Development and Evaluation of Biodegradable Mulch Mats Using CocoPeat and Recycled Paper Waste for Sustainable Agriculture

M.Elakkiya[1], Uppara Aadarsh [2], M. Sandosh surya[2], J. Jackson ajay[2], Harini Shri. J.N[3], Ashok S[2]

[1] Department of Chemical Engineering, Kalasalingam Academy of Research and Education, Krishnankoil 626126, India

[2] Department of Computer Science & Engineering, Kalasalingam Academy of Research and Education, Krishnankoil 626126, India

[3] Department of Food Technology, Kalasalingam Academy of Research and Education, Krishnankoil 626126, India

Abstract

Weed control, a critical factor in sustainable agriculture and gardening, has traditionally been using polyethylene-based weed barriers. Unfortunately, these create long-term environmental problems such as plastic pollution, soil degradation, and microplastic contamination. Biodegradable mulch mats, however, offer an alternative and holistic approach to weed suppression while improving soil health. This research delves into the design of biodegradable mulch mat using coco peat and recycled paper waste as the major raw materials. Coco peat is a byproduct of coconut processing. It has high absorptivity, retention of soil moisture and improves aeration. The recycled paper waste serves as a binder, helping to develop the structural integrity of the mulch mat while allowing biodegradability. This form of material combination is therefore a design, cost-effective, and natural compostable alternative to plastic mulching sheets. Research will focus on the optimization of the formulation, durability, and efficiency of the mulch mats in weed suppression and moisture retention in soils. Key parameters being looked into include types of materials used, degradation rate, tensile strength, water retention capacity, and influence on soil microbial activity. A comparison against conventional plastic mulch will give an insight into the efficacy and sustainability of the proposed solution. Aim of this project is to integrate agricultural waste and recycled materials to make a greener impact on the environment and improve soil fertility and eco-friendly agricultural/gardening practices.

Contributions of the research results strengthen the larger movements towards sustainable agriculture into offering biodegradable and responsible ecological alternatives to synthetic mulching products.

Introduction

Mulching is one such agricultural practice much in use and plays an important role in the improvement of soil health, crop productivity, and weed suppression. Traditionally, synthetic plastic mulch films were used as they have been very effective in the suppression of the growth of weeds, moisture conservation of soil, and temperature regulation of soil. These synthetic plastic materials have been non-biodegradable and have always left serious environmental challenges like pollution from plastics, soil degradation, and aversion of microplastics. Over time plastic mulch fragments accumulate in a soil, which adversely affects the microbial activity in the soil and reduces its fertility; thereby bringing forth ill effects for a longer time.

To address it, there are increasing efforts being directed toward biodegradable alternatives, which can, in fact, bestow on the agricultural system similar benefits at par with the environmental concerns. Among them are the ways directed toward developing compostable mulch mats using coco peat (coir pith) and recycled paper waste. The discarded husk portion of the coconut in its processing offers coco peat, which is found to be a very good soil conditioner because of its high water-holding capacity, aeration property, and organic nature. On the other hand, recycled paper waste acts as a structural binder, thereby improving further the durability and decomposition features of the mulch mats while minimizing the accumulation of waste paper in landfills. The outcome with such a combination is an eco-friendly, cost-effective, and sustainable alternative to old-fashioned plastic mulching sheets.

Study Objectives:

The first objective of this study is to create biodegradable mulch mats that would be a good environmental and effective substitute for plastic mulch films, and; The specific objectives of this study are,

Natural weed suppression without herbicides or any chemical interventions.

Soil moisture conservation so that less frequent irrigation is done thus saving water.

Improving soil structure and fertility through the decomposition process and gradual enrichment of soil with organic matter.

Minimizing plastic waste in agriculture and promoting environmental farming.

Scope of the Study:

The present research involves optimizing the proportion, durability, and efficacy of biodegradable mulch mats. Various parameters involved are such as water retention capacity, degradation rate, tensile strength, weed suppression efficiency, and impact on soil health effects of these variables on these matrices, along with a comparative study with traditional plastic mulch, would be undertaken to analyze feasibility and performance with respect to agricultural applications.

Through developing a viable compostable alternative, this study intends to forward the sustainable agricultural practice towards lowering its environmental strain while at the same time keeping or increasing yield. The results gained would give support to the transition toward eco-friendly, regenerative farming by an innovative solution to one of the pressing challenges in modern agriculture, plastic pollution from mulching materials.

Materials Required:

This section lists the necessary components, which are divided into primary raw materials, additives, equipment, and testing tools to ensure the mats' durability, biodegradability, and efficacy in weed suppression and soil improvement. These materials are needed to create biodegradable mulch mats using coco peat and recycled paper waste.

1. Essential Raw Materials

1.1 The coconut husk processing industry is the source of coco peat (coir pith).

Features: lightweight, biodegradable, high water retention capacity, and good aeration.

Function: Serves as the primary organic and absorbent component, promoting microbial activity and assisting in moisture retention.

Processing: Excess salts and contaminants were eliminated by washing, drying, and sieving.

1.2 Source of Recycled Paper Waste: Used paper goods like cardboard, office paper, and newspapers.

Properties include fibrousness, biodegradability, and structural integrity.

Role: Increases the mulch mat's durability by acting as a binding agent.

Processing involves shredding paper, soaking it in water, and turning it into pulp.

2. Reinforcement materials and additives (optional for optimization)

2.1 Natural Binders (for Durability & Strength of the Mat)

Corn or tapioca-based starch: improves fiber cohesion.

Agar or Arabic gum: Increases water resistance and suppleness.

