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# BIOPOLYMER BASED SOLUTION FOR REDUCING PLASTIC WASTE IN PACKAGING AND AGRICULTURE

**Ravi D. Yadav, Dr. Amrita Singh and Dr. Brijesh Gaud**
Department of Chemistry, Vande Mataram Degree College of Art, Commerce & Science, Dombivali (W)

## ABSTRACT

*This project explores the development and application of bioplastics as sustainable alternatives to conventional petroleum-based plastics. Derived from renewable sources such as starch and pectin, the bioplastics produced in this study are biodegradable and environmentally friendly. A specific formulation using starch, pectin, glycerol, and natural preservatives was developed to create a durable yet compostable material capable of holding up to 2500 grams. Beyond packaging, the research emphasizes the potential of bioplastic byproducts to enhance plant growth. Upon degradation, these bioplastics release organic matter and essential nutrients that improve soil fertility, microbial activity, and water retention. Various tests including tensile strength, biodegradability, and pH analysis were conducted to evaluate performance. The findings highlight a dual-purpose solution—reducing plastic pollution while promoting sustainable agriculture. This study underscores the role of bioplastics in advancing environmental conservation, waste reduction, and soil health, aligning with circular economy principles for a greener future.*

***Keywords:*** *Eco-friendly packaging, Bioplastics, Renewable resources, Biodegradability, Biodegradable coatings, Sustainable agriculture*

## INTRODUCTION

Bioplastics are a class of materials derived from renewable biological sources, designed to replace conventional plastics, which are primarily made from petroleum-based resources. These materials, produced from natural polymers like starch, cellulose, and proteins, have gained significant attention due to the growing environmental concerns over plastic pollution. The production and use of plastics have led to substantial ecological issues, including waste accumulation, resource depletion, and pollution, prompting a search for more sustainable alternatives. Bioplastics present a potential solution by offering the benefits of biodegradability, renewability, and a lower environmental impact. The term "bioplastic" broadly refers to two different categories of materials: those that are made from renewable biological sources and those that are biodegradable. It's important to note that not all bioplastics are biodegradable, nor are all biodegradable plastics derived from biological materials. There is a distinction between bio-based plastics, which are made from renewable resources, and biodegradable plastics, which can break down naturally over time. While both types of bioplastics aim to reduce the dependence on fossil fuels and reduce environmental harm, their properties and functionalities vary significantly. Bioplastics, in general, are distinguished from traditional plastics not only by their source material but also by their potential to offer more sustainable alternatives. The vast majority of plastics that are currently in use today, such as polyethylene and polypropylene, are derived from petroleum. These plastics are highly durable and versatile, which is why they are used in a wide range of applications.

However, they also take hundreds or even thousands of years to break down in the environment, leading to significant problems with plastic pollution. By contrast, bioplastics are made from renewable resources that can be replenished more quickly, theoretically making them more sustainable in the long term. Some bioplastics can break down relatively quickly in the environment, reducing the risk of pollution. Others are designed to be recyclable or compostable, offering alternative solutions to the waste management problems associated with conventional plastics. The earliest use of bioplastics can be traced to the 19$^{th}$ century. One of the first instances of a plastic material made from natural sources was in 1862, when a British chemist named Alexander Parkes introduced Parkesine, a material derived from cellulose, the organic compound found in plants. Parkesine was the first synthetic plastic made from plant fibers, and although it was not widely commercialized due to its instability, it marked an early experiment with plant-based materials for creating plastic-like substances. In the early 20$^{th}$ century, bioplastics gained more attention with the advent of celluloid, which was invented by John Wesley Hyatt in the 1860s. Celluloid, derived from cellulose, was initially used for items like combs, buttons, and photographic film. By the early 1900s, celluloid had become a widely used material in the production of various everyday objects. While it is now largely obsolete due to its flammability and brittleness, it was an important step in demonstrating that plastics could be made from renewable resources. The resurgence of interest in bioplastics began in the latter half of the $20^{th}$ century, primarily driven by environmental concerns over plastic waste and pollution. The oil crises of the 1970s also sparked interest in finding alternatives to fossil fuels, and bioplastics were viewed as a possible solution.

