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# BIOPLASTIC DIFFUSION IN THE AGRICULTURE SECTOR AND BUSINESS GROWTH PROSPECTS

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## ABSTRACT

**Plastics find applications in a wide array of products, ranging from everyday items like polythene bags to specialized applications in the biomedical industry. In the agriculture sector too, plastic products have become an integral component worldwide. Various products used in agricultural applications like clips, wires, nets, pheromone dispensers, and geotextiles have adverse effects on the ecosystem due to their short-lived period. This characteristic results in a huge amount of waste that must be treated properly. Strategic planning and effective implementation of end-of-life strategies are essential to tackle environmental issues and mitigate the buildup of plastic waste. Policy interventions should focus on implementing robust incentives for recycling and improving source-level sorting. Efficient legal frameworks are essential to enforce disposal obligations effectively. Strengthening global cooperation is necessary to create circular plastic value chains and achieve net zero plastic leakage. The escalating issue of plastic pollution has prompted a need for more sustainable development, with bioplastics emerging as a crucial solution. Biodegradable bioplastics possess the inherent ability to decompose rapidly and naturally, releasing organic molecules that have no harmful effects on the environment. Due to huge environmental concerns, nations worldwide are actively progressing in building bioplastics markets through a combination of push and pull policies. The growing innovation in recycling technologies indicates the effectiveness of policy synergy. This paper aims to highlight the importance of bioplastic usage worldwide and its business growth prospects in the agriculture and allied sectors. Various factors for the growth of the global bioplastic market, like macroeconomic factors, regulatory factors, technological factors, and social factors, are discussed in the paper.**

**KEYWORDS:** Bioplastic, Agriculture, Pollution

The extensive use of plastic commenced in the 1950s and has consistently grown since then. Plastics are deeply ingrained in our daily lives and used in various forms, such as bags, films, and containers, for packaging food and other products. These plastics, when introduced into the natural environment, can inflict harm through multiple mechanisms and pathways. The detrimental effects span a range of ecological aspects which are extensively documented in both popular media and scientific literature (Gall, S.C., & Thompson, R.C., 2015; McHardy, C.L., 2019). The larger plastic items break down and deteriorate; their consequences extend to the cellular level, influencing not just individual organisms but also, conceivably, entire ecosystems (GESAMP, 2015; Shen, M. *et al.*, 2020). A substantial volume of plastic waste accumulates in the environment, breaking down into microplastics—tiny fragments measuring less than 5 mm. (Agarwal, 2020).

When talking about pollution, soils serve as significant receptors for agricultural plastics, containing higher amounts of microplastics compared to oceans (Schwabl, P. *et al.*, 2019). Microplastics are believed to pose specific threats to the health of animals. Studies have demonstrated occurrences of consumption and bioaccumulation along specific food chains, emphasizing the potential impact of these processes on ecosystems and organisms within them (Beriot *et al.*, 2021; Huerta Lwanga *et al.*, 2017). Recent research has even detected microscopic plastic particles in human stool (Schwabl *et al.*, 2019) and fetal membranes (Ragusa *et al.*, 2021). Notably, there is proof of the transfer of nanoplastics (plastics smaller than 1 μm) from mother to fetus, as recorded in rats (Fournier *et al.*, 2020). Microplastics have demonstrated the ability to absorb and intensify persistent organic contaminants, and they can harbor colonies of pathogenic microorganisms. Given these findings from studies (Andrady, 2011: GESAMP, 2015a: Harding, 2016: Horton *et al.*, 2017: and Bowley *et al.*, 2021), it is highly probable that microplastics cause harm to human health that has not yet been fully quantified.

The issue of plastic pollution has arisen as a critical environmental concern, necessitating a shift towards more sustainable development in the immediate future. In response to this urgency, bioplastics are poised to play a pivotal role. Over the past two decades, there has been a noticeable surge in market demand for

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bioplastics in diverse fields such as packaging, textiles, and agriculture. As bioplastics represent a relatively recent innovation, it is imperative that we learn from past mistakes and adopt a meticulous approach to designing their end-of-life strategies. Bioplastics have the capacity to improve resource efficiency by establishing a circular pathway and employing cascades of use, ultimately serving in energy recovery, such as the generation of renewable energy. (European-bioplastics, 2020).

