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Harnessing microbial biosurfactant for agricultural applications

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Abstract Biosurfactant refers to surface-acting substances that can enhance surface-surface interactions by generating micelles that are derived from natural sources including plants, microorganisms, and animals. Biosurfactants are a structurally diverse group of secondary metabolites with lots of potential to serve mankind. The structural and compositional diversity of biosurfactants is unambiguously substrate-dependent. Microbial surfactants are environment-friendly alternatives to synthetic surfactants. Biosurfactants are surface-active agents produced by microorganisms that have higher efficiency and stability, lower toxicity and higher biocompatibility and biodegradability than chemical surfactants. The differences between biosurfactant production can be attributed to the different compositions of the hydrolyzates.

Keywords: Agriculture, Biodegradability, Biosurfactant, Plant defence, Sustainability

Introduction

The challenges of food security and environmental management are made more difficult by the world's fast industrialization and growing population. A greater population of developed countries depend upon chemical pesticides, in the soaps and detergent industries as emulsifiers, detergents, and dispersants (Kumar *et al.,* 2021, Marchut-Mikołajczyk *et al.,* 2021). Oil spills at sea are frequently treated using chemical dispersants as a first-step response method. Organo-chemical synthesis is used to produce the dispersants that have been licensed and are kept in stockpiles across the world in case of an oil spill (Nikolova and Gutierrez, 2021). The synthetic surfactants (organo-chemical) that have been utilized in the present are of high risk to the environment as they are derived from non-renewable petroleum sources and a finite source (de Oliveira Schmidt *et al.,* 2021). Another such consideration is where that scientist is

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extremely concerned about the growing threat that toxic heavy metal pollution of soil poses to the ecosystem due to its toxicological manifestations and adverse impacts across the world (Mishra *et al.,* 2021). Using materials to the fullest extent possible, such as oil hydrocarbons and heavy metals such as cadmium, iron, titanium, copper, zinc, mercury, insecticides, herbicides, air pollutants (carbon monoxide, nickel), particulate pollution, ozone, acid rain, and volatile organic compounds), bisphenol, sulphonamides, nitroaromatic chemicals, organophosphorus compounds, trichloroethylene, perchloroethylene, solvents, and chlorinated. However, it is imperative to implement remediation solutions for such dangerous contaminants. The use of remedial techniques such as soil washing, pumping, aeration, oxidation, and incineration is rather rare. The production of additional secondary pollutants, which is economically unfeasible, is one of the many downsides of these remediation techniques. To address these issues, microbial bioremediation one of the sustainable and affordable techniques for removing environmental contaminants is bioremediation. (Sharma *et al.,* 2021).

As a result, finding natural alternatives to artificial surfactants and using them responsibly is essential (Eras-Muñoz *et al.,* 2022). One of the most recently discovered microbially produced/synthesized bimolecular molecules are termed biosurfactants which are becoming more and more popular due to their exceptional benefits over synthetic ones (Mohanty *et al.,* 2021, Yun *et al.,* 2018). The word "biosurfactant" refers to surface-acting substances that can enhance surface-surface interactions by generating micelles that are derived from natural sources including plants, microorganisms, and animals (Yun *et al.,* 2018). Bioremediation is a natural, sustainable, and environmentally advantageous technology for treating environmental contaminants without prod any secondary pollutants or adverse effects. Outstanding microbial products known as biosurfactants, also known as biologically active chemicals, have been effectively used in the detoxification and removal of hazardous heavy metals (Mishra *et al.,* 2021). The benefits of green surfactants (biosurfactants made from microorganisms) over synthetic surfactants have been emphasized in several papers. In comparison to synthetic surfactants, biosurfactants are low or nontoxic, biodegradable, exhibit outstanding surface activity, have a high specification, are effective in harsh environments, and may also be recycled through regeneration (Sachdev and Cameotra, 2013). Microbial surfactants are a common occurrence in human lifestyles nowadays and are a major component of everyday items like detergents, food additives, and cosmetics (Pardhi *et al.,* 2022). They are used commercially as cheaper manufacturing alternatives to chemical surfactants, particularly in the pharmaceutical industry (Sajid *et al.,* 2020). There are already more than 2000 different biosurfactant structures that have been identified, including chemically separate families of compounds as well as groups of congeners, or structurally similar compounds with slight structural changes (Kubicki *et al.,* 2019). The effectiveness of a surfactant is determined by its ability to reduce surface tension (ST) and interfacial tension (IFT) between two immiscible phases. (Nikolova and Gutierrez, 2021).