Researchers began investigating ways to create plastics from renewable resources that could potentially be biodegradable or more environmentally friendly. In the 1980s and 1990s, companies started to experiment with polylactic acid (PLA), a bioplastic made from fermented plant sugars. PLA, made primarily from corn starch or sugarcane, showed potential as an eco-friendly alternative to petroleum-based plastics. Today, bioplastics continue to evolve, with ongoing research focused on improving their properties, reducing production costs, and expanding their applications. The demand for bioplastics has grown, fueled by both environmental concerns and advances in biotechnology, which have made it possible to produce bioplastics more efficiently and on a larger scale.

**METHOD AND MATERIALS**

**Materials:**
The components in the given formulation are starch, glycerol, acetic acid, tartaric acid, pectin, and water. Starch is collected from Thane market Thane (W). Glycerol, acetic acid are collected from local vender Dombivli (w). Pectin is extracted from banana peels. Tartaric acid is collected from any citrus fruits.

**Methods:**

**Extraction of Pectin from Banana Peels:**
Banana peels is collected from Mumbra market. Thane. Take 500 grams of clean banana peels for each treatment. Blend the peels into a fine consistency. Boil the blended banana peels in a solution of 2% citric acid. To prepare this, dissolve 20 grams of citric acid in 1 liter of water. Heat the mixture at 90°C for 3 hours. This process helps release pectin from the banana peels. Once the boiling is done, filter the mixture to separate the liquid extract from the solid residue. Collect the liquid, which contains the pectin. Add ethanol to the filtered liquid in a 1:1 ratio. This helps the pectin to precipitate (separate out). Filter the mixture again to collect the solid pectin. Dry the collected pectin in an oven at 50°C for 8 hours to remove any remaining moisture. Once dried, store the pectin for further use. [7]

**Preparation of Bioplastic:**
Bioplastics, obtain starch, glycerol, acetic acid, and tartaric acid from a local vendor, along with banana pectin extracted from banana peels. Begin by measuring the required quantities of each ingredient and placing them in a suitable container. Add water to the mixture to create a homogeneous mixture, ensuring there are no lumps. Once mixed, heat the solution to a temperature of 80–90°C while continuously stirring to prevent sticking or uneven heating. Maintain this temperature for 20–25 minutes to facilitate the interaction of ingredients and the formation of a biopolymer matrix. After heating, pour the prepared mixture onto a flat surface or mold to form a thin sheet. Allow it to cool and solidify into a flexible and biodegradable sheet of bioplastic, ready for further use or testing.

| Sr. No: | Ingredients | Quantity |
|---|---|---|
| **1.** | Starch | 16 g |
| **2.** | Pectin | 1 g |
| **3.** | Glycerol | 5.5 ml |
| **4.** | Tartaric acid | 0.5 g |
| **5.** | Acetic acid | 3 ml |
| **6.** | Water | 75 ml |