The term ‘‘bioplastics’’ stands for ‘‘biobased polymers.’’ According to IUPAC, a bioplastic is derived from ‘‘biomass and which, at some stage in its processing into finished products, can be shaped by flow’’ (Niaounakis, 2013). Bioplastics represent a diverse family of materials with varying properties and applications. A plastic material is classified as bioplastic if it possesses either bio-based, biodegradable,or a combination of both properties. (European-bioplastics.org, 2022).

With the increasing demand for plastics in agricultural practices, there is an immediate requirement for improved monitoring of the plastic quantities used and their leakage into our ecosystem. Emphasizing circular approaches becomes crucial to decreasing plastic waste creation, focusing on prevention, reduction, reuse, and recycling. In 2019, the agricultural sector utilized 12.5 million tonnes of plastic products for crop and livestock cultivation and 37.3 million tonnes for food wrapping. Moreover, projections from the agricultural plastic industry indicate a 50 percent increase in global demand for greenhouse, mulching, and silage films, rising from 6.1 million tonnes in 2018 to 9.5 million tonnes in 2030. The crop cultivation and animal farming sectors are the primary consumers, collectively constituting 10 million tonnes annually, followed by fisheries and aquaculture with 2.1 million tonnes, and forestry with 0.2 million tonnes.(FAO report, 2021).

It is imperative to urgently implement measures aimed at reducing both the direct environmental impact of agricultural plastic contamination and the secondary consequences of greenhouse gas emissions linked to the use of synthetic plastics. Addressing agricultural plastic pollution is a crucial step towards achieving the objectives outlined in the United Nations Decade on Ecosystem Restoration, launched jointly by FAO and the UN Environment Programme in 2021. This initiative aligns with FAO's Strategic Framework 2022-2030, emphasizing the program priority area of Bioeconomy for Sustainable Food and Agriculture. (UNDP Report, 2021). Agricultural plastics present a significant risk of pollution and can pose threats to the entire ecosystem when they undergo damage, degradation, or are improperly treated. (Kumar, *et al.*, 2021).

As of 2019, India's annual plastic waste generation stood at about 9.4 million tonnes, contributing approximately 3.1% to the global total of over 380 million tonnes. Globally, the packaging sector consumes 42% of the total plastic production, and the construction sector consumes 17%. In India, the packaging sector accounts for 35%, while the construction sector consumes 23%. Notably, bioplastic production constitutes a mere 1% of the annual output of conventional plastics, which amounts to 380 million tonnes worldwide (Rafey & Siddiqui, 2021). Asia is projected to be the largest consumer of plastics in the agriculture sector, using up to six million tonnes per year, representing nearly half of the worldwide consumption. India's bioplastics market is predicted a Compound Annual Growth Rate (CAGR) of 24.36%, reaching US$1,420.870 million by 2027, compared to US$308.942 million in 2020. (Knowledge Sourcing Intelligence, 2022).

In developing nations like India, the use of bioplastics has huge potential, as it is at its nascent stage. (Kamath *et al.*, 2020). The surge in environmental awareness stands out as a key driver propelling the Indian bioplastics market to unprecedented heights in the forecast period. Furthermore, prominent market players are strategically entering this market to align with the rising environmental concerns, concurrently reinforcing their market presence—a factor contributing significantly to market growth. Another driving force poised to foster market expansion is the escalating emphasis on sustainability, with various companies directing their efforts to reduce their carbon footprint.

This paper shows the compelling need for coordinated action to enforce effective operational strategies and mitigate the detrimental effects of plastic consumption in agriculture and allied sectors. Resolving agricultural plastic pollution is crucial for establishing efficient, inclusive, resilient, and sustainable agrifood systems that contribute to enhanced production, nutrition, and environmental quality, ensuring an improved quality of life for all. This paper also focuses on the requirements of stringent policy interventions, considering the future growth prospects of bioplastics worldwide.