Since these natural surfactants are found to be utilized as carbon sources by soil-dwelling bacteria, they can replace the harsh surfactants now employed in the pesticide industry (Sachdev and Cameotra, 2013). Agricultural waste and leftovers of food processing can be used as a carbon source for the creation of microbial fuels because they are readily available and inexpensive. biosurfactants (Marchut-Mikołajczyk *et al.,* 2021).

Impact of sustainable agriculture

There is a need to avoid the degradation of land as it is high time for us to preserve the land since there is an increase in human population and subsequent raise in food consumption. Providing food security for a growing population need, entails the implementation of sustainable land use techniques and the protection of any degraded or margined soil (Ahmad *et al.,* 2018). The micronutrient deficiencies in the soil must also be addressed to fulfil the crops increasing demands. Increasing the use of nutrient availability by a biosurfactant, which is a multifunctional microbial metabolite may be a suitable strategy to increase agricultural output (Singh *et al.,* 2018). Numerous potentials for sustainable agriculture have been provided by biocontrol techniques involving the use of biomaterials and biomolecules. The green strategy uses multifunctional biomolecules including biosurfactants, chitosan, and nanoparticles synthesized from chitosan because of their biocompatibility. (Karamchandani *et al.,* 2022). Since surfactants of chemical origin have a number of adverse effects on the environment, such as toxicity towards lesser forms of life, soil contamination, etc. Biocontrol strategies have been adopted (Sangwan *et al.,* 2022). Affordable feedstocks are used in the economy and circular economy of biosurfactants, which supports the utilization of waste converted into useful products. Waste reduction, reuse, and recycling are supported by novel, inexpensive, renewable health-grade biosurfactants in an integrated green economy bioprocess. (Mgbechidinma *et al.,* 2022).

Microbial biosurfactant classification

Microbial Biosurfactnts are classified into various types that are depending on their diverse properties. But are mainly classified based on their Molecular weight. The low and high molecular weight molecules are the two main groups into which biosurfactants fall. Generally, high molecular weight biosurfactants often referred to as bioemulsifiers or bioemulsans, may stabilize emulsions and powerfully attach to surfaces, whereas low molecular weight surfactants effectively lower surface and interface tension. The first class consists of lipopeptides and glycolipids, whereas the second class is made up of proteins, polysaccharides, and lipoproteins. (Ravinder *et al.,* 2022). Surface and interface tension, which may reach levels below 30, is connected to effectiveness (Moutinho *et al.,* 2021).

Glyclolipds

For use in biotechnology, glycolipid biosurfactants have gained a lot of interest (Mnif *et al.,* 2018). Glycolipids A carbohydrate moiety is joined to a fatty acid chain to form glycolipid molecules. The Rhamnolipids, trehalolipids, mannosylerythritol lipids (MELs), and cellobiose lipids are examples of the class of biosurfactants. It has been demonstrated that several glycolipids can create holes and weaken cellular membranes. The antibacterial, antifungal, anticancer, and anti-biofilm properties of glycolipid biosurfactants have been investigated. (Paraszkiewicz *et al.,* 2021). Because they contain both hydrophilic glycosyl and lipophilic lipid residues, simple glycolipids are amphiphilic molecules (Abdel-Mawgoud and Stephanopoulos 2018). Certain antiviral, antibacterial and antifungal properties are exhibited by glycolipid surfactants (Jezierska *et al.,* 2018). The fermentation conditions, strain selection, culture media and growth conditions are what led to the various structures of glycolipid biosurfactants (Dardouri *et al.,* 2021, Sekhar and Nayak, 2018). Studies have been conducted where the glycolipid can be used as a feasible bioplastic (Fukuoka *et al.,* 2018).

