FOOD SECURITY FOR COLOMBIA: Immobilized microalgae cultures for the recovery of nutrients from waters contaminated with wastewater and agricultural waste, for use as safe biofertilizers

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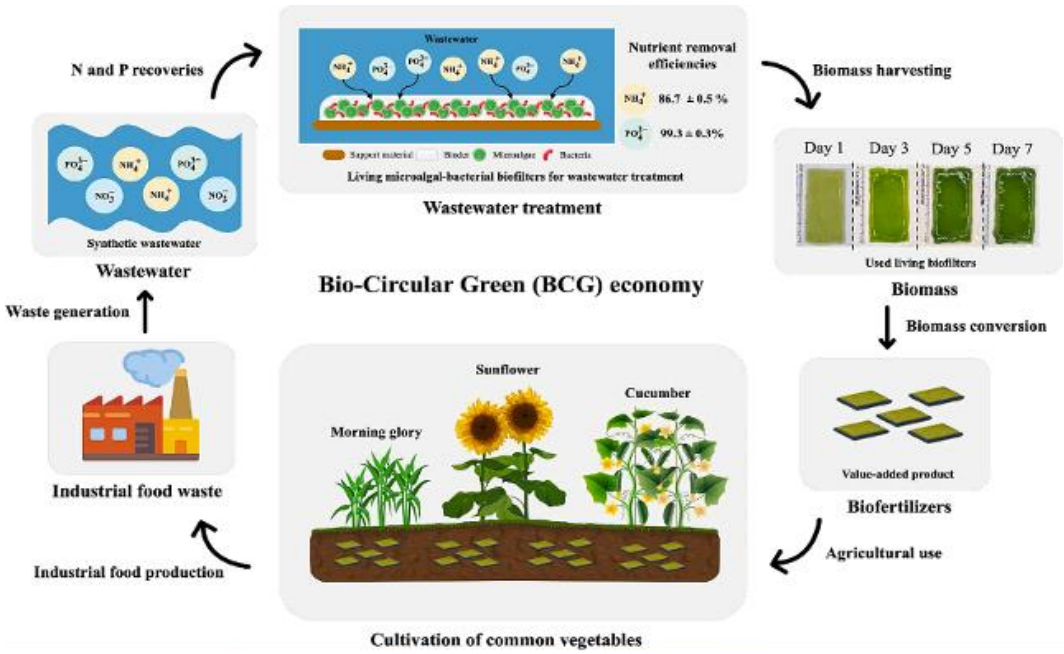
Executive Summary

Access to fertilizers is vital for global food security but faces significant threats from economic, geopolitical, environmental, and logistical factors. High prices and reduced subsidies make fertilizers unaffordable for many farmers, particularly in developing countries (Fuglie & Rada, 2013). Geopolitical issues like trade restrictions and political instability in major fertilizer-producing nations complicate access (International Fertilizer Association, 2020). Environmental concerns, including pollution, resource depletion, and climate change, further add risks (Cordell & White, 2014). Logistical challenges such as supply chain disruptions and inadequate infrastructure also hinder timely delivery (FAO, 2021). Additionally, environmental regulations and sustainable practices, while beneficial long-term, pose challenges for smallholder farmers and increase regional inequalities, potentially leading to reduced crop yields, higher food prices, and increased malnutrition (World Bank, 2020).

The Cundiboyacense region*, like many agricultural areas globally, faces the challenge of sustainable food production. Traditional agriculture's intensive use of chemical fertilizers and pesticides has negatively impacted the environment and human health. Additionally, crop irrigation waters are contaminated with household, industrial, and agricultural discharges, affecting water quality and limiting sustainable production. High transportation costs for fertilizers from distant seaports further burden small and medium-sized farmers. Addressing these challenges sustainably is crucial for stable and sufficient food production, particularly in developing countries.

The use of microorganisms to recover nutrients from waste in circular agriculture has great potential (Nguyen & Vu, 2020). Engineered consortia of live microorganisms can recover nutrients from wastewater and convert them into biofertilizers, improving water quality and strengthening food security. Recent studies have demonstrated the effectiveness of co-immobilized cultures of microalgae and bacteria in nutrient recovery from wastewater for use as biofertilizers (Bioresource Technology, 2024).



