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THE POTENTIAL OF PLASTIC DEGRADATION AS SOIL REMEDIATOR FOR PLANTS: A REVIEW

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ABSTRACT

The considerable accumulation of plastic wastes around the globe posed hazards to the environment. Thus, the potential of biological systems to degrade synthetic plastics is now a recent focus. Some insects, bacteria and fungi have been shown to ingest these polymers and convert them into environmentally friendly carbon compounds (Amobonye *et al*. 2021). Most microorganisms are used as a foundation of bioplastic production and also used for the decomposition of plastics. Earth is a home to promising microorganisms that have potent use and solution to the never ending plastic wastes. Yet, there is still limited study on the use of plastic compost as fertilizer and soil conditioner. Bioplastics applied in plants such as corn, soya bean, safflower, groundnut, sesame and sunflower present contrasting effects. Hence, there is a need to explore the varied effects of composted plastics to various kinds of plants. This review therefore presents potent plastic degrading microbes for the production of composted plastics as soil conditioner and fertilizer to crops.

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Keywords: Water, conservation, technology, soak pit, drip-irrigation.

INTRODUCTION

The use of plastics globally is tremendous. Plastic polymers with different properties have been developed in the last 150 years to replace materials such as wood, glass and metals across various applications. Nevertheless, the distinct properties which make plastic desirable for our daily use also threaten our planet's sustainability (Amobonye et al. 2021). This posed detrimental effects to the environment as a source of pollutants to the soil, air and aquatic resources.

The degradation of plastics takes thousands of years and hence, the role of microorganisms is vital in the decomposition of plastics in the environment. Plastic waste serves as the source of energy and carbon required for their growth and development. It is a key part of recycling materials by the natural ecosystem (Joel, 1995). Recent focus has been placed more on the potential of biological systems to degrade synthetic plastics. In this regard, some insects, bacteria and fungi have been shown to ingest these polymers and convert them into environmentally friendly carbon compounds (Amobonye et al. 2021). Earth has rich natural resources hence, are potential sources of undiscovered yet promising microorganisms that may be useful and solutions to the never ending plastic wastes. Rutkowska et al. (2002) reported that microorganisms such as bacteria, fungi, and algae could degrade polymer materials through their metabolic activity, the so-called “biodegradation,” without the involvement of heat energy under aerobic or anaerobic conditions. Most microorganisms are used as a foundation of bioplastic production and also used for the decomposition of plastics. Selection of appropriate microbial strains, genetic, molecular analysis for identifying genes responsible for producing plastic degrading enzymes and

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*Corresponding author: *alminda.fernandez@jmc.edu.ph* recombinant DNA technology can improve and accelerate remediation of plastic waste and its disposal (Venkatesh et al. 2021).

Up to date there is still limited study on the use of plastic compost as fertilizer for plants and as a soil conditioner. The bioplastic mixed in cattle manure compost could reduce soil acidity and electrical conductivity but did not affect plant nutrients (Tangkoonboribun, et al. 2013). However, the biodegraded polythene caused a decreased percentage of seed germination in plants including soya bean, safflower, groundnut, sesame and sunflower (Aswale, 2010). Hence, these contrasting effects need much more studies to explore the varied effects of composted plastics to various kinds of plants. This paper therefore presents the potential use of bioplastics as soil conditioner and plant fertilizers.

PLASTICS DEGRADATION FOR SOIL AND PLANTS: A REVIEW

Plastics Use and Degradation

Plastic polymers with different properties have been developed in the last 150 years to replace materials such as wood, glass and metals across various applications. Nevertheless, the distinct properties which make plastic desirable for our daily use also threaten our planet's sustainability. Plastics are resilient, non-reactive and most importantly, non-biodegradable. Hence, there has been an exponential increase in plastic waste generation, which has since been recognized as a global environmental threat. Plastic wastes have adversely affected life on earth, primarily through their undesirable accumulation in landfills, leaching into the soil, increased greenhouse gas emission, etc. Even more damaging is their impact on the aquatic ecosystems as they cause entanglement, ingestion and intestinal blockage in aquatic animals. Furthermore, plastics, especially in the microplastic form, have also been found to interfere with chemical interaction between marine organisms, to cause intrinsic toxicity by leaching, and by absorbing persistent organic contaminants as well as pathogens. The current methods for eliminating these wastes (incineration, landfilling, and recycling) come at massive costs, are unsustainable, and put more burdens on our environment. Thus, recent focus has been placed more on the potential of biological systems to degrade synthetic plastics. In this regard, some insects, bacteria and fungi have been shown to ingest these polymers and convert them into environmentally friendly carbon compounds. Hence, in the light of recent literature, this review emphasizes the multifaceted roles played by microorganisms in this process. The current understanding of the roles played by actinomycetes, algae, bacteria, fungi and their enzymes in enhancing the degradation of synthetic plastics are reviewed, with special focus on their modes of action and probable enzymatic mechanisms. Besides, key areas for further exploration, such as the manipulation of microorganisms through molecular cloning, modification of enzymatic characteristics and metabolic pathway design, are also highlighted (Amobonye et al. 2021).