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**RESULTS AND DISCUSSION:**

**Tensile Strength Test:**

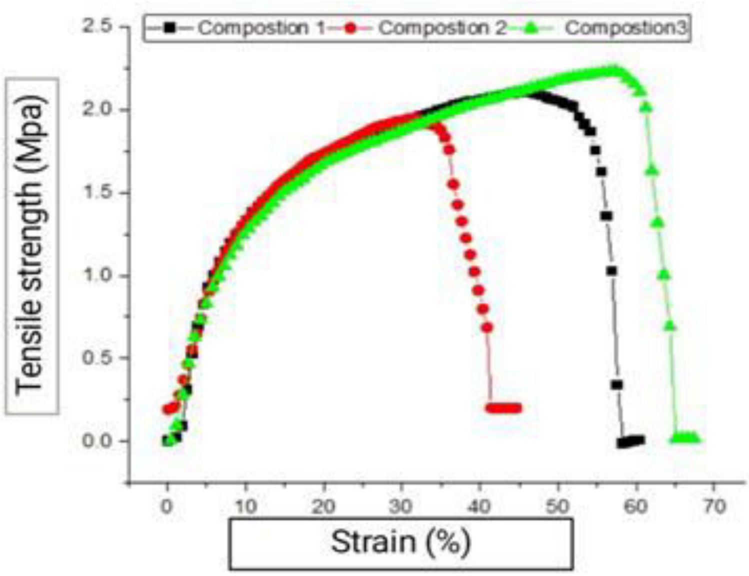


**Fig 1:** Tensile Strength of Bioplastic

The tensile strength test of the bioplastic samples revealed variations In mechanical performance among the three compositions. Composition 3 exhibited the highest tensile strength 2.25 Mpa and strain 65% , indicating superior flexibility and durability, making it the most robust among the samples. Composition 2 showed moderate tensile strength 2 Mpa and strain 58%, balancing flexibility and rigidity. In contrast, Composition 1 displayed the lowest tensile strength 1.5 Mpa and strain 41%, suggesting limited mechanical resilience. The differences in tensile properties can be attributed to variations in material composition and molecular structure. These results indicate that optimizing bioplastic composition significantly impacts its mechanical properties, catering to diverse application needs such as packaging or structural uses.

**Antimicrobial Test:**

The antimicrobial analysis of the bioplastic sample demonstrates minimal microbial contamination. The mold count and yeast count were both below the detectable limit (<1 CFU/cm²), indicating effective resistance to fungal growth. The total bacterial count was measured at $4.7 \times 10^2$ CFU/cm², suggesting a low but present level of bacterial contamination. These results indicate that the bioplastic exhibits antimicrobial properties, particularly against fungi, while some bacterial presence persists. This highlights the potential of the bioplastic for applications requiring moderate microbial resistance, though further improvements may be necessary to reduce bacterial contamination to meet stricter hygiene standards.

| Sr. No: | Parameters | Units | Methods | Result of analysis |
|---|---|---|---|---|
| **1.** | Mold Count | cfu/cm² | SOP-MCB-46-01 | <1 |
| **2.** | Total Bacterial Count | cfu/cm² | SOP-MCB-46-01 | $4.7x(10)^2$ |
| **3.** | Yeast Count | cfu/cm² | SOP-MCB-46-01 | <1 |

**Antibacterial Test:**

The antibacterial test of bioplastic, conducted using the disc-diffusion method against Escherichia coli, revealed significant antibacterial activity. The control sample (Fig.1)

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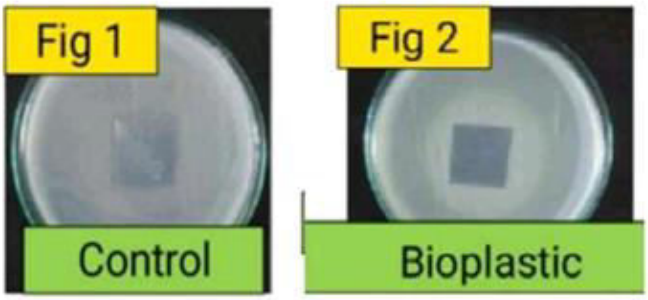


**Fig 2:** Antibacterial Test for Bioplastic

displayed no zone of inhibition, indicating the absence of antibacterial properties. In contrast, the bioplastic sample (Fig. 2) exhibited a clear zone of inhibition measuring 6.8 mm, demonstrating its antibacterial effectiveness. The observed inhibition suggests that the bioplastic possesses active antibacterial agents capable of suppressing bacterial growth. These findings highlight the potential application of bioplastic in antimicrobial materials, providing a sustainable and effective alternative for reducing microbial contamination in various environments.

