The Role of Pyrenomycetous Fungi in Environmental Ecology – A Review

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Abstract— *Pyrenomycetous fungi, the diverse group within the Ascomycota phylum, play a critical role in environmental ecology through their involvement in the decomposition of plastic, organic matter and nutrient cycling. These fungi inhabit a variety of ecological niches, including soil, leaf litter, and decaying wood, where they contribute significantly to the breakdown of complex organic compounds. This decomposition process releases essential nutrients back into the ecosystem, promoting soil fertility and supporting plant growth. Pyrenomycetous fungi exhibit a wide range of enzymatic capabilities, including cellulases, laccases, esterases and peroxidases, which enable them to degrade cellulose, lignin, plastic and other complex organic molecules. Their activity accelerates the conversion of organic matter into humus, enhancing soil structure and water retention. Additionally, these fungi form intricate relationships with other soil microorganisms, facilitating the formation of stable soil aggregates and promoting microbial diversity. The ecological importance of saprophytic pyrenomycetous fungi extends beyond nutrient cycling. They play a pivotal role in carbon sequestration by decomposing organic material and regulating carbon dioxide release from soils. Their presence influences the dynamics of soil organic carbon pools, contributing to the mitigation of climate change. Furthermore, these fungi are involved in the detoxification of soil pollutants, including heavy metals and xenobiotics, through various biochemical pathways. Research into the biodiversity and functional roles of saprophytic fungi are essential for understanding ecosystem processes and developing sustainable land management practices*.

Keywords— Ecology, Environment, Organic Matter, Pyrenomycetous Fungi, Saprophyte.

I. INTRODUCTION

Pyrenomycetes are fungi that mainly grow as tiny, flask-shaped fruiting bodies called perithecia that contain asci and ascospores. We can find them on a variety of surfaces like soil, animal waste, decaying leaves, wood, and even other fungi. These "little black dots" make up the largest group of fungi in the Ascomycota phylum. Pyrenomycetes are both ecologically and economically important because they include fungi which are often used in research, as well as harmful pathogens that cause diseases like chestnut blight, Dutch elm disease, and beech bark disease. These fungi are found all over the world in different ecosystems and geographical areas primarily as saprobes, playing a key role in breaking down organic matter and recycling nutrients. Most of them are hard to spot without a keen eye since their fruiting bodies are usually small (less than 1 mm in diameter) and dark-coloured, often blending into the surface of plant material, both living and dead. Many Pyrenomycetes also have a stroma, a much larger structure embedding the perithecia in fungal tissue. In narrow sense Pyrenomycetes encompass the class Sordariomycetes, but some species of Dothideomycetes, Eurotiomycetes and Lecanoromycetes with superficially similar fruiting bodies. The terms “Pyrenomycetes” is no longer used in a taxonomic sense and have been replaced by the terms Sordariomycetes, to refer to one major Class of fungi in the Phylum Ascomycota. In this paper the term “pyrenomycetes” is used in a general sense to refer to the fungi that occur in the class Sordariomycetes.

Fungi are the principal decomposers in terrestrial ecosystems and one of the most important ecological roles of fungi, is there function as decomposer also known as saprophyte. Fungi breakdown Complex organic matters such as dead plants, animals and other organic materials, into simpler compounds. This decomposition process is vital for nutrient cycling in ecosystems. Without this, organic materials would accumulate and essential nutrients like carbon, nitrogen and phosphorus would become trapped, preventing their return to the soil and the food chain. fungi secrete enzymes that breakdown tough substances such as cellulose, Lignin and chitin which most other organisms cannot degrade efficiently. Pyrenomycetous fungi not only decompose organic matters but also play an important role in plastic biodegradation. The main classes of enzymes involved in plastic biodegradation are hydrolases and oxidoreductases. These enzymes have been extensively studied due to their involvement both in natural and industrial processes. For example, in nature and industry they are essential in lignocellulose biodegradation , fungal pathogenesis and the hydrolysis of triacylglycerol to fatty acids. These enzymes also have applications in the food and textile industries and in bioremediation processes.