The degradation of plastics takes thousands of years and hence, the role of microorganisms is vital in the decomposition of plastics in the environment. Plastic waste serves as the source of energy and carbon required for their growth and development. It is a key part of recycling materials by the natural ecosystem (Joel, 1995). The ecosystem is rich with natural resources. Hence, these areas are potential sources of undiscovered yet promising microorganisms that may be useful and solutions to the never ending plastic wastes. Various attempts have been made since the industrial use of plastics to minimize the accumulation of plastic wastes such as the use of biodegradable and compostable plastics obtained from biomass derived monomers (Ciriminna, R., & Pagliaro, M. 2019).

Recent discoveries of plastic-eating microorganisms show that evolution is already getting to work. A year after the 2016 discovery of Ideonella sakaiensis in Osaka, scientists reported a fungus able to degrade plastic at a waste disposal site in Islamabad, Pakistan. In 2017 a biology student at Reed College in Oregon analyzed samples from an oil site near her home in Houston, Texas, and found they contained plastic-eating bacteria. In March 2020, German scientists discovered strains of bacteria capable of degrading polyurethane plastic after collecting soil from a brittle plastic waste site in Leipzig (Carpenter, S. 2021). In order to make any of these naturally-occurring bacteria useful, they must be bioengineered to degrade plastic hundreds or thousands of times faster. Scientists have enjoyed some breakthroughs. In 2018, scientists in the U.K. and U.S. modified bacteria so that they could begin breaking down plastic in a matter of days. In October 2020 the process was improved further by combining the two different plastic-eating enzymes that the bacteria produced into one “super enzyme” (Carpenter, S. 2021).

Plastic Biodegradation

Biodegradation involves biodeterioration, fragmentation, assimilation and mineralisation. PE, PU, PET, PS and nylon enzymes are major groups involved in plastic biodegradation. Rutkowska et al. (2002) reported that microorganisms such as bacteria, fungi, and algae could degrade polymer materials through their metabolic activity, the so-called "biodegradation," without the involvement of heat energy under aerobic or anaerobic conditions. In the aerobic biodegradation, the end products produced were CO2 and H2O in the soil composite method. The anaerobic biodegradation of landfills and sediments includes methane, H2O and CO2 as the end products. Usually, it is a complex process to produce water and CO2 from the long-chain polymer, which needs various steps and different microbial activity. In each step, a particular microbial community will break the polymer into granules and the others will utilize the monomers and excrete them.

Microbial depolymerases, hydrolases, and peroxidases are the key enzymes in biodegradation. Decomposition of PE has been initiated with its attachment to the microbial cell surface as reported by Venkatesh et al. (2021). Various bacteria, including Streptomyces setonii 75Vi2 and Streptomyces viridosporus T7A and Streptomyces badius 252 and fungi, secrete extracellular enzymes that facilitate the decomposition of PE (Iiyoshi et al., 1998, Pometto et al., 1992, Kim et al., 2005). In fungi, the ligninolytic system's extracellular enzymes contain laccases, oxidases enzymes and catalases that produce the extracellular hydrogen peroxide (Ruiz-Dueñas and Martínez, 2009). Based on the microbe, culture conditions, strains, and enzymes involved the degradation of plastic may vary (Seneviratne et al., 2006). The decomposition of lignin involves three enzymes, the MnO2 (Manganese peroxidase) and lignin peroxidase (LiP) and phenoloxidase, with copper, called laccase. (Iiyoshi et al., 1998, Maciel et al., 2010). Based on this ligninolytic enzyme's potency, they have been used widely in different industries such as chemical, textile, fuel, agricultural, food, cosmetic, paper, and used to remediate xenobiotic compounds dyes (Maciel et al., 2010). During the degradation of phenolic compounds, the lignin materials are degraded via oxidation under MnO2 (MnP) and H2O2. MnO2 oxidizes monomeric phenols and Mn-II to Mn-III (Gilan et al., 2004), and Mn-III oxidizes synthetic lignin (Wariishi et al., 1991) and phenolic lignin dimmers (Wariishi et al., 1989) via the formation of phenoxy radicals (Kim et al., 2005). The production of various secondary products from PE degradation is based on biodegradation conditions. Under aerobic conditions, CO2, H2O is the end product produced and anaerobic degradation leads to methane (under methanogens), water and carbon dioxide as final products. H2S is produced under the existence of sulfate-reducing bacteria (Arutchelvi et al., 2008). Natural decomposition of the polymer can be characterized by uptake of O2, the rate of CO2 released alterations in the polymer's physical and chemical properties, and microbial growth rate (Mohan and Srivastava, 2010).

