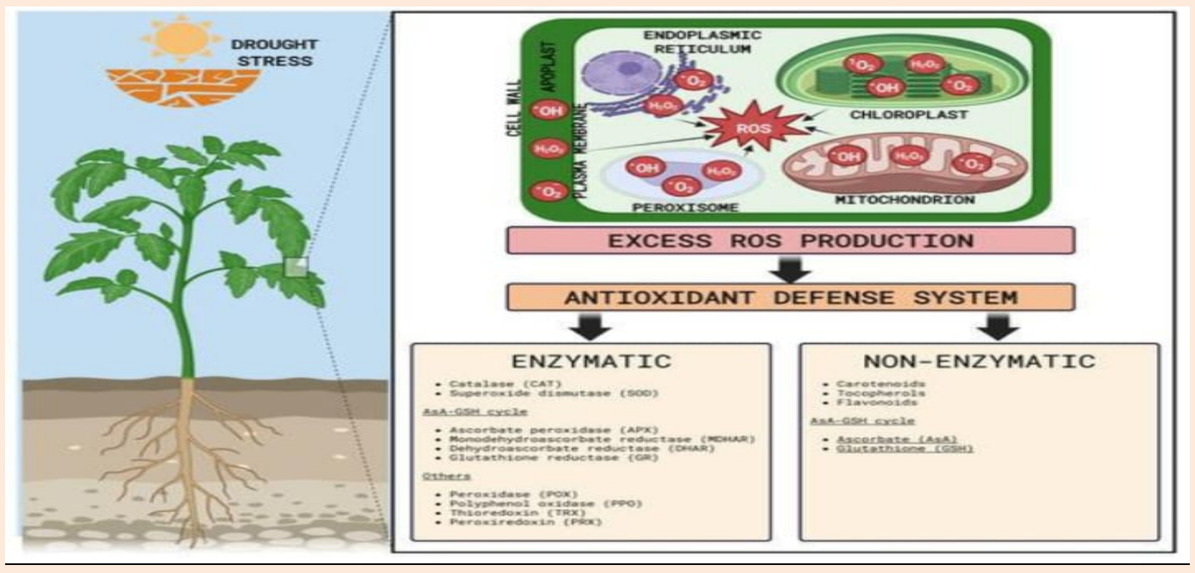


Results

Plant toxin bioaccumulation mechanism



Plant Stress Response and Defense Pathways



- Effect of Microcystins Alone↓ Plant growth↓ Chlorophyll content↓ Protein content↑ Oxidative stress (MDA)↑ Sugars and polyphenols↑ Antioxidant enzyme activity (SOD, CAT, POD), Effect of Lichen Extract + Microcystins✓ Improved plant growth✓ Restoration of biochemical parameters✓ Increased stress tolerance, Reduction of Microcystin Accumulation At 40 µg/L MC + 1 g/L extract:* Roots: 24.78 → 9.58 µg/kg FW* Leaves: 10.53 → 5.97 µg/kg FWHuman Health RiskEDI from contaminated roots:* Without extract: 0.48 µg/kg bw/day* WHO limit: 0.04 µg/kg bw/dayLichen treatment significantly reduced this risk.

Conclusion

Pseudevernia furfuracea extract acts as an effective natural biostimulant capable of improving radish tolerance to microcystin stress, reducing toxin bioaccumulation, and enhancing food safety. Lichen-derived bioactive compounds represent a promising sustainable solution for protecting crops irrigated with contaminated water.

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