1.1 Systematic Position of Pyrenomycetes:

Pyrenomycetes (Sordariomycetes of Eriksson and Winka 1998) is a class name formerly used to refer to a group of species with a particular shared morphology. It now is used to designate a clade that includes the orders Diaporthales, Halosphaeriales, Hypocreales, Lulworthiales, Microascales, Ophiostomatales, Phyllachorales, Sordariales and Xylariales [25]. Although the taxa in the clade encompass a wide range of macromorphologies and micromorphologies, the vast majority have a flask-shaped ascomata or perithecia. The Pyrenomycetes clade also includes numerous lineages of cleistothecial fungi, which represent multiple and repeated losses of the perithecial neck and ostiole [25]. Although almost all perithecial ascomycetes are included in the pyrenomycetes clade, there are a few exceptions. Pyxidiophora species and the Laboulbeniales are arthropod-associated ascomycetes comprising a separate clade based on SSU rDNA analyses .

In traditional taxonomy ascomycetes were classified according to their ascoma-types, with the class Pyrenomycetes including all taxa having perithecia. Later, the development of ascomata and the type of ascus were employed for higher-level classification, and consequently, Loculoascomycetes was separated from Pyrenomycetes[7,9,13]. However, molecular studies show that even these revised classifications were too coarse. The Loculoascomycetes fall into two distinct and not closely related groups, which are placed in two clades: Chaetothyriomycetidae and Dothideomycetes[14,16]. Ascospore morphology has been widely used in taxonomy of ascomycetes, and Sordariales is a prominent example of this. Molecular data suggest that ascomatal wall morphology is a better predictor of phylogenetic relationships in these fungi. Further, the molecular data helped to redefine the circumscription of Sordariales. The majority of non-lichenized pyrenomycetes form a monophyletic group: Sordariomycetes. However, the lichenized pyrenomycetes are highly polyphyletic.

Pyrenocarpous lichen-forming fungi occur in several lineages each in Dothideomycetes, Chaetothyriomycetidae and Lecanoromycetes, whereas no lichenized forms are currently known in the classical Sordariomycetes [27]. Sordariomycetes are also known as Pyrenomycetes, from the Greek πυρὴν - 'the stone of a fruit' - because of the usually somewhat tough texture of their tissue [5].

II. MATERIALS AND METHODS

Literature Review was the primary method of present study. The data gathered herein was from a variety of sources, including published research, online databases, and direct communications. Information on plastic-degrading fungi mostly came from platforms like Google Scholar, ResearchGate, PubMed, and Web of Science.

III. DISCUSSION

The members of Pyrenomycetes are found in very diverse condition in nature. They exist in a wide range of Habitats as biotrops, necrotrophs and as well as saprotrophs. The biotrobes are ecologically obligate parasite and 'in vivo' obtain nutrients only from living host cells. Many of the Pyrenomycetes are saprotrophs and cause damage to various objects like paper, leather, food stuffs and wood. They utilize non-living materials, other than that killed by the fungus itself. Saprotrophic Pyrenomycetes are usually found on decaying plant materials such as logs and stumps, dead twigs and branches of tree, dead leaves and stems of herbaceous plants, Others are coprophilous, inhabiting the dung of animals. Some of these perithecial Ascomycetes also are well known for their production of mycotoxins in stored grains, and these metabolites cause adverse effect in mammals. Pyrenomycetes are a group of fungi that are ecologically important and play a role in many ecosystems:

3.1 Lignin Degradation:

Lignin is a complex aromatic polymer found in the cell walls of vascular plants, providing rigidity and resistance to microbial attack. Saprophytic pyrenomycetous fungi possess specialized enzymes, such as lignin peroxidases and manganese peroxidases, which allow them to break down lignin. This process is essential for converting wood and other lignin-rich materials into simpler compounds, making nutrients available to other organisms. Effective lignin degradation contributes to soil formation and carbon cycling, as it releases carbon dioxide and other nutrients back into the ecosystem. The ability of several Pyrenomycetes (*Biscogniauxia nummularia, Daldinia concentrica, Graphostroma platystoma, Hypoxylon howeanum, H. multiforme, H. truncatum, Rosellinia aquila and Ustulina deusta*) fungi to degrade Japanese beech (*Fagus crenata*) wood, microcrystalline cellulose and lignin-related dimeric compounds was studied. Changes in the lignin component of the wood during decay were also measured [24].

3.2 Cellulose Decomposition

Cellulose is a primary structural component of plant cell walls, consisting of long chains of glucose molecules. Pyrenomycetous fungi produce cellulases, enzymes that hydrolyze cellulose into simpler sugars. This decomposition process is crucial for recycling carbon and other nutrients, enabling the growth of plants and microorganisms in the soil. By breaking down cellulose, these fungi play a vital role in enhancing soil fertility and maintaining healthy ecosystems, especially in forested areas where plant debris accumulates.

3.3 Organic Matter Recycling:

Organic matter recycling refers to the breakdown of dead plant and animal material into simpler organic compounds by saprophytic fungi. Pyrenomycetous fungi are key players in this process, as they decompose various organic substrates, including leaf litter, dead wood, and animal remains. Through enzymatic activity, they convert complex organic materials into simpler forms that can be assimilated by soil microorganisms and plants. This process not only enriches the soil with essential nutrients but also helps in maintaining soil structure and health, promoting biodiversity and ecosystem stability.

3.4 Faunal Interaction:

Some pyrenomycetous fungi, such as *Trichoderma*, can trap nematodes, using them as a nutrient source while influencing soil food webs.

3.5 Plastic Biodegradation:

Plastic waste accumulates in the environment to hazardous levels, because it is inherently recalcitrant to biological degradation. Biodegradation is a complex process of physico-chemical transformation of polymers into smaller units mediated by microorganisms. Microorganisms, including pyrenomycetes fungi, are able to biochemically degrade, assimilate and metabolise complex organic compounds, xenobiotics and recalcitrant substances for their energy needs. The main classes of enzymes involved in plastic biodegradation are hydrolases and oxidoreductases. These enzymes have been extensively studied due to their involvement both in natural and industrial processes. For example, in nature and industry they are essential in lignocellulose biodegradation [6], fungal pathogenesis [3] and the hydrolysis of triacylglycerol to fatty acids [13]. *Chaetomium globosum, Cladosporium* [2] *Curvularia senegalensis* and *Trichoderma harzianum* [23] etc. improve and promote the biodegradation of complex and polluting polymers through enzyme like esterases, Laccases and Peroxidaces.

3.6 Bioremediation:

Bioremediation is a process that occurs by using microorganisms that pollutants could transit or degrade into low-degree pollution. Bacterias, fungus, algae, and plants use in this method. In other words, enzymes of these microorganisms attack the pollutants and convert them to low risk pollutants [1,8]. In bioremediation after degradation of pollutions, the society of microorganisms reduced, and the presence of microorganisms don't create more pollutions [13]. Bioremediation is a new technology which can be used for treatment of a different group of environmental pollutants with other physical and chemical methods of treatment, simultaneously [17,26].

3.6.1 Microbial bioremediation:

Microbial bioremediation are a process that use spent biomass, enzymes, or microorganisms for removing environmental pollutions. Pollutants in the various environmental sections, always have contact with microorganisms due to the microorganisms' existence everywhere. Microbes allow the pollutant to be channeled into the normal microbial metabolic pathway for biotransformation and degradation. Microbes transform or break down the pollutants via their intrinsic metabolic processes with or without slight pathway modifications. In the bioremediation process, by using naturally occurring microbial catabolic capabilities, most of the synthetic compounds such as metals, radionuclides, polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and hydrocarbons (e.g., oil) can be accumulated, transform or degrade [8, 22]. Microbial bioremediation includes processes such as aerobic process, anaerobic process, and combination of these two methods. Cellules that need the oxygen molecules presence during the cellular processes named aerobic, and cellulose that do not require for the presence of oxygen molecules named anaerobic [15,17]. Microorganisms include fungi adsorb pollutions into their active cites and degrade the pollutions and convert them in other forms and finally remove the pollutions.