Rhamnolipids

Rhamnolipids are equally stable and effective in emulsifying as the widely used anionic surfactant sodium dodecyl sulphate (Salek *et al.,* 2022). They are extracellular secondary metabolites that are released by different Pseudomonas strains, primarily by the opportunistic pathogen *Pseudomonas aeruginosa*. These bacteria use them at different phases of the biofilm-building process. Rhamnolipids are useful in environmental technology, especially in water and soil remediation procedures, because they can remove different organic and inorganic contaminants more quickly. On the other hand, have anti-adhesive and disruptive properties when it comes to biofilms produced by certain pathogenic microbes (Paraszkiewicz *et al.,* 2021). Biosurfactants produced by *Klebsiella* species are identified to be monorhamnolipid (Ahmad *et al.,* 2021). Due to its adverse effects, severe foaming is not experienced while rhamnolipid undergoes fermentation (Gong *et al.,* 2021). Rhamnolipid biocomplex are biosynthesized by *Pseudomonas* species which is cheaper and environmental friendly and acts as an alternative for purified rhamnolipids (Kłosowska-Chomiczewska *et al.,* 2021).

Sophorolipds

Two glucose rings connected by a 1-2 glycosidic bond make form the sophorose polar group of the glycolipid known as sophorolipds, which also has a hydroxylated fatty acid lipid tail (Salek *et al.,* 2022). Sophorolipids are intriguing substitutes for surfactants made of petrochemicals due to all these characteristics. They have little foaming, quick wetting and low toxicity, as well as strong surface activity (Liwarska-Bizukojc *et al.,* 2018). Candida bombicola and C. apicola are two examples of non-pathogenic yeast that produce sophorolipids, which are biosurfactants that include the fatty acid and the sugar sophorose bound together. Examined the antimicrobial qualities and biofilm disruption activity of sophorolipid biosurfactants against both Gram-negative and Gram-positive microorganisms (Paraszkiewicz *et al.,* 2021).

Lipopeptides

A physically varied family of extracellular compounds produced by bacteria and fungi is called lipopeptides. The most widely used lipopeptide biosurfactants include substances from the surfactin, iturin, and fengycin families generated by various Bacillus strains and Pseudomonas lipopeptides (divided into four primary groups: viscosin, amphisin, tolaasin, and syringomycin) (Paraszkiewicz *et al.,* 2021). Microorganisms that usually undergo environmental stress produce Antibiotic lipopeptides (Vazquez *et al.,* 2018). One of the most well-known lipopeptides is fengycin from *Bacillus subtilis*. *Bacillus*-related lipopeptides, *Pseudomonas*-related lipopeptides, other bacterial-related lipopeptides, *actinomycete*-related lipopeptides, and fungal-related lipopeptides are the different categories of lipopeptides (Mnif and Ghribi, 2015).

Properties of biosurfactant

Numerous prokaryotic and eukaryotic microorganisms produce biosurfactants, which are molecules that lower surface and interfacial tension and are either produced extracellularly or linked to compounds that are associated with cells. It is not only possible for biosurfactants to form water-in-oil and oil-in-water emulsions, but also dehydrate emulsions, which is a promising technology in businesses that depend on petroleum (Najmi *et al.,* 2018). The asymmetric structure of surfactant molecules causes them to adsorb micelles (Zdziennicka *et al.,* 2018). When we modify their metabolic pathway through rational design, their structures and characteristics may also be changed. Thus, new products with a certain profile can be created (Vazquez *et al.,* 2018).

Physicochemical properties of biosurfactants

For biosurfactants to be successfully used in practice, one must be aware of their physicochemical characteristics (Jahan *et al.,* 2020). The Fatty Acid chain length and the isomerism are known to affect the physicochemical property of biosurfactants (Hu *et al.,* 2019). The values of the tail and head's surface tension (a macroscopic characteristic) and the size of specific molecular components (a microscopic property) determine the surfactant's propensity to form micelles at a critical concentration (CMC) and adsorb at the water-air and soil-water interfaces (Zdziennicka *et al.,* 2018). They are typically divided into low and high-atomic-weight surfactants based on their synthetic approach and sub-atomic weight (Abbot *et al.,* 2022). In addition, the physicochemical properties of the support must be chosen by the desired reaction because they can affect the efficiency of the enzyme. It is hypothesized that an increasing amount in the rate of reaction conversions was caused by a decrease in the hydrophilicity of the support (Zago *et al.,* 2021).

Surface and interfacial tension

One of the most crucial characteristics of amphiphilic substances is their capacity to lower surface and interfacial tension. For example, this is necessary for the development of kinetically stabilized emulsions. Due to their dual hydrophobic-hydrophilic nature, amphiphilic compounds, such as biosurfactants, adsorb at interfaces. Surfactant molecules efficiently lower intermolecular interactions between solvent molecules when they replace water or oil molecules at the contact, hence reducing surface or interfacial tension (Jahan *et al.,* 2020). Surfactants are added to the solution to lower the surface tension of the (air/water) and (oil/water) interfacial tension, which promotes the deposition of solid phase (adsorption state) oil contaminants and enhances their ability to migrate into the aqueous phase or their contact efficiency with aqueous phase remediation agents of microorganisms (Liu *et al.,* 2019). Surfactin was able to roughly 2.5 times lower the water surface tension even at low concentrations. (Iglesias-Fernández *et al.,* 2015).

Air-water interface

With the hydrocarbon chain facing air and the hydrophilic groups towards bulk water, the air-water surface tension measures how tightly the surfactants are packed at the air-water interface. The air-water interface configuration causes a low degree of surfactin immersion in the aqueous phase, making it a more hydrophobic nanoparticle and enabling it to create a very compact surface layer that is denser than that of ordinary amphiles (Otzen, 2017). Hydrophobic chains group together to avoid water molecules, whereas surfactin molecules tend to assemble near the interface with polar residues facing the water phase. The peptidic residues of surfactin are typically found parallel to the water/air boundary, and the flexibility end of the fatty acyl chains (Iglesias-Fernández, *et al.,* 2015). At the air-water interface, the surface adsorption characteristics of saponin, and escin are been studied using neutron reflectivity and surface tension (Tucker *et al.,* 2020).

Antibiofilm property

The way that bacteria express themselves can change in response to their environment. The ability of bacteria to carry out quorum-sensing activity, this capability is related to the formation of biofilms (Abbot *et al.,* 2022). Biofilm production has been seen to be inhibited by biosurfactants. They can change the surface's physicochemical characteristics to lessen adhesion (Janek *et al.,* 2012). Gram-negative bacteria (*Salmonella enteritids*), Gram-positive bacteria (*Staphylococcus aureus*, *Bacillus pumilus* and *Listeria monocyotgens*) and fungal strains (*Yarrowia lipolytica*) possess antimicrobial and antibiofilm properties (Khalid *et al.,* 2019). Biosurfactants have gained interest in the therapeutic and sanitary domains due to their biodegradable nature, low cytotoxicity, anti-microbial and antibiotic activities, and capacity to dissolve microbial biofilms. (Cheffi *et al.,* 2021). Because of their inherent surface activity and the possibility that they could be used to prevent the formation of biofilms, biosurfactants have antibacterial, antibiofilm, and antiadhesive properties (Abdollahi *et al.,* 2020). Microbial surfactant has received more attention recently (Giri *et al.,* 2020).

Application

Biosurfactants have multiple uses in a variety of industries, including agriculture, biomedicine, construction, the pulp and paper sector, metal, textile, pharmaceutical, and cosmetics (Moutinho *et al.,* 2021) (Figure 1).

Cosmetic industry

Biosurfactants are essential to the beauty sector because of their high-added-value products, high specificity, and skin compatibility. Given their significant qualities, including detergency, foaming, wetting, emulsifying, solubilizing, and dispersing, biosurfactants are widely wanted for usage in cosmetics. Because of its physicochemical properties, biological activity, and biocompatibility, the glycolipids group, which comprises the rhamnolipids, sophorolipids, and mannosylerythritol lipids, is the largest and most diversified biosurfactant group used in the cosmetic and personal care industry (Moutinho *et al.,* 2021). The choice of a biosurfactant for a definite cosmetic product is a delicate task that depends on several factors based on the requirement of the product (Bezerra *et al.,* 2018).

Petroleum industry

Biosurfactants are essential in the petroleum industry as well. For instance, the Microbial Enhanced Oil Recovery (MEOR) technology employs the addition of microorganisms to the reservoir rock that are then stimulated to generate polymers and surfactants to lower the surface tension of the oil rock and enable the transportation of the oil through the rock's pores (Moutinho *et al.,* 2021) Additionally, biosurfactants lessen the viscosity of crude oil residues that have been left behind and deposited at the bottom of oil storage reservoirs (Moutinho *et al.,* 2021).