**Biodegradability Test of Bioplastic:**

**Soil Biodegradability Test Discussion:**

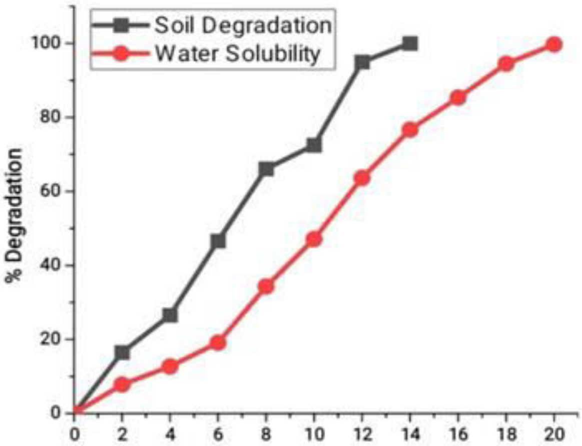


**Fig 3:** Biodegradability Test of Bioplastic

The soil biodegradability test indicates that the bioplastic degrades rapidly in soil environments. According to the graph, the degradation process starts immediately and reaches approximately 60% by day 6. The degradation rate continues to increase significantly, achieving 100% by day 12. This rapid degradation suggests that the bioplastic is highly susceptible to microbial activity in soil. The favorable conditions in the soil, such as the presence of microorganisms, moisture, and nutrients, likely accelerated the breakdown process. These results demonstrate the bioplastic's suitability for use in composting or agricultural applications, where quick decomposition is necessary to minimize environmental impact. Overall, the bioplastic shows excellent biodegradability in soil, making it a sustainable alternative to conventional plastics in terrestrial environments

**Water Solubility Test Discussion:**

In the water solubility test, the bioplastic demonstrates a slower degradation rate compared to soil. As shown in the graph, the solubility process is gradual, with around 20% degradation observed by day 6. The rate increases steadily, reaching 60% by day 12 and achieving 100% solubility by day 20. This slower breakdown in water indicates the bioplastic's resistance to immediate disintegration, which could be attributed to reduced microbial activity and slower hydrolysis in aquatic environments. The delayed solubility makes the material suitable for short-term applications requiring water exposure, such as packaging or containers. These results highlight the bioplastic's controlled solubility in water, balancing functionality and environmental safety in aquatic ecosystems.

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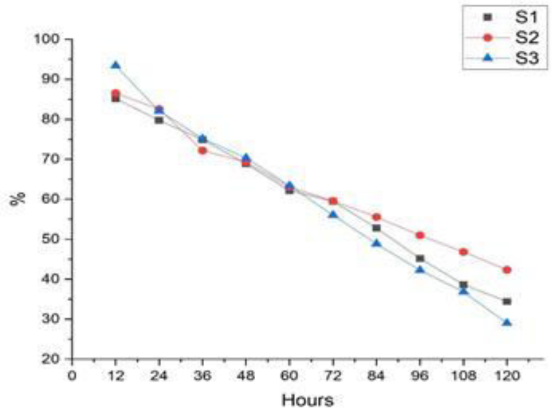


**Fig 4:** Moisture Determination Test for Bioplastic

**Moisture Determination Test:**

The moisture content of bioplastics for samples S1, S2, and S3 decreases over time, as observed in the graph. Initially, all samples exhibit high moisture percentages (above 80%). However, significant moisture loss occurs after 24 hours, with S1 maintaining relatively higher levels compared to S2 and S3. S3 shows the steepest decline, indicating less resistance to moisture loss, reaching the lowest final moisture content (~29%) after 120 hours. S2 follows a more gradual trend, stabilizing at a moderate level (~42%). S1 consistently retains the highest moisture content (~34%) across the duration, highlighting Its superior moisture retention properties, likely due to differences in composition or structural characteristics. The data suggests that S1 may be more suitable for applications requiring higher moisture retention, whereas S3 is less effective in this aspect. These results are critical for selecting bioplastic materials based on moisture stability in varying environments.