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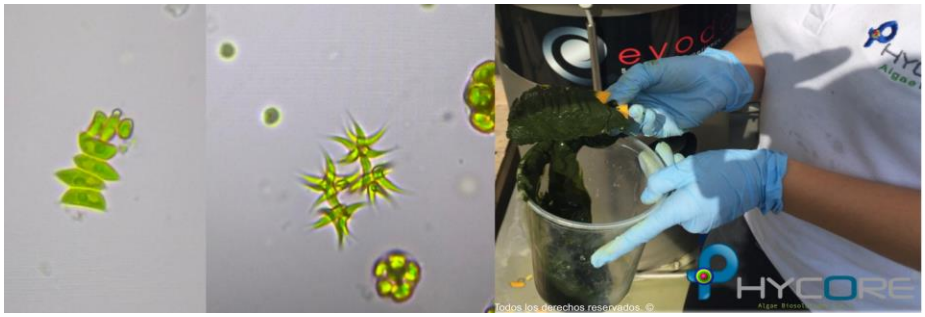
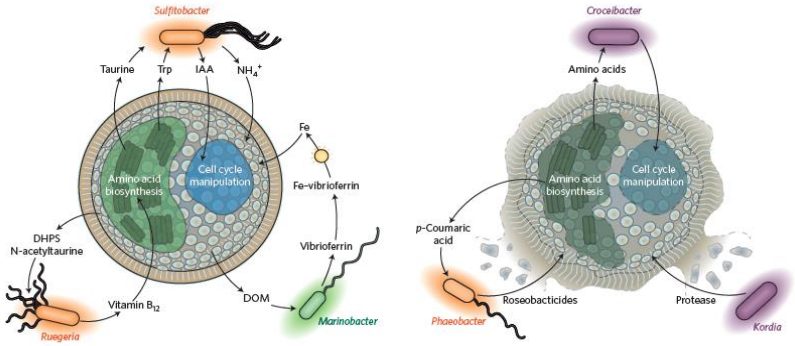
(* The Cundiboyacense region has historically been the most important area for food production for the Colombian population (Moreno, 2017).)

Our team has been working for more than a decade with an innovative approach, which integrates the concept of the phycosphere of microalgae consortia in this field, offering a pioneering vision on how to integrate not only bacteria and fungi, but more diverse microbiological consortia (MPMC: Microalgae-Predominant Microbial Consortium), organized around to microalgae and their phycosphere (Indian J Microbiol. 2022 Jun;62(2):307-311).



Gutiérrez JE, Gutiérrez-Hoyos N, Gutiérrez JS, Vives MJ, Sivasubramanian V. Bioremediation of a Sewage-Contaminated Tropical Swamp Through Bioaugmentation with a Microalgae-Predominant Microbial Consortium. Indian J Microbiol. 2022 Jun;62(2):307-311. doi: 10.1007/s12088-021-00990-y. Epub 2021 Nov 11. PMID: 35462717; PMCID: PMC8980186.

The diverse and complex interactions that occur within the microalgal phycosphere give these microbial consortia powerful capacities to obtain and make bioavailable nutrients that would not be otherwise.



Seymour, J. R., Amin, S. A., Raina, J. B., & Stocker, R. (2017). Zooming in on the phycosphere: The ecological interface for phytoplankton-bacteria relationships. *Nature Microbiology*, *2*(May). https://doi.org/10.1038/nmicrobiol.2017.65

Additionally, microalgae promote the formation of a biofilm in their extracellular polymeric substances, creating a protective environment for symbiotic bacteria. This makes the consortium more resistant to toxic contaminants and more efficient at biodegradation (Gutiérrez, 2021).

Our team aims to conduct research leveraging MPMC phycosphere diversity to enhance nutrient recovery from Cundiboyacense sheet rivers' water for developing a potent biofertilizer. This innovation promises to enhance regional access to affordable, safe, and effective biofertilizers, fostering regenerative, productive agriculture.

By promoting resilient agricultural systems, this initiative will create employment opportunities, stabilize income, and substantially improve food security within our communities.

Mission and Objectives

- Biofilm induction surfaces of immobilized MPMC will be constructed to recovery nutrients form polluted river water.
- The nutrient content of the biomass obtained from the biofilms will be measured.
- The biomasses will be tested as biofertilizer for three plant crops.
- The impact of biomasses used as biofertilizers on the soil will be verified.
- The tool will be socialized with farmers in the region.