## PLASTICS AND AGRICULTURE

The adoption of plastic products in modern agriculture is getting more prevalent globally. The world's consumption of plastics in agriculture amounts yearly to 12.5 million tons (Hofmann *et al.*, 2023). The wide range of plastic polymers, their convenience of production, physical characteristics, and cost-effectiveness position them as the preferred material for numerous agricultural applications. Over the last seven decades, plastic

integration into agrifood systems and supply chains has become widespread. Embedded in various aspects of our food systems, from fishing gear and tree guards to greenhouses, these cost-effective and adaptable plastic products enhance productivity and efficiency while aiding in the reduction of food loss and waste. Plastic greenhouses and mulching films, along with drip irrigation, help fruit and vegetable cultivators enhance productivity, reduce costs, and manage produce quality. Plastic-coated controlled-release fertilizers ensure optimal nutrient delivery, minimizing emissions to water and air. Silage films enable livestock farmers to produce quality fodder without building barns. Plastic tree guards in plantations offer various benefits, sustaining livelihoods, improving output, and lessening environmental footprints (Gioia *et al.*, 2021).

However, extensive and prolonged use of plastics, linked with the absence of systematic handling and sustainable practices, leads to the stockpiling of plastics in soils and water. Many agri-plastic items are intended for one-time use, persisting in the ecosystem beyond their planned lifespan. As they break down into microplastics, there is a potential risk of accumulation in the food cycle, posing threats to human well-being (Kamath, 2020; Kalita, 2019).

Transitioning to sustainable alternatives enables the agricultural sector to decrease its carbon footprint while ensuring the long-term sustainability of farming practices. Biodegradable bioplastics possess the inherent ability to decompose rapidly and naturally, releasing organic molecules that have no harmful effects on the environment. In addition to reducing the carbon footprint, the use of bioplastics in agriculture offers several advantages (FAO report, 2021), including:

- Absence of heavy metals
- Weed suppression properties similar to standard mulching
- Temperature stabilization of the root
- Preservation of soil nutrients and moisture
- Enhancement of stable plantation development
- Reduction of non-biodegradable waste, preventing long-term environmental pollution in landfills
- Standard installation procedures without the need for special machinery
- No consumption of non-renewable raw materials
- Production of quality plastic products without harmful chemical additives, ensuring safety for food contact
- Widespread use of bioplastics eliminates negative environmental impacts and provides a viable option within the agricultural sector, contingent on proper recycling and maintenance within the circular economy.

The integration of bioplastics in the agricultural sector has implications for social awareness, economic viability, and environmental responsibility across three dimensions. Firstly, the Social Dimension involves activities such as raising awareness, community engagement, and influencing consumer preferences. The second dimension, Economic Dimension, encompasses considerations such as production costs, market opportunities, and job creation. The third dimension, Environmental Dimension, highlights the positive contributions of bioplastics in reducing plastic pollution, enhancing soil health, conserving resources, and minimizing the carbon footprint. (Mominul S.,2020).

On the global stage, there is a critical need to formulate a comprehensive voluntary code of conduct that addresses every facet of plastics within agriculture and agrifood value chains. This code must intricately consider the complete life cycle of a plastic product, ranging from its inception in design and regulatory approval to manufacturing, distribution, sale, utilization, and eventual management at the end of its life. The development of this code of conduct should be firmly rooted in scientific principles and fostered through an inclusive, participatory, and transparent approach. This collaborative effort should involve governments, local organizations, plastic manufacturers and consumers, the waste handling sector, organizations establishing standards and providing certification, educational institutions, and non-governmental organizations.