Medical industry

The number of potential applications for biosurfactants in the medical sector has increased significantly during the last ten years. Several biosurfactants were shown to have biological properties, including antibacterial, antifungal, antiviral, anticancer activity, suppression of clot formation and hemolysis, anti-adhesiveness, and creation of ion channels in membranes, which encouraged their usage in the biomedical industry (Jahan *et al.,* 2020).

Other applications

The marine and shipping industries suffer severe issues and financial losses as a result of biofouling. Marine bacteria with the potential to produce biosurfactants can be a great choice when looking for new antifouling agents because they have the amphipathic surface-active property that confers antibacterial and antibiofilm actions (Alemán-Vega *et al.,* 2020). In food industries these factors play an advantageous role where the biosurfactants possess specific resistance to variations in temperature, acidity and salinity, and allow biomolecules to maintain their original characteristics, this may have a favourable impact on the end product's quality (Ribeiro *et al.,* 2020).

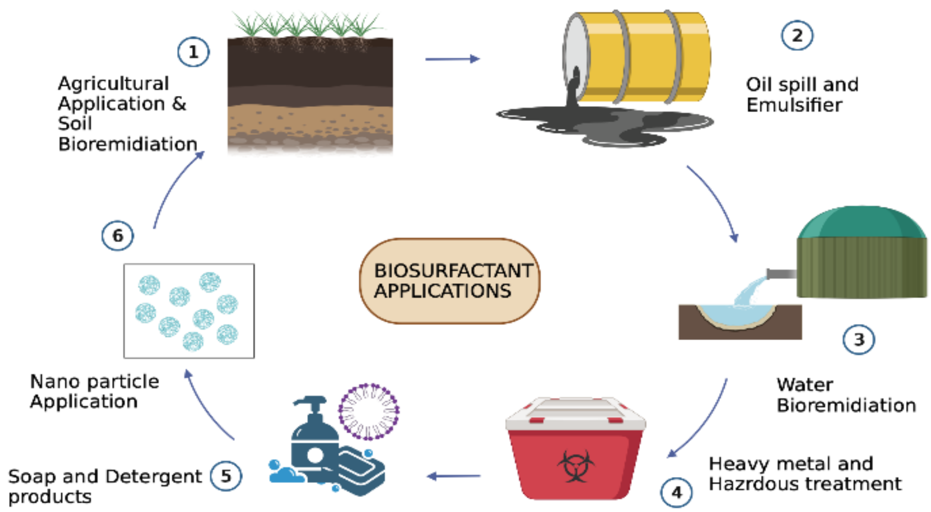

Figure 1. The various industrial application in which biosurfactants are being applied in the recent decades (Mohanty *et al.,* 2021, Mishra *et al*., 2021, Domínguez *et al.,* 2019

Sources of biosurfactant

The Microbial biosurfactants are being derived from various species, though there is n number of variants these are a few of the species that are been listed (Table 1) (Moutinho *et al.,* 2021). *Planococcus* a gram-positive bacterium is a pioneer marine resource for biosurfactant production and even other secondary metabolites (Waghmode *et al.,* 2020). Several other phyla like Actinobacteria, Firmicutes, Proteobacteria, Ascomycota, and Basidiomycota have been utilized for the production of diverse biosurfactants (Alemán-Vega *et al.,* 2020). Pony Lake from Ross Island, Antarctica is a source for the *Psychrobacter arcticus* Strain that is used to isolate biosurfactants The Cotton Glacier stream in Victoria Land rich source of *Janthinobacterium svalbardens* which come under the classes of sophorolipids and di-rhamnolipids (Trudgeon *et al.,* 2020).

Table 1. The table lists some of the strains from which the specific biosurfactants are been derived (Moutinho *et al.,* 2021, Malviya *et al.,* 2020)

S.No	Source Organism	Lipopeptide Class
1	*Actinoplanes friuliensis*	Friulimicin
2	*Arthrobacter* spp. MIS38	Arthrofactin
3	*Bacillus subtilis*	Iturin A, Bacillomycin
4	*B. subtilis* HC8	Surfactin, Fengycin A
5	*B. subtilis* K1	Fengycin A, and B, Fengycin A2
6	*B. subtilis* GA1	Iturins, Fengycins, Surfactins
7	*B. subtilis* and *B. amyloliquefaciens*	Surfactins, Bacillomycin
8	*Pseudomonas chlororaphis, Pseudomonas putida and Burkholderia thailandensis*	Glycolipid
9	*Bacillus pumilus, Bacillus subtilis*3, *Brevibacilis brevis*	Lipopeptide