General Objective

Develop and implement a methodology for immobilized MPMC cultures for the recovery of nutrients from waters contaminated with household and agricultural discharges from the Bogotá River, for their use as safe biofertilizers, in the Municipality of Cota.

Specific Objectives

Specific objective 1: Develop and optimize immobilized MPMC cultures for the efficient recovery of nutrients from contaminated waters.

Specific objective 2: Evaluate the effectiveness and safety of biofertilizers produced from MPMC in 3 different crops.

Specific objective 3: Strengthen local community capacities for environmental and social management and oversight.

Implementation Plan

This project, a joint initiative of the Microbiological Research Center (CIMIC) at Universidad de Los Andes and the biotechnology startup Phycore®, combines the university's expertise in environmental microbiology with Phycore®'s proven ability to produce and scale microalgal microbial consortia (MPMC) to industrial quantities.

			Schedule																								
GENERAL OBJECTIVE	SPECIFIC OBJECTIVES	Activities	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24
Develop and implement a immobilized MPMC cultures for the recovery of nutrients from waters contaminated with household and agricultural discharges from the Bogotá River, for their use as safe biofertilizers, in the Municipality of Cota.	SO1: Develop and optimize immobilized MPMC cultures for the efficient recovery of nutrients from contaminated waters.	A1. Carry out hydrobiological studies in the body of water and formulate the microalgal predominant microbial consortium (MPMC) necessary for the efficient recovery of nutrients from contaminated																									
		A2. Carry out the efficient recovery of nutrients from water contaminated with household and agricultural discharges using the formulated MPMC.																									
	SO2: Evaluate the effectiveness and safety of biofertilizers produced from MPMC in 3 different crops	A3. Carry out three cultivation cycles of three fast-growing species cultivable in the Bogotá savanna.																									
		A4. Evaluate the microbiological safety of the crops to which the recovered nutrients were applied.																									
		A5. Evaluate the nutritional quality of the crops to which the recovered nutrients were applied.																									
		A6. Evaluate the effect of residues from the nutrient recovery process with immobilized MPMC crops on the water resource used.																									
	SO3: Strengthen local community capacities for environmental and social management and oversight.	A7. Establish (strengthen) a community environmental management and oversight system based on local associative capacities.																									
		A8. Provide environmental education to the community on the use of immobilized MPMC crops for the efficient recovery of nutrients from contaminated waters for agricultural applications																									
		A9. Consolidation of geographic information (Geodatabase) of the intervened areas, in georeferenced polygons under the current IGAC standards and regulations.																									
		A10. Create (strengthen) local capacities to formulate initiatives for socio-environmental sustainability and sustainable agricultural production.																									
		A11. Accompany the formulation of tools to evaluate the continuity of processes in order to expand the scope of socio-environmental intervention.																									

Funding Requirements

To achieve these objectives, we seek to raise USD$1,303,000 in donations that will be received and administered from the University. Funds will be allocated over the course of 2 years, as follows:

1. Operational Costs USD$497,878.64: 24 months of salaries for the scientific staff made up of five scientists, two professionals and six technicians. Administrative support staff consisting of two more professionals, and administrative overhead costs.

2. Technological equipment USD$ 176,430.83: 2 microalgal biofilm induction photobioreactors of 20,000 liters each for biofertilizer production experiments. 8 compact portable automated photobioreactors of 1,000 liters each for PAR activities and community projects. Hydraulic systems for the operation of photobioreactors.

3. Laboratory testing USD$199,582.06: Physicochemical analysis of water quality before and after treatment with biofilm induction photobioreactors to verify nutrient recovery. Microbiological safety analysis of the cultures obtained with the recovered nutrients. Analysis of nutritional quality of the crops obtained with the recovered nutrients.

4. Participatory action research (PAR) activities USD$174,757.28: Community workshops to provide environmental education on using immobilized MPMC (microbial-plant-microalgae consortia) crops for efficient nutrient recovery from contaminated waters for agricultural applications. These workshops will integrate hands-on training and theoretical knowledge, enhancing local capacities to formulate socio-environmental sustainability initiatives and sustainable agricultural practices.

5. Sub-contractors Costs USD$ 254,053.40: Rental costs of arable land, property security, logistics and weekly transportation of river water to the property for nutrient recovery tests.

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