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Microbial biosurfactants: Multifarious applications in sustainable agriculture

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ABSTRACT

Agriculture in the 21st century faces grave challenges to meet the unprecedented food demand of the burgeoning population as well as reduce the ecological footprint for achieving sustainable development goals. The extensive use of harsh synthetic surfactants in pesticides and the agrochemical industry has substantial adverse impacts on the soil and environment due to their toxic and non-biodegradable nature. Biosurfactants derived from plant, animal, and microbial sources can be an eco-friendly alternative to chemical surfactants. Microbes producing biosurfactants play a noteworthy role in biofilm formation, plant pathogen elimination, biodegradation, bioremediation, improving nutrient bioavailability, and can thrive well under stressful environments. Microbial biosurfactants are well suited for heavy metal and organic contaminants remediation in agricultural soil due to their low toxicity, high activity at fluctuating temperatures, biodegradability, and stability over a wide array of environmental conditions. This green technology will improve the agricultural soil quality by increasing the soil flushing efficiency, mobilization, and solubilization of nutrients by forming metal-biosurfactant complexes, and through the dissemination of complex nutrients. Such characteristics help it to play a pivotal role in environmental sustainability in the foreseeable future, which is required to increase the viability of biosurfactants for extensive commercial uses, making them accessible, affordable, and economically sustainable.

1. Introduction

Global agriculture faces a stiff challenge to meet the rising food demands of the 21st century while addressing soil and environmental deterioration and food safety concerns. Agricultural soil has been severely contaminated with bioaccumulative, nephrotoxic, and non-biodegradable heavy metals (Cadmium, Lead, Copper, Nickle, Arsenic, etc.) and organic hydrocarbons. Besides affecting plant growth negatively, these heavy metals also find their way from contaminated agricultural soil to food grains which can cause detrimental health effects (Kumar et al., 2022). Heavy metals have been linked to cancer, liver and kidney damage, learning impairments, and birth problems. Modern commercial agriculture envisages extensive use of pesticides and agrochemicals containing surfactants as primary ingredients. Surfactants are surface active ingredients that work mainly by altering the system's free enthalpy, energy, and entropy and with close coverage, the surface tension gets reduced significantly (Mehta et al., 2010). Surfactants are amphiphilic compounds, featuring both hydrophobic and hydrophilic components within their molecular structure, and possess surface or interface modifying properties which reduce the interfacial tension between two immiscible substances (Zhong et al., 2017). In agriculture, surfactants are used as wetting agents, dispersants, or emulsifiers. According to projections, the market for surfactants would increase from $41.22 billion in 2021 to $57.81 billion by 2028 (https://www.fortunebusinessinsights.com). Chemically surfactants are widely referred to as synthetic surfactants which consist of a hydrophobic chain of paraffin, olefins, alkyl phenols, alkyl benzenes, and alcohols. However, their continuous usage over decades, can lead to agrochemical pollution and soil and environmental contamination.

Biosurfactants are surface-active compounds of low molecular weight that are commonly derived from microbial origin such as bacteria, yeasts, and other fungi (Dobler et al., 2016). These natural

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