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Active Contribution of Soil Fungi to Sustainable Development: A review

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Abstract

Globally, there is an increase in the frequency of biotic and abiotic stressors that affect primary crop yield. Because of climate change, extreme occurrences including protracted droughts, heavy rains, flooding, heat waves, and frost damage are expected to become more frequent in the future. If we can take advantage of microorganisms' special abilities to withstand extreme temperatures, their ubiquity, genetic diversity, and interactions with crop plants, as well as develop strategies for their effective application in agriculture production and industry, they could be very important in this regard (Sustainable Development).

Among other eukaryotic groups, fungi provide a source of food, organic acids, antibiotics, growth-promoting agents, enzymes, and amino acids. They consist of microbes such as yeast, molds, and mushrooms. They feed on the tissue of living or dead plants and animals. Unlike other living organisms, fungi are the main material decomposers in the ecological system. Fungi provides unique possibilities for addressing the pressing issues facing all humans and have the power to convert organic resources into a wide range of beneficial goods. Fungal biotechnology has the potential to produce resilient sources of food, feed, chemicals, fuels, textiles, and materials for the building, automotive, and transportation industries, as well as for furniture and other uses. It can also facilitate the shift from our petroleum-based economy to a bio-based circular economy.

Keywords: soil, antibiotic, nitrogen, Bioremediation, enzymes

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Introduction

The loosely structured, multifaceted outer layer of the Earth's crust is known as soil. Both organic and inorganic materials often make up this mixture (1). The organic portion of soil is separated into two categories: biomass, which consists of living things, and necromass, which consists of dead organisms and the results of their transformation (2). The most important factor in preserving soil stability and resilience is organic matter in the soil (3) Sustainable agriculture depends on healthy soil, particularly on the number of microorganisms and soil dynamics (4). Therefore, changes in fungal communities will have an impact on the functional stability of soils (5). The soil's neutral pH, high clay content, and adequate nutrient availability are all maintained by microbial biomass (6). By maintaining the pH of the soil neutral, the productivity of soil biomass is maximized through microbial substrate optimization (7). Because the physical and chemical makeup of the soil determines the general composition and size of the mycoflora, soil composition is vital and is maintained by all microorganisms (8).

The Kingdom Fungi is home to eukaryotes with astonishingly diversified life cycles that are vital to human industry, research, medicine, and the biosphere. It includes molds, mushrooms, lichens, rusts, smuts, and yeasts (9). True fungi (Kingdom

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Eumycota) have been shown to have a significant role in the colonization of land by the progenitors of terrestrial plants (10) as well as the cessation of carbon (C) deposition into geological reserves, or fossil fuels (11).On the other hand, soil fungi play a significant part in the environment's metabolic processes, disease prevention, nutrient recycling, and water dynamics(12). Fungi may originate in nearly any type of habitat and can tolerate a broad pH and temperature range (13). Fungi are particularly effective occupants because of their remarkable plasticity and ability to take on many shapes in response to harsh or bad situations (14). Because of their metabolic activity and ability to participate in the cycling of nutrients, soil fungi are an essential part of the soil and may be impacted by human activity, long-term fertilization components, and other treatments (15). There are over 70,000 different species of soil fungus known to exist, with an estimated 1.5 million species found globally (16). Living microorganisms, which regulate ecosystems, are also in charge of forming soil structure (17), altering the habitats of other creatures, and acting as principal decomposers, releasing components such as nitrogen and carbon (18). This article aims to highlight the effective role of fungi in sustainable development, in addition to the environmental importance, industrial and food applications, and the benefits expected from fungi.

Fungi's Function Soil Restoration and Agriculture

Depending on the extent of soil degradation, the formation of a nitrogen reserve is crucial to a successful restoration (19). This reserve was first created by weathering, atmospheric deposition, plant detrital inputs, and the addition of fertilizers and organic amendments (20). The accumulation of microbial biomass and organic matter in soils, as well as the resulting nutrient reserves, are often negligible unless these organic inputs are stabilized (21). As previously mentioned, the development of soil aggregates usually protects or stabilizes organic wastes within soils (22). The establishment of favorable circumstances to produce stable soil macroaggregates should thus be a primary objective of any soil restoration since this will enable a crucial stage in the construction of a nutrient reserve (23). The application of beneficial biological products is being driven by the growing desire for sustainable, organic, and environmentally friendly agriculture techniques (24). These days, sustainability is a crucial part of the agricultural system. Improved plant health and development, water absorption, nutrient availability, stress tolerance, and biocontrol are possible benefits of using fungus in agriculture (25). Fungi play a part in the development of sustainable agricultural systems (26). The hyphae of the fungus found in the soil of terrestrial ecosystems form an extensive network that is intricately entwined with a variety of organisms, such as bacteria, nematodes, and arthropods (27). The symbiotic fungal connection with crops exhibits great potential due to its efficaciousness, mode of action unique to certain habits, and capacity to offer several advantages (28). This relationship, known as endophytism, provides a new field of study centered on the advantages of mutualistic interactions between nonpathogenic fungi and host crops (29). One of the benefits of endophytic fungi is that they can help plants develop and become more resilient to biotic (such as insects and plant diseases) and abiotic (such as heat, drought, and salt) challenges (30). It is frequently claimed that arbuscular mycorrhizal symbiosis increases plant resilience to drought stress and water shortage by changing plant physiology and gene expression (31). Native mycorrhizal fungus and the native microbiome reintroduction enhance plant variety, quicken succession, and promote the establishment of species that are frequently absent from restored ecosystems (32). Many studies have shown the importance of adding fungi and mycorrhizal fungi to soil and plant roots (table 1).

Table No. 1 shows the studies that show the success of using fungi in restoring soil and plants, which fall within sustainable development

Citation	Area of Study	Type of Study	Ectomycorrhizal fungi species used or found in the soil	Target sample	Result
(33)	Antaibao/ china	forest, scrubland, and grassland	*Ascomycota, Basidiomycota, Zygomycota*	Soil of forest, scrubland, and grassland	During the reclamation stage, soil C and N greatly improved.
(34)	Yaolin town, Tonglu country/China	Grassland	*Aspergillus Penicillium*	eggplant	The current study's fungal isolates were able to generate organic acids and solubilize phosphorus. impacted eggplant growth and biomass buildup
(35)	Nova Lima/ Brazil	Soil that contains arsenic	mycorrhizal fungi	*Anadenanthera peregrina*	The injection of arbuscular mycorrhizal fungus in the root plant *Anadenanthera peregrina* enhanced the shoot's phosphorus content and biomass output. In addition to the AMF inoculation, the organic matter addition lowered the pH of the soil, enhancing the roots' capacity to absorb arsenic.
(36)	Bloomington, Indiana	Hilltop Garden and Nature Center	Entrophospora infrequens ,Claroideoglomus lamellosum ,Claroideoglomus claroideum ,Aralia spinosa.	Grassland and plant	We discovered that the composition of plant communities was influenced by arbuscular mycorrhizal fungal inoculation; ideal prairie species redominated in plots infected with certain arbuscular mycorrhiza fungal treatments.
(37)	England	Acacia Reservation (Cleveland Metroparks) in Lyndhurst,	Liriodendron tulipifera P. serotina, and Q. rubra	Trees and Grassland	Soil and tree response to fungal inoculation
(38)	United States	Plot in Illinois, Kansas, and Oklahoma	AM fungal	Bothriochloa spp. Bromus inermis And Festuca arundinacea	Similar gains in plant establishment were observed when just native arbuscular mycorrhizal fungus communities were included, as opposed to entire soil microbiome amendment.
(39)	China	Loess Plateau	Ascomycota, Basidiomycota, and Zygomycota	artificial forest,; artificial grassland,; natural shrub,; natural grassland; and slope cropland,.	The presence of fungi helped the vegetation to flourish as well as the diversity of fungi due to the characteristics of the soil and plant.

Industry and Food

Since ancient times, fungi have been used in the manufacturing of many foods and drinks, including bread and alcoholic beverages (40). On the other hand, current industrial fermentation for the production of food components involves both yeasts and molds (41). Among other things, they are employed as biotransformation agents for the large-scale manufacture of pigments, fatty acids, organic acids, vitamins, and enzymes (42). When it comes to solving significant global issues, fungi are crucial. By using natural resources more effectively, the usage of fungi and their products can promote sustainability (43). A wide range of industrial fermentative processes, including the synthesis of pigments, lipids, polysaccharides, vitamins, and polyhydric alcohols, rely on the usage of fungi (44). Due to their high protein content, they are consumed as food (45), Yeast (Saccharomyces ssp.) has been used to make bread and beverages since 2500 BC (46). Then, in 1781, techniques for producing a high concentration of yeast were established (47,48). In Rome, edible mushrooms were widely consumed in the first century B.C. (49). Fungi are utilized in biomineralization and have antibacterial properties (50). In addition to promoting plant development and suppressing disease, fungi are highly beneficial in the synthesis of mycoproteins (51) The research is presented in Table 2.