## BUSINESS PROSPECTS OF BIOPLASTICS

The global bioplastics market was valued at approximately USD 12.42 billion in 2022 and is projected to reach around USD 63.55 billion by 2032, experiencing a robust compound annual growth rate (CAGR) of 17.80% from 2023 to 2032. In the Asia Pacific region, the bioplastics market is witnessing substantial growth with a CAGR of 14% over the forecast period (Precedence research, 2023). The global bioplastics market is dynamically evolving, with competitors increasingly concentrating on enhancing research and development activities, leading to expanded production capacities. The widespread adoption of bioplastics across diverse applications is attributed to their exceptional technical characteristics. The industry has witnessed substantial growth in various plastic applications, driven by

favorable regulations enacted by several countries worldwide (Precedence research, 2023; Nanda, 2021).

The large-scale bioplastic diffusion has not happened at the rates that were anticipated in the early 2000s. Less than 1% of the more than 367 million tons of plastic generated yearly in 2021 came from bioplastics (European Bioplastics, 2022). However, according to European Bioplastics (2022), the capacity for bioplastics is anticipated to rise from roughly 2.22 million tons in 2022 to roughly 6.30 million tons in 2027. These numbers imply that in the upcoming years, bioplastics will begin to contribute more significantly to the plastics sustainability goals.

Key drivers for the bioplastics market include their environmentally friendly attributes, growing consumer acceptance of bio-based products, regulatory frameworks promoting the use of degradable containers, and the availability of clean energy sources for bioplastics manufacturing. The non-toxic and readily decomposable nature of bioplastics makes them environmentally friendly, with negligible greenhouse gas emissions during the decomposition process (Precedence research, 2023).

Major players in the market, including Nestle, Nike, Coca-Cola, and Ford, are investing significantly in the production of bioplastic materials for a wide range of applications, such as plastic bottles and automotive components. The versatile uses of bioplastics extend to catering, packaging, agriculture, and automotive sectors. Bioplastics are particularly favored in organic farming, where farmers utilize biodegradable mulching films. Consumers prefer bioplastic packaging over synthetic alternatives due to its compatibility with food and decomposable nature (Precedence research, 2023).

According to the FAO report (FAO,2021) approximately 12.5 million tonnes of plastics are utilized in global agricultural output each year, accounting for nearly 3.5 percent of the total plastic generation of 359 million tonnes in 2018. (Plastics-the Facts, 2021).

Numerous market leaders are investing in innovative research and development to enhance bioplastic technologies, aiming to reduce end-use costs and accelerate adoption. In June 2020, Lygos, Inc. (Berkeley, California) and Praj Industries Ltd. (Pune, India) signed an MOU for co-developing Lygos's proprietary yeast to facilitate lactic acid production. Total Corbion PLA, a global technology leader in lactide monomers and Poly Lactic Acid (PLA) announced in September 2019 its intent to enter the Indian bioplastics market. This strategic move involves a technical collaboration with Konkan Specialty Poly Products Pvt Ltd. (Mangalore, India), aiming to launch a fully biodegradable and compostable plastic option (Knowledge Sourcing Intelligence, 2022; Sengupta, 2023).

Bioplastics have consistently shown growth rates exceeding 20–30% across various materials for several years, and this trend is anticipated to persist. There is a potential for up to 90% substitution of the total plastics consumption with biobased polymers. (Ali *et al.*, 2023).

To foster advancements in technology, raw materials, and production, there is a need for increased initiative. An essential initial step in this direction involves raising awareness about environmental issues and emphasizing the long-term benefits of bioplastics. The state-level body of the National Green Tribunal set a deadline of August 31, 2019, for the government to implement a plastic ban, reflecting a commitment to addressing environmental concerns. The Indian bioplastics industry is rebounding strongly post-COVID and the challenges of the October 2, 2019, single-use plastic (SUP) ban. Growth hinges on government policies, rule enforcement, cost competitiveness, and public awareness. The SUP ban, initially announced in 2019, faced opposition, leading to staggered guidelines starting in October 2021. The industry struggled due to unclear directives and pandemic impacts. India's government stance on plastics, particularly the commitment to phase out single-use plastics by 2022, creates new opportunities for the Indian bioplastics market. Current guidelines include bans on various single-use plastic items from July 1, 2022, and polythene bags under 120 microns from December 31, 2022. Despite nationwide effectiveness since September 2021, state-level implementation varies. States with strict bans are driving industry growth, fostering optimism, and export market development. New players are entering biopolymer compounding and compostable product manufacturing, with 162 companies registered to trade in compostable items in India (Dadhania, 2022). As of 2019, 18 states in India have enforced a ban on single-use plastics (Knowledge Sourcing Intelligence, 2022).