**Chemical Oxygen Demand (Cod) Value for Bioplastic :**

Test indicates the bioplastic released 600 mg/L of oxygen-demanding substances upon oxidation. The observed green and orange color solutions (before and after digestion) represent the reduction of potassium dichromate due to the organic matter present. The orange color post-digestion confirms the presence of oxidizable organic material in the

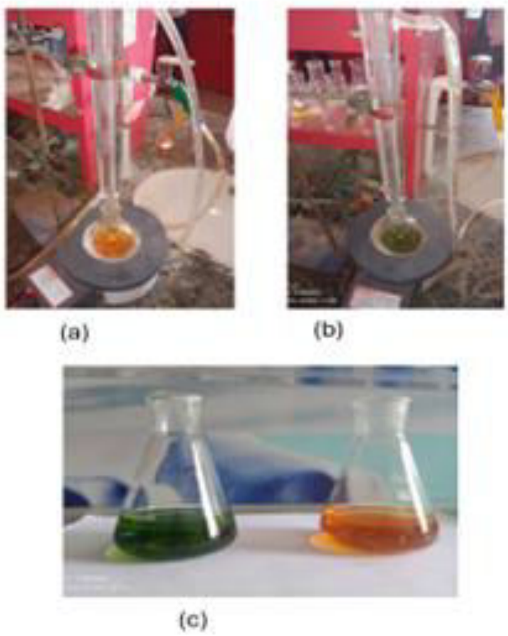


**Fig 5:** COD Test of Bioplastic

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bioplastic. A COD of 600 mg/L suggests moderate to high organic load, implying that the bioplastic contains biodegradable organic content. This is expected for starch- or cellulose-based bioplastics, which break down into simpler compounds. The result is useful for assessing biodegradability and environmental safety. However, further analysis like BOD or biodegradation rate under soil or composting conditions is recommended for a comprehensive evaluation.

**Biodegradable Plastics in Plant Growth Trials**

**Brassica Juncea (Rai/Mustard):**
A comparative study was conducted on mustard (rai) plants using two soil conditions—one mixed with bioplastic byproducts and one without (control). In both conditions, 30 grams of mustard seeds were sown. The bioplastic used was biodegradable and derived from natural sources, with its byproducts added to the soil as a growth enhancer. Observations were recorded on day 3, day 7, day 11, and day 15. By day 8, the bioplastic-treated group showed quicker germination and stronger leaf development. By day 12, these plants exhibited greater

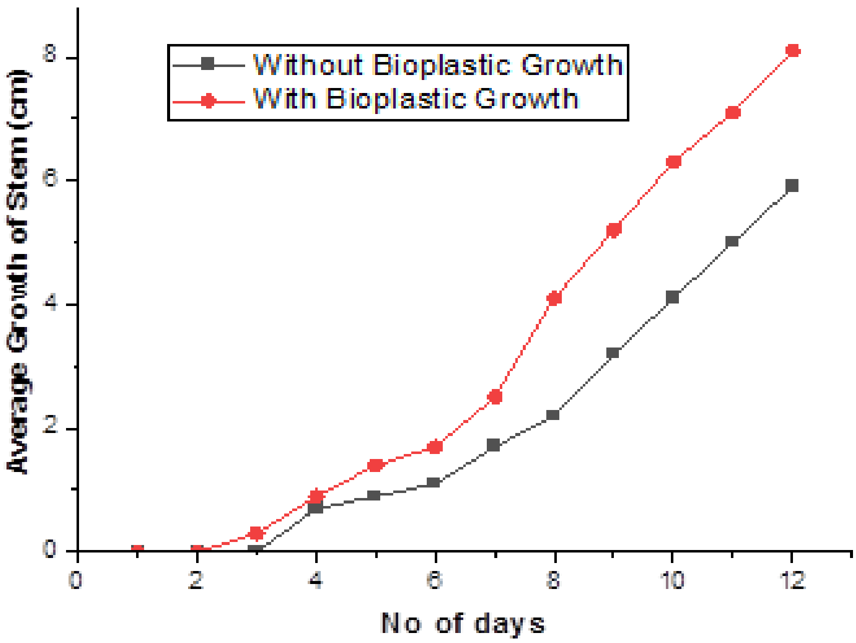


**Fig 6:** Comparing Brassica Juncea Plant With And Without Plastic

stem height and a higher number of leaves compared to the control group. By day 15, they had broader, greener leaves and taller stems. This enhanced growth is attributed to the slow degradation of bioplastic, which likely released organic compounds that improved microbial activity and nutrient availability in the soil. In contrast, control plants showed stunted growth. Graphs and photographs confirmed these findings, highlighting bioplastic byproducts as promising soil conditioners.