Table No. 2 shows the research that shows the success of using fungi in the food and food industries

citation	material	Uses
(52)	Fungal melanin	Despite being a Polylactic acid promising bioplastic, its low solvent resistance and low heat stability currently limit its usage in food packaging applications. Fungal melanin modification of polylactic acid resulted in better barrier qualities.
(53)	Fungal melanin	microbial melanin has clear potential in industrial dyes.
(54)	Fungal melanin	fungal melanin's use in textiles is limited, investigators recently examined the ability of synthetic allomelanin to adhere to nylon-cotton fabric swatches
(55)	Fungal melanin	Anti bacterial for *E. coli*, *Proteus sp.*, *Klebsiella pneumonia*, and *Pseudomonas fluorescens* and anti fungi for *Trichophyton simii* and *T. rubrum*
(56)	Mushrooms	Because they contain all of the required amino acids and have a relatively high protein content (20–30% dry matter as crude protein), fungi provide an excellent dietary source. In addition to providing dietary fiber, fungal biomass is almost completely cholesterol-free.
(57)	Yeast	They have been employed in customary fermentation procedures such as the production of wine, beer, and bread. Yeasts have many uses in the health food industry today, including as food additives, conditioners, and flavoring agents; they are also used as alternative sources of high-nutritional value proteins, enzymes, and vitamins; they are also used to produce microbiology media and extracts, as well as livestock feeds.
(58)	*Aspergillus wentii*, *Penicillium citrinum*, and *Candida lipolytica*	Fungi are the source of several substances used in food processing, including flavorings, enzymes, acidulants, colorants, vitamins, and polyunsaturated fatty acids, which are produced by industrial fermentation.

Pharmaceutical industries

Microorganisms can change their surroundings and have an impact on nearly every ecological activity (59). Humans are facing problems from the rapidly changing microbial population, including drug-resistant pathogenic microorganisms and the advent of novel illnesses (60,61). Additionally, the adverse effects of synthetic medications during medical treatment have increased demand globally for natural medications (62). Bioremediation processes due to fungi's physiological and metabolic properties that allow them to convert even highly harmful xenobiotic chemicals, fungus are known to be incredibly understood microorganisms (63). Growing research suggests that fungi can alter the structures of several medicinal molecules (64,65), such as antibiotics (66), β-blockers (67), and anti-inflammatories (68). This is made feasible by many processes working in tandem with extracellular and intracellular enzymes, which have a wide range of biotechnological uses. Fungi have been employed in antibiotics such as *penicillin* (69) and the immunosuppressant cyclosporine (70), along with anticholesterol statins (71). It was found that some fungi, *Aspergillus terreus*, produce Lovastatin, which can lower blood cholesterol levels (72). Also, *Penillium citrinum*, which reduces the occurrence of simvastatin (73), which is a fermentation product, reduces the occurrence of neurodegenerative disorders such as Alzheimer's disease and Parkinson's disease (74).

Effect of fungal community on decomposition of organic matter

In ecosystem functioning, decomposition is a process that is on par with primary production (75). Although decomposer (saprotrophic) fungi are susceptible to disturbance, pollution, and environmental change, they are an important part of the carbon and nutrient cycle in ecosystems (76,77). Understanding how decay rates rely on the quantity, regularity, and function of the fungal species present is crucial because the effects of environmental change on fungal diversity may affect ecosystem function through decomposition (78). For instance, the species richness of decomposer fungus linked to plant litter is sometimes quite great (79). Decomposition of litter and wood, mainly in the forest, takes place by the combined action of different types of fungi (80), Fungi like Fusarium, Chaetomium, Chitridium, Penicillium, Aspergillus, etc (81,82)' can decompose the structural polymers such as cellulose, hemicellulose, lipid, protein, starch, etc (83- 85). By decomposing the organic matter, fungi help to increase minerals and other substances, thereby the fertility of the soil is increased (86). Plant litter mostly consists of lignocellulose (87). Enzymatic systems play a major role in the breakdown of lignocellulose by white-rot fungus (88). These systems comprise oxidative enzymes that break down lignin (such as laccases and Class II peroxidases), as well as enzymes that break down polysaccharides (such as lytic polysaccharide monooxygenases (LPMOs, previously GH61) and cellobiose dehydrogenase (CDH) (89). The advantage of fungi doing this is not so much the acquisition of metabolic carbon as it is the release of nitrogen that has been trapped in organic matter complexes that are resistant to hydrolysis (90). A logical and simple theory is that mycorrhizal fungi gain from the breakdown of organic materials in a way that is comparable to that of free-living saprotrophs that is, as a source of reduced carbon molecules to sustain metabolism (91). Because of this facultative saprotrophism, mycorrhizal fungi can thrive when their hosts don't produce enough carbon dioxide or when their hosts don't produce enough of it (92).

Conclusion

The last 25 years have seen the scientific community become aware of the significant role fungus plays in industries, biotechnology, agriculture, medicine, and ecology. Additionally, applied in the fermentation industry. Mushrooms are grown and sold in both developed and developing nations, and the current structure of the cultivation sector allows the world's mushroom growers to reap significant benefits. The monetary return on the mushroom crop is significantly contributing to rural income, because fungi contain proteins, it has become necessary to cultivate them to support food and is considered a sustainable alternative. A significant component of the microbial ecosystem is fungi. Most fungi break down lignin and other indigestible soil organic matter; however, certain fungi are more specialized and require a steady supply of food, since they thrive in undisturbed soil environments. Fungi have a symbiotic relationship with soil and recycle nutrients from it.

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