Most microorganisms are used as a foundation of bioplastic production and also used for the decomposition of plastics. Although bioplastics production is considered more expensive than artificial plastic, it has many advantages over them. Some bio-polymers have also gained public acceptance and are now being produced. The useful breakdown of plastic bags takes more than a thousand years. For the decomposition of plastics, microorganisms should be calculated extensively so that solid wastes can be decomposed. Thus, microbes have played an important role in decomposition as well as the production of plastics. Selection of appropriate microbial strains, adapting suitable in-situ and ex-situ remediation techniques, continuous monitoring of remediation site, and proper maintenance such as providing proper aeration, nutrients necessary for microbial growth and physicochemical conditions are highly required. Genetic, molecular analysis for identifying genes responsible for producing plastic degrading enzymes and recombinant DNA technology can improve and accelerate remediation of plastic waste and its disposal (Venkatesh et al. 2021).

Effects of Bioplastics on Soil and Plants

There is still limited study on the use of plastic compost as fertilizer for plants and as soil conditioner. The effect of bioplastic mixed in organic fertilizer on corn growth and soil properties was studied in a pot experiment. The bioplastics were mixed in organic fertilizer and tested in corn compared with different types and rates of fertilizer application e.g., control, compost of cattle manure rate 1562.5, 3125, 6250 Kg/ha, compost of cattle manure mixed with polyethylene 15 m thickness, compost of cattle manure mixed with bioplastic 15 and 25 m thickness rate 1562.5, 3125, 6250 Kg/ha. Thirteen treatments were designed in Randomized complete block design with 4 replications at the greenhouse of Thailand Institute of Scientific and Technological Research. The results were found significantly different on fresh and dry weight of stalk. The composted bioplastic 25 m with cattle manure at the rate of 3,125 Kg/ha has maximum weight of stalk then was composted of bioplastic 15 m thickness with cattle manure at the rate of 1,000 Kg/rai and cattle manure compost at the rate of 3,125 Kg/ha respectively. Yield of corn was not different between treatments but the highest dry weight of seed was used composted of bioplastic 25 m thickness with cattle manure at the rate of 3,125 Kg/ha then was composted of bioplastic 15 m thickness with cattle manure at the rate of 3,125 Kg/ha and cattle manure compost at the rate of 3,125 Kg/ha respectively. The bioplastic mixed in cattle manure compost could reduce soil acidity and electrical conductivity but did not affect plant nutrients (Tangkoonboribun, et al. 2013).

However, in 2010, Aswale monitored the effect of biodegraded polythene on seed germination in plants including soya bean, safflower, groundnut, sesame and sunflower. During the observation, the pre-treated seeds show a decreased percentage in seed germination. Hence, much more studies are needed to explore the varied effects of composted plastics to various kinds of plants.

CONCLUSION

Microbial depolymerases, hydrolases, and peroxidases are the key enzymes in biodegradation using microorganisms such as bacteria, fungi, and algae that could degrade polymer materials through their metabolic activity, without the involvement of heat energy under aerobic or anaerobic conditions. In order to make any of these naturally-occurring bacteria more potent, they must be bioengineered to degrade plastic hundreds or thousands of times faster.

At the moment, there is still limited study on the use of plastic compost as fertilizer for plants and as soil conditioner. The effect of bioplastic mixed in organic fertilizer on corn growth and soil properties could reduce soil acidity and electrical conductivity, with highest dry weight of seed but did not affect plant nutrients. Biodegraded polythene used for seed germination in plants including soya bean, safflower, groundnut, sesame and sunflower showed a decreased percentage in seed germination. Therefore, more studies are yet to explore the varied effects of composted plastics to various kinds of plants.