**Vigna Radiata (Green Gram / Mung Dal):**
The experiment utilized 30 grams of moong dal seeds to evaluate the impact of bioplastic as a byproduct on plant growth. Visual observations over a 15-day period, along with stem length measurements, indicate that the seeds grown in soil enriched with bioplastic showed faster and healthier growth compared to those without it. Germination began as early as Day 3 in both setups, but the seedlings with bioplastic demonstrated more uniform and denser sprouting. By Day 13, plants with bioplastic had reached greater heights (approximately 21 cm) than those without (around 19 cm), as supported by the growth graph. The enhanced growth suggests that bioplastic may have acted as a natural soil enhancer, possibly improving moisture retention and nutrient availability. Overall, bioplastic proved beneficial for seed germination and plant development, indicating its potential as a sustainable agricultural input for promoting plant health and productivity.

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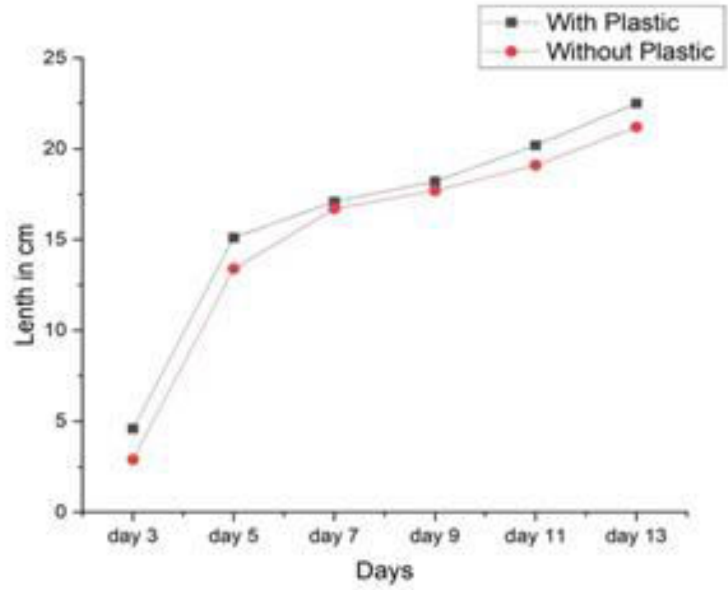



**Fig 7:** Comparing Vigna Radiata Plant Growth With And Without Plastic

**Trigonella Foenum-graecum (Methi / Fenugreek):**

The results show that bioplastic significantly enhances the growth of plants compared to those grown without it. As observed in the images and graph, the plants exposed to bioplastic consistently showed higher growth rates across all observation days (from day 3 to day 13). This is evident from the increased length of the plants with bioplastic, which reached over 12 cm by day 13, compared to the plants without bioplastic, which grew only up to 8 cm. The visual comparison between the ”wo groups indicates that plants with bioplastic also exhibited healthier and more robust foliage, with a dense growth pattern. This suggests that bioplastic may improve soil moisture retention, reduce water evaporation, or enhance nutrient uptake, thereby contributing to better overall plant health. The use of 30 grams of seeds for planting provides a fair basis for evaluating growth, and bioplastic appears to be an effective, eco-friendly solution to boost agricultural productivity.