Researchers have discovered and isolated biosurfactant-producing bacteria from various marine environments of the Canadian Arctic; they noted that the most common species were of the genus *Rhodococcus*, followed by *Bacillus* and antibiofilm activities and biosurfactants at 4 °C by the genera *Pseudomonas*, *Pseudoalteromonas* and *Rhodococcus*, were collected from Antarctic and Arctic polar environments (Schultz and Rosado, 2020). Studies have concluded the antimicrobial activity of biosurfactant extract that was obtained from the enduring stream of the corn-milling industry (Rodríguez-López *et al.,* 2020). The lactic acid bacteria such as *Lactobacillus agilis*, *Lactobacillus Plantarum*, *Lactobacillus paracasei*, and *Lactobacillus pentosus* are the most researched glycolipopeptides and glycopeptide microbial biosurfactants (Moldes *et al.,* 2020). *Serratia* species have been shown to create two kinds of biosurfactants, namely lipopeptides and glycolipids. These species include *Serratia marcescens, Serratia rubidaea, and Serratia surfactantfaciens* (Clements *et al.,* 2019).

Agriculture impacts of biosurfactants

Anti-phytopathogenic activity

Sophorolipids, cellobiose lipids, and mannosyl-erythritol-lipids are involved in plant protection by inhibiting the growth of phytopathogenic fungi. Sclerotinia sclerotiorum and Phomopsis helianthi are phytopathogenic fungi that are inhibited from growing by the cellobiose lipid of Pseudozyma fusiformata and Cryptococcus humicola. The phytopathogenic fungus Sphaerotheca fuliginea was resistant to the antifungal action of cellobiose lipids produced by Pseudozyma flocculus (Mnif and Ghribi, 2016). Because they can be produced at scale for commercial purposes, have low toxicity, and have a high biodegradability, Biosurfactants are promising compounds for a variety of uses that are created by bacteria, yeast, and fungi. (Crouzet *et al.,* 2020).

Plant defence

Huge economic losses come from plant infections that cause significant agricultural damage, that range from 10-40% depending on the crops before and after harvest (Savary *et al.,* 2019). However, to overcome this scenario chemical pesticides were in implementation. However, they have the potential to be harmful to both human and environmental health, which has prompted the creation and improvement of alternate crop protection measures. (Berg *et al.,* 2017). Recent research has also demonstrated that some rhamnolipids can protect plants from phytopathogenic fungi and bacteria through the activation of the plant immune system. It has been shown that P. aeruginosa rhamnolipid activates defence genes in Arabidopsis thaliana, wheat, and tobacco (Mnif and Ghribi, 2016). The area of biomedicine and agriculture may be able to use rhamnolipids as possible antimicrobials, immunological modulators, virulence factors, and anticancer agents to help fulfil the growing need for pharmacological therapy and food safety in the coming years (Chen *et al.,* 2017). Because of their potential to generate pores in pathogens, siderophore action, biofilm inhibition, and dislodging activity, as well as their antiviral and other activities, lipopeptides have several applications in plant protection. Lipopeptide-containing microorganisms are effective biocontrol agents. Investigating these antimicrobial substances may open up new avenues for biological pest management of established and newly emergent plant diseases (Malviya *et al.,* 2020). One of the safer green alternatives for the chemical pesticide is mannosylerythritol lipids (Matosinhos *et al.,* 2022).

Various pathogens infect *Capsicum* spp (Pepper) which is an important spice, this contributes to economic losses on a global range. Where the *Cucumber mosaic virus* (CMV) is the most destructive pathogen (Jones, 2016, Mandadi and Scholthof, 2013). We face limitations in which the commercially available CMV plants that have been developed by breeding technologies and transgenic method face time-limited and environmental issues (Khalid *et al.,* 2017). This strain (biocontrol), *Bacillus amyloliquefaciens* PPL exhibits various useful properties, such as antibacterial and antifungal activities against various plant pathogens, also including *Colletotrichum gloeosporioides, Phytophthora capsici, Rhizoctonia solani*, and *Fusarium oxysporum* that also fight against the CMV (Kang *et al.,* 2019). *Bacillus* species that produce cyclic lipopeptides have been reported to exhibit antiviral and antifungal activity in plants (Kang *et al.,* 2021).