REFERENCES

1. **Amobonye, A., Bhagwat, P., Singh, S., Pillai, S.** (2021). Plastic biodegradation: Frontline microbes and their enzymes, Science of The Total Environment, Volume 759, 143536, ISSN 0048-9697, in https://doi.org/10.1016/ j.scitotenv. 20200.143536.
2. https://www.sciencedirect.com/ science/article/ abs/pii/S0048969720370674.
3. **Arutchelvi, J., Sudhakar, M., Arkatkar, A., Doble, M., Bhaduri, S.,** 2008. Biodegradation of polyethylene and polypropylene. *Ind. J. Biotechnol.* 7, 9–22.
4. **Aswale, P.,** 2010. Studies on biodegradation of polythene PhD thesis. Dr Babasaheb Ambedkar Marathwada University, Aurangabad, India.
5. **Carpenter, S.** (2021). The Race To Develop Plastic-Eating Bacteria.
6. https://www.forbes.com/sites/scottcarpenter/2021/03/10/the-race-to-develop-plastic-eating-bacteria/?sh= 54c0a597406a.
7. **Ciriminna, R., & Pagliaro, M.** (2019). Biodegradable and Compostable Plastics: A Critical Perspective on the Dawn of their Global Adoption. ChemistryOpen, 9(1), 8–13. https://doi.org/10.1002/open.201900272https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6946947/
10. **Gilan, I., Hadar, Y., Sivan, A.,** 2004. Colonization, biofilm formation and biodegradation of polyethylene by a strain of Rhodococcus ruber. *Appl. Microbiol. Biotechnol.* 65, 97–104.
11. **Iiyoshi, Y., Tsutsumi, Y., Nishida, T.,** 1998. Polyethylene degradation by lignindegrading fungi and manganese peroxidase. *J. Wood. Sci.* 44, 222–229.
12. **Joel, F.R.,** 1995. Polymer Science & Technology: Introduction To Polymer Science, Eds. 3, Pub: Prentice Hall PTR Inc, Upper Saddle River, New Jersey 07458, 4-9.
13. **Kim, Y., Yeo, S., Kum, J., Song, H.G., Choi, H.T.,** 2005. Cloning of a manganese peroxidase cDNA gene repressed by manganese in Trametes versicolor. *J. Microbiol.* 43, 569–571.
14. **Maciel, M.J.M., Silva, A.C., Ribeiro, H.C.T.,** 2010. Industrial and biotechnological applications of ligninolytic enzymes of the basidiomycota: A review. *Electron. J. Biotechnol.* 13.
15. **Mohan, K.S., Srivastava, T.,** 2010. Microbial deterioration and degradation of polymeric materials. *J. Biochem. Tech.* 2 (4), 210–215.
16. **Pometto, A.L., Lee, B., Johnson, K.E.,** 1992. Production of an ExtracellularPolyethylene-Degrading Enzyme(s) by Streptomyces Species. *Appl. Environ.Microbiol.* 58, 731–733.
17. **Ruiz-Dueñas, F.J., Martínez, A.T.,** 2009. Microbial degradation of lignin: how a bulky recalcitrant polymer is efficiently recycled in nature and how we can take advantage of this. *Microb. Biotechnol.* 2, 164–177.
18. **Rutkowska, M., Heimowska, A., Krasowska, K., Janik, H.,** 2002. Biodegradability of Polyethylene

Starch Blends in Sea Water. Pol. J. Environ. Stud. 11, 267–274.

19. **Seneviratne, G., Tennakoon, N.S., Weerasekara, M.L.M.A.W., Nandasena, K.A.,** 2006.Polyethylene biodegradation by a developed Penicillium-Bacillus biofilm. Curr.Sci. 90, 20–22
20. **Snowden, S.** (2020). New Enzyme Breaks Down Plastic In Hours And Enables High-Quality Recycling. https://www.forbes.com/sites/scottsnowden/2020/04/11/new-enzyme-breaks-down-plastic-in-hours/?sh=5f1e65b95e4e
21. **Tangkoonboribun, R., Sassanarakkit, S., Tantisiriwit, R., Rungkvae, P., & Bumrungsuk, P.** (2013). The Effect of Bioplastic Mixed in Organic Fertilizer on Corn Growth and Soil Properties. Journal of Biobased Materials and Bioenergy. 7. 516-518. 10.1166/jbmb.2013.1330.
22. **Venkatesh, Shahid Mahboob, Marimuthu Govindarajan, Khalid A. Al-Ghanim, Zubair Ahmed, Norah Al-Mulhm, R. Gayathri, S. Vijayalakshmi**, 2021, Microbial degradation of plastics: Sustainable approach to tackling environmental threats facing big cities of the future, Journal of King Saud University - Science, Volume 33, Issue 3, 101362, ISSN 1018-3647, https://doi.org/10.1016/j.jksus.2021.101362. https://www.sciencedirect.com/science/article/pii/S1018364721000239.
23. **Wariishi, H., Valli, K., Gold, M.H.,** 1989. Oxidative cleavage of a phenolic diarylpropane lignin model dimer by manganese peroxidase from Phanerochaete chrysosporium. *Biochem*. 28, 6017–6023.
24. **Wariishi, H., Valli, K., Gold, M.H.**, 1991. In vitro depolymerization of lignin by manganese peroxidase of Phanerochaete chrysosporium. Biochem. Biophys. Res. Commun. 176, 269–276.