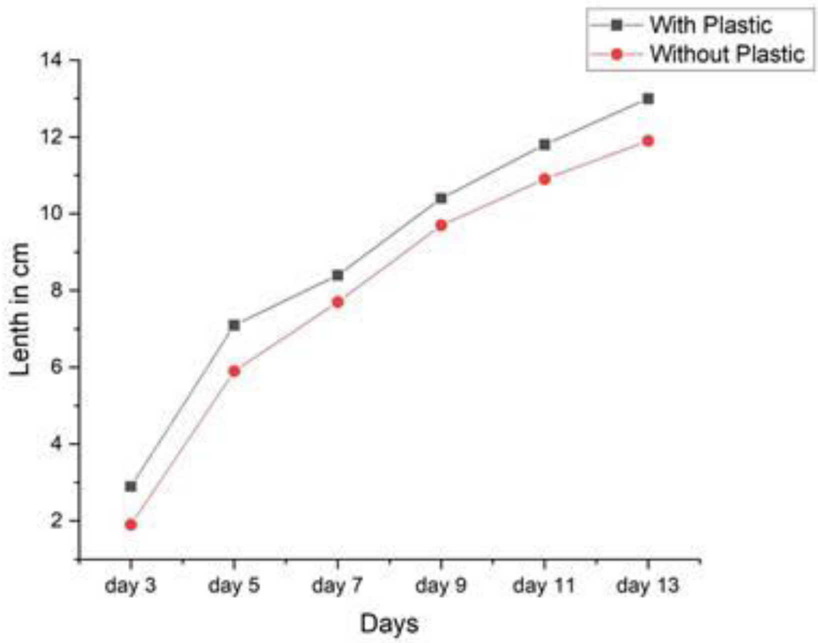
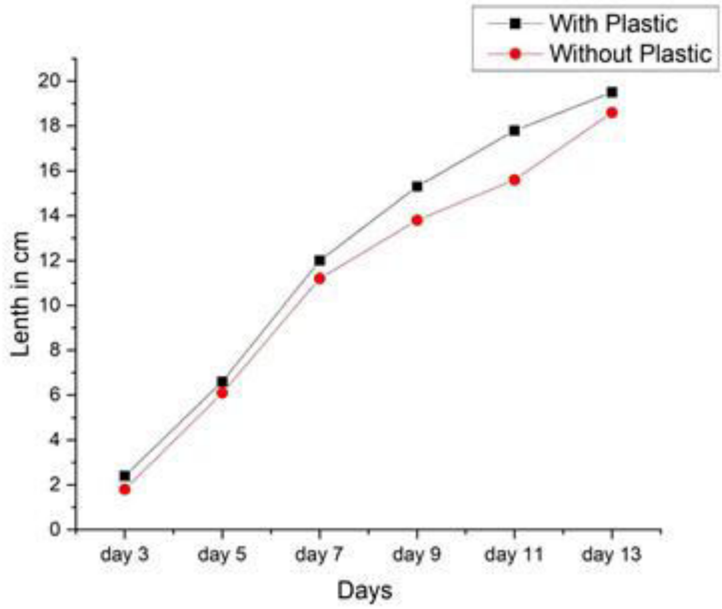



**Fig 8:** Comparing Trigonella Foenum-graecum Plant Growth With And Without Plastic

**Triticum (Wheat):**




**Graph 7:** Comparing Triticum Plant Growth With And Without Plastic

The use of bioplastics as a byproduct in plant seed growth shows encouraging outcomes. Comparative analysis between plants grown with and without bioplastic indicates enhanced growth in the bioplastic-treated group. From Day 1 to Day 17, plants with bioplastic consistently exhibit taller and more vigorous development. By Day 5, noticeable differences appear, with bioplastic plants growing faster—likely due to improved moisture retention and a more favorable microenvironment. This trend continues, and by Day 17, the plants with bioplastic show significantly denser shoots and healthier overall growth. The 30 grams of bioplastic used per plantation appears effective in supporting root and shoot development. The data and visual evidence support the conclusion that bioplastics positively impact plant growth. This suggests that bioplastics could serve as a sustainable aid in agriculture, especially for small-scale plantations, offering an eco-friendly method to improve plant productivity and health while potentially enhancing crop yield in a more sustainable manner.

## CONCLUSION:

This study successfully developed a biodegradable plastic using natural starch, pectin, glycerol, and organic acids. The bioplastic demonstrated excellent tensile strength, antimicrobial properties, and rapid biodegradability in soil, making it a promising alternative to conventional plastics. The material exhibited antibacterial activity against Escherichia coli and showed controlled solubility in water, enhancing its suitability for various applications. The findings highlight the potential of bioplastics to reduce plastic pollution and contribute to environmental sustainability. Further research can optimize composition and production techniques to enhance durability, moisture resistance, and large-scale feasibility for industrial applications.

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