Sheath blight (ShB) of rice is a pathogenic disease, caused by Rhizoctonia solani, which obligates significant yield losses globally. Currently, chemical fungicides are used to control the disease. (Kumar *et al.,* 2011). Endophytic bacteria have been widely used to produce potent biocontrol agents as they elicit antagonism at the site of infection. Some of the endophytic bacteria strains are endophytic diazotrophic, and *Bacillus* subtilis under gnotobiotic conditions can suppress the ShB in rice (Shabanamol *et al.,* 2017). Biosurfactants can penetrate and harm fungal cell membranes, which reduces the likelihood that they will develop resistance, compared to traditional antibacterial treatments or insecticides (Choub *et al.,* 2021).

Banded leaf and sheath blight is a plant disease, caused by *Rhizoctonia solani*, where the infection restricts the crop output in climatic situations critically during the monsoons in India (Singh *et al.,* 2020). An economically significant crop, pepper (Capsicum annuum L.), is subject to several illnesses. Pathogens of the genus *Colletotrichum* can cause severe yield loss (Park *et al.,* 2022). Bacillus *subtilis* and Bacillus *amyloliquefaciens* strains have reportedly been particularly successful in treating several soil-borne plant illnesses. (Borriss *et al.,* 2011, Liu *et al.,* 2019).

Plant growth promotion

Organic and inorganic contaminants that cause abiotic stress in crop plants have an impact on the productivity of agricultural land. Bioremediation is necessary to improve the condition of the soil that has been polluted with hydrocarbons and heavy metals. Biosurfactants produced by microorganisms and/or biosurfactants can be utilised to remove heavy metals and hydrocarbons from a solution (Sachdev and Cameotra, 2013). The majority of the bactericides in use today are persistent organic compounds, which pose a threat to both human and environmental health (López-Prieto *et al.,* 2019). Alkyl polyglucosides (APG), which are generated from plants, have been demonstrated to be natural biosurfactants that are useful in bovine nutrition due to their favourable effects on physiological and production parameters in, for example, ruminants. Increased duodenal microbial nitrogen flux results from improved ruminal and intestinal organic matter digestion and ruminal microbial protein synthesis (Naughton *et al.,* 2019). Many rhizosphere-dwelling microorganisms have the potential to promote plant growth; as a result, they are also known as plant growth-promoting rhizobacteria or plant growth-promoting bacteria (PGPB). (Ahmad *et al.,* 2018). *Rhodococcus erythropolis* other to the genera *Rahnella, Serratia and Proteus* where some of these bacteria exhibit features of plant growth-promoting bacteria which increase the biomass of plants under several mechanisms (Pacwa-Płociniczak *et al.,* 2016). Lipopeptides from *Bacillus subtilis* under low-cost production exhibit a great stability range of pH (1–11), salinity (1–8%), and temperature (20–121°C) even after autoclaving. Which acts as a potent plant growth-promoting agent that significantly increases seed germination and plant growth promotion of chilli pepper, lettuce, tomato, and pea maximum with maximum concentration added to the soil (Umar *et al.,* 2021). Streptomyces show traits of plant growth initiation of chilli under greenhouse conditions, whereas *Streptomyces puniceus, and Streptomyces median* showed significant biosurfactant and plant growth-promoting activity (Ravinder *et al.,* 2022). Biosurfactant-producing Pseudomonas sp. that utilize petroleum as a carbon source showed great plant growth potential in plants under various petroleum concentrations with high values of high values for all the parameters studied namely germination, shoot length, root length, fresh and dry weight and pigments (Das and Kumar, 2016).

Conclusion

There are several uses for surfactants in the agrochemical and agricultural sectors. Biosurfactants, which are more environmentally friendly, are only sometimes used. The precise role of surfactants in assisting other systems as biocontrol agents is still poorly known and calls for further research. These investigations will aid in the transition to eco-friendly surfactants from harsh chemical ones. Working on the manufacturing cost of green surfactants is required if the use of biosurfactants in agriculture and other industries is to yield a net economic gain. More serious consideration is also needed for the overproduction of biosurfactants from agricultural waste. By altering the production process, the chemical compositions of biosurfactants that have been identified as powerful biocontrol agents can be changed. This strategy could result in the biosynthesis of highly targeted green surfactants.

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