India laid the foundation for its plastic industry in 1957, initiating the production of polystyrene. Since its inception, the Indian plastics industry has experienced significant growth, emerging as a prominent player in global plastics production, encompassing over 20,000 processing units. Evolving into a multi-billion dollar sector, it stands as a vital contributor to India's economy, providing employment for approximately four million individuals. Furthermore, it serves as a global supplier, with India's polymer exports reaching around 1.5 million metric tons in 2021 (Statista Research Department, 2023).

India's scientific community is playing an active role in advancing the development of bioplastics, and notable breakthroughs have emerged through this initiative (Kalita et.al., 2019). These advancements are not just confined to the laboratory; they are being translated into practical applications and commercially produced by Biogreen, the country's pioneer biotechnology company specializing in biodegradable products (Biogreen, 2017). This demonstrates the successful integration of scientific innovation into the market.

Several noteworthy companies are making significant contributions to the bioplastics sector in India. Truegreen, Plastobags, Ecolife, and Envigreen are among the key players shaping the landscape. These companies are actively engaged in the production and distribution of bioplastics, offering environmentally friendly alternatives to traditional plastics. Their presence in the market underscores the growing momentum and interest in sustainable materials within the Indian industrial and commercial sectors (Biogreen, 2017).

Driven by increasing environmental consciousness and a focus on sustainability, India's bioplastics market is experiencing substantial growth. Consumer demand, legal restrictions, and the eco-friendliness of compostable and biodegradable plastics are contributing to their popularity as alternatives to traditional plastics. As businesses strive to reduce their carbon footprint and adopt sustainable practices, the bioplastics industry is rapidly expanding across various sectors, including packaging, agriculture, and automotive.

Bioplastics have the potential to significantly contribute to the development of a fully sustainable and circular bioeconomy. Annually, the global usage of plastics in farming reaches 6.5 million tons. Many traditional plastic applications in farming practices have a brief lifespan, typically not exceeding two years. This characteristic results in significant waste generation that requires proper disposal. Approximately 30% of the plastic waste generated in farming practices is attributed to short-life applications such as clips, wires, nets, pheromone dispensers, and geotextiles. There is a high probability that these items may persist in the agricultural system, leading to environmental pollution. Bioplastics, characterized by their sustainable nature and derived from renewable resources as an alternative to petroleum-based polymers, have gained significant traction. Notably, they have the potential to reduce carbon dioxide emissions by 30 to 70%, resulting in a substantial 42% reduction in carbon footprints. Bioplastic production is an energy-efficient process, requiring 65% less energy than traditional petroleum-based plastic (Precedence research, 2023).

To promote environmentally friendly agricultural practices, an alternative approach involves utilizing bio-based agricultural raw materials. This strategy aims to lessen the ecological impact associated with plastic waste by incorporating materials obtained from alternative sources that are more sustainable in the agricultural context. The trajectory of bioplastic demand in the coming years will be influenced by factors such as the cost of conventional plastics, raw material expenses, economies of scale, and technological advancements. Legislative measures promoting environmentally friendly substitutes for fossil fuel-based plastics can also significantly impact consumer demand for bioplastics. Extended Producer Responsibility (EPR) is a policy strategy that holds manufacturers accountable for their products during the post-consumer phase of the product life cycle (OECD: EPR, 2023).

Enabling the establishment of a traditional waste plastic processing facility and the manufacturing of bioplastics in India poses certain hurdles related to technology, the formulation of a standardized framework, and the provision of financial incentives. It is essential to create a legal framework for bioplastic manufacturing in India, coupled with a comprehensive strategy for harnessing energy from plastic residues. The markets for processing synthetic plastic waste and initiating bioplastic projects are still in an early stage of development in India. There is a pressing need to formulate a roadmap for environmental friendly and sustainable strategies for both regular plastics and bioplastics. (Rafey & Siddiqui, 2021). The abundance of biomass raw materials in India, coupled with increasing consumer awareness, positions the country as a potential global catalyst for a shift in consumer behavior away from traditional plastics.

The following factors are contributing to the growth of the global bioplastics market: ( Moshood *et al.*, 2021)

**Macroeconomic Factors**

Crude Oil Prices: Fluctuations in oil prices impact bioplastics demand. High oil prices make bioplastics more attractive as an alternative.

GDP Influence: Higher GDP leads to increased plastics production, contributing to greater bio-plastic consumption, especially if high-income players invest more in eco-friendly solutions.

Feedstock Costs: Bioplastics production costs depend on feedstock prices, primarily maize starch or

sugar cane. Market volatility in maize and sugar prices affects bioplastics production.

**Regulatory Factors**

Taxes: Taxes on fossil-based products could raise traditional plastics prices, making bioplastics more competitive.

Subsidies: Government incentives may lower bioplastic prices, stimulating demand.

Bans/Prohibition: State bans on fossil plastics enhance the bioplastics market, but they might face challenges if bans extend to specific types.

**Technological Factors**

Cost Reduction Factors: Ongoing technological advancements, learning effects, and economies of scale can reduce bioplastics manufacturing costs over time.

**Social Factors**

Awareness: Growing consumer awareness of environmental conservation and natural resources positively impacts bio-plastic production.

Bioplastics stand out as a viable and promising solution to tackle the pervasive problem of plastic pollution. The complex interplay of these factors, such as oil prices, GDP, feedstock costs, regulations, and technological advancements, influences the demand for bioplastics. While challenging to predict accurately, ongoing developments and increasing environmental awareness contribute to the evolving landscape.

The bioplastics market in India is still in its early stages, with only a few companies currently operating in this segment. Bioplastics offer various advantages, such as a diminished carbon footprint, energy efficiency, and eco-safety. However, they encounter challenges such as elevated costs and a lack of robust legislation (Sinan, M., 2020). Studies suggest that bioplastics offer numerous advantages compared to conventional plastics. In conclusion, while bioplastics are currently in the early stages of development, synthetic plastics have reached a mature stage. However, the increasing consumer awareness of the benefits of bioplastics suggests significant potential for their widespread adoption across various sectors, including agriculture.

## CONCLUSION

The plastics industry worldwide is exploring alternatives, like bioplastics, which are more eco-friendly. Currently, bioplastics make up only 1% of the market, but they're expected to grow by 20-30% soon. Unlike regular plastics, making bioplastics don't rely on fossil fuels, and they need only half the energy. They also break down faster and produce less harmful emissions.

Because regular plastic waste causes a lot of environmental issues, scientists are working on creating new biodegradable materials from natural sources like plants and bacteria. Future improvements in bioplastics could make them more efficient and useful in various industries. The growing interest in bioplastics is due to their eco-friendly nature. Also, using microorganisms in technology helps make bioplastics suitable for agriculture, medicine, and more.

To ensure the responsible use of bioplastics globally, we need clear rules and guidelines. Improved labels based on what materials are used and how much energy is consumed during production are crucial. Continued innovation, technology improvements, and global support are essential to fully realize the potential of bioplastics. Despite being in its early stages, India's bioplastics industry shows promise. Limited enterprises are currently engaged in the bioplastics sector in India, and government support, readily available feedstock, and environmental awareness campaigns play pivotal roles in aiding the country's bioplastics producers. Governments worldwide are actively implementing favorable laws and regulations to promote the resilience and degradability of bioplastics, with the European Union emerging as a major political supporter of the industry. The abundant availability of feedstocks such as maize, grain, corn, and sugarcane in nearly every country reduces the impact of global crude oil price fluctuations on the expansion of the bioplastics sector. These factors collectively contribute significantly to the burgeoning growth of the bioplastics market.

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