Some species of pyrenomycetous fungi (Sordariomycetes) are economically important as bio-control agents, [11] and other genera can produce a wide range of chemically diverse metabolites, that are important in agricultural, medicinal and other biotechnological industries. [12]

IV. CONCLUSION

Pyrenomycetes are a remarkably diverse and functionally significant group of fungi. Their roles in **decomposition, biodegradation, bioremediation, biocontrol, and industrial applications** highlight their ecological and economic importance. While some species pose challenges as plant pathogens, their potential in sustainable environmental solutions and industrial applications cannot be overlooked. Further research into their enzymatic pathways and genetic mechanisms will enhance our ability to harness their capabilities for environmental conservation, waste management, and biotechnological advancements.

REFERENCES

[1] Ahmadi S, Fazilati M, Mousavi SM, Nazem H. Anti bacterial/fungal and anti-cancer performance of green synthesized Ag nanoparticles using summer savory extract. Journal of Experimental Nanoscience. 2020;15(1):363-80.

[2] Álvarez-Barragán J., Domínguez-Malfavón L., Vargas-Suárez M., González-Hernández R., Aguilar-Osorio G., Loza-Tavera H. Biodegradative activities of selected environmental fungi on a polyester polyurethane varnish and polyether polyurethane foams. Appl. Environ. Microbiol. 2016;82:5225–5235. doi: 10.1128/AEM.01344-16. [DOI] [PMC free article] [PubMed] [Google Scholar]

[3] *Arya G.C., Cohen H. The Multifaceted Roles of Fungal Cutinases during Infection. J. Fungi. 2022;8:199. doi: 10.3390/jof8020199.* [DOI] [PMC free article] [PubMed] [Google Scholar]

[4] *Behbudi G., Yousefi K., Sadeghipour Y. Microbial Enzymes Based Technologies for Bioremediation of Pollutions. J. Environ. Treat. Tech. 2021;9:463–469.* [Google Scholar]

[5] Century Dictionary entry for pyrenomycetes

[6] Daly P., Cai F., Kubicek C.P., Jiang S., Grujic M., Rahimi M.J., Druzhinina I.S. From lignocellulose to plastics: Knowledge transfer on the degradation approaches by fungi. Biotechnol. Adv. 2021;50:107770. doi: 10.1016/j.biotechadv.2021.107770. [DOI] [PubMed] [Google Scholar]

[7] Eriksson, Ove & Baral, Hans-Otto & Currah, R.S. & Hansen, Karen & Kurtzman, Cletus & Rambold, G. & Læssøe, Thomas. (2001). Outline of Ascomycota. Myconet. 7. 1-88.

[8] Goudarzian N, Sadeghi Z, Mousavi SM, Hashemi SA, Banaei N. Chemical constituent and determination of antimicrobial and antifungal activities of Ulva lactuca species obtained from Iranian Gheshm Island. Int J Sci Eng Res. 2017;8:1275-9.

[9] H. Thorsten Lumbsch, Sabine M. Huhndorf, Whatever happened to the pyrenomycetes and loculoascomycetes?, Mycological Research, Volume 111, Issue 9, 2007, Pages 1064-1074, https://doi.org/10.1016/j.mycres.2007.04.004

[10] Helaly, S.E.; Thongbai, B.; Stadler, M. (2018). "Diversity of biologically active secondary metabolites from endophytic and saprotrophic fungi of the ascomycete order Xylariales". Natural Product Reports. 35 (9): 992
1014. doi:10.1039/C8NP00010G. PMID 29774351.

[11] Kaewchai, S.; Soytong, K.; Hyde, Kevin D. (2009). "Mycofungicides and fungal biofertilizers". Fungal Diversity. 38: 25–50.

[12] Karigar CS, Rao SS. Role of microbial enzymes in the bioremediation of pollutants: a review. Enzyme research. 2011;2011.

[13] Kohlmeyer, Jan & Spatafora, Joseph & Volkmann-Kohlmeyer, Brigitte. (2000). Lulworthiales, a New Order of Marine Ascomycota. Mycologia. 92. 453. 10.2307/3761504

[14] Lundqvist, N. (1972). "Nordic Sordariaceae s. lat". Symbolae Botanicae Upsalienses. 20: 1–374. ISSN 00820644. urn:nbn:se:uu:diva-124116.

[15] *Mehta A., Bodh U., Gupta R. Fungal lipases: A review. J. Biotech Res. 2017;8:58–77.* [Google Scholar]

[16] Miller AN, Huhndorf SM. 2009. Pyrenomycetes of the World: https://www-s.life.illinois.edu/pyrenos/ (Accessed on <date>).

[17] Mousavi SM, Hashemi SA, Babapoor A, Savardashtaki A, Esmaeili H, Rahnema Y, et al. Separation of Ni (II) from Industrial Wastewater by Kombucha Scoby as a Colony Consisted from Bacteria and Yeast: Kinetic and Equilibrium Studies. Acta Chimica Slovenica. 2019;66(4):865-73.

[18] Novotný Č, Svobodová K, Erbanová P, Cajthaml T, Kasinath A, Lang E, et al. Ligninolytic fungi in bioremediation: extracellular enzyme production and degradation rate. Soil Biology and Biochemistry. 2004;36(10):1545-51.

[19] Ogunbayo, A.; Olanipekun, O.; Adamu, I. Preliminary Studies on the Microbial Degradation of Plastic Waste Using *Aspergillus niger* and *Pseudomonas* sp. J. Environ. Prot. 2019, 10, 625–631. [CrossRef]

[20] Pathirana, R.; Seal, K. Gliocladium Roseum (Bainier), a Potential Biodeteriogen of Polyester Polyurethane Elastomers; John and Wiley and Sons: Hoboken, NJ, USA, 1983.

[21] Sangale, M.K.; Shahnawaz, M.; Ade, A.B. Potential of Fungi Isolated from the Dumping Sites Mangrove Rhizosphere Soil to Degrade Polythene. Sci. Rep. 2019, 9, 5390. [CrossRef] [PubMed]

[22] Singh P, Singh VK, Singh R, Borthakur A, Madhav S, Ahamad A, et al. Chapter 1 - Bioremediation: a sustainable approach for management of environmental contaminants. In: Singh P, Kumar A, Borthakur A, editors. Abatement of Environmental Pollutants: Elsevier; 2020. p. 1-23.

[23] Sowmya H.V., Krishnappa M., Thippeswamy B. Degradation of polyethylene by Trichoderma harzianum—SEM, FTIR, and NMR analyses. Environ. Monit. Assess. 2014;186:6577–6586. doi: 10.1007/s10661-014-3875-6. [DOI] [PubMed] [Google Scholar]

[24] Tanaka, H.; Itakura, S.; Enoki, A.(2002). Memoirs of the Faculty of Agriculture of Kinki University 35: 13-20.

[25] Taylor, J.W., Swann, E.C., Berbee, M.L. (1994). Molecular Evolution of Ascomycete Fungi: Phylogeny and Conflict. In: Hawksworth, D.L. (eds) Ascomycete Systematics. NATO ASI Series, vol 269. Springer, Boston, MA. https://doi.org/10.1007/978-1-4757-9290-4_17

[26] Tekere M. Microbial Bioremediation and Different Bioreactors Designs Applied. Biotechnology and Bioengineering: IntechOpen; 2019.

[27] Wijayawardene, N.N.; Hyde, K.D.; Dai, D.Q.; Sánchez-García, M.; Goto, B.T.; Saxena, R.K.;et al.(2022). "Outline of Fungi and fungus-like taxa – 2021". Mycosphere. **13**(1):53-453[160] . doi:10.5943/mycosphere/13/1/2. hdl:10481/76378. S2CID 249054641

[28] Yang, S.; Liu, M.; Long, L.; Zhang, R.; Ding, S. Characterization of a Cutinase from Myceliophthora thermophila and Its Application in Polyester Hydrolysis and Deinking Process. Process Biochem. 2018,66, 106–112. [CrossRef].