Cellulose extracts: Reduce degradation and reinforce mat structure.

2.2 Biodegradability Microbial inoculants (such as Trichoderma and Bacillus species) and enhancers (for controlled decomposition): Enhance the soil microbiota and encourage degradation.

Alginates and pectin are examples of compostable polysaccharides that prolong the mulch mat's life while preserving its biodegradability.

2.3 Natural Water-Resistant Coatings (Optional for Extended Field Use Life)

In moist environments, beeswax or soy wax slows down the rate of breakdown.

Plant-Based Oils (Neem Oil, Linseed Oil): Increase pest and moisture resistance.

3. Tools and Equipment

3.1 Equipment for Material Processing

Shredder: To cut recycled paper into tiny bits.

A pulper, also called a blender, is used to turn shredded paper into a fine pulp.

Sieves: Used to filter processed coco peat of coarse particles.

Mixing Tank: For evenly mixing paper pulp, coco peat, and additives.

3.2 Equipment for Molding and Drying

The mulch mats are shaped into uniform sheets using a mold or pressing frame.

A hydraulic press, also known as a manual press, is used to compress the mixture into a uniformly thin, compact sheet.

Before testing, the formed mulch mats are dried in a drying chamber, also known as a sun drying area.

4. Instruments and Materials for Testing

4.1 The Mechanical Characteristic Testing

Tensile Strength Tester: To evaluate the mulch mat's resilience and pliability.

Thickness Gauge: To guarantee that every sample has the same thickness.

4.2 Absorption and Retention of Water

Weighing balance testing: To quantify weight changes brought on by water absorption.

Moisture Analyzer: To ascertain the mulch mat's ability to retain moisture.

4.3 Biodegradability and Decomposition The purpose of the soil burial test setup is to assess the rate of degradation in natural soil conditions.

Microbial Activity Assessment Kit: To investigate how microorganisms interact with the mulch mat.

4.4 Experimental Crop Plot for Field Performance Testing (Greenhouse or Agricultural Field): to examine the effects on plant growth, soil moisture retention, and weed suppression.

Sensors of soil moisture: To track the effectiveness of water retention.

Methodology:

Material Preparation:

• Paper Processing: Paper waste (primarily newspapers and office paper) was collected and sorted. The paper was shredded into small pieces, soaked in water for 6- 12 hours at room temperature, and blended into a homogeneous pulp.

• Coco Peat Preparation: Coco peat blocks were hydrated according to manufacturer instructions, sieved to remove coarse particles, and moisture content was adjusted.

• Adhesive Preparation: A corn starch-based adhesive was prepared by heating starch with water until thickened, then allowed to cool to room temperature before use.

Mat Formation Process:

1. The prepared paper pulp and coco peat were mixed in a 2:1 ratio by weight. Natural adhesive was added at 10% of the total mixture weight.

2. The components were thoroughly blended until homogeneous.

3. The mixture was poured into a wooden frame and even pressure was applied to achieve uniform thickness. The mat was left

to set for 2 hours.

4. After the initial setting, the mat was removed from the frame and transferred to the drying area.

5. The mats were sun-dried for 24-48 hours (depending on weather conditions).

6. Finished mats were inspected for uniformity and structural integrity.

Testing Protocol:

• Physical Testing: Thickness was measured at multiple points across each mat, and density and structural integrity were assessed.

• Functional Testing: Water absorption capacity was tested by immersing samples in water and measuring weight gain. Water retention was monitored by observing moisture loss over time, and light penetration was visually assessed.

• Field Performance Testing: Weed suppression efficacy was evaluated by comparing weed emergence in treated versus control plots. Soil moisture conservation was checked through visual and touch assessments, and plant growth impact was tested by assessing germination rates and early growth of mustard seedlings.

• Biodegradation Assessment: The mats were monitored for visual decomposition over time, and changes in structural integrity were observed.

Photographic Documentation:

Fig.1: Mulching Mat

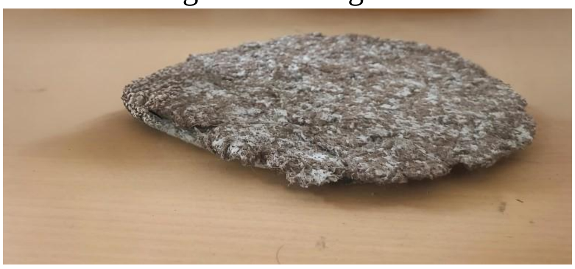

Fig.2: Mulching Mat

Fig.3: Soil Test Pots

WORKING PRINCIPLE:

Biodegradable mulch mats function as a sustainable alternative to plastic mulch films by creating a protective layer over the soil surface. This protective barrier helps in weed suppression, moisture retention, temperature regulation, and soil enrichment, ultimately promoting eco-friendly and sustainable agriculture.

Weed Suppression Mechanism

Preventing Weed Germination by Blocking Sunlight

For photosynthesis and growth, weeds need sunlight

Because of the physical barrier that the mulch mat creates, less light can reach the soil's surface.

This eliminates the need for chemical herbicides by preventing seed germination and weed growth.

Stopping the Development of Weed Roots

Weed root penetration is limited by the mulch mat's compact structure.

Weeds that try to grow beneath the mat eventually deteriorate because they are unable to obtain enough oxygen and nutrients.

2. Retaining Soil Moisture to Lower Evaporation

By limiting direct exposure to wind and sunlight, the mulch mat retains soil moisture.

This maintains ideal soil hydration by preventing excessive water loss through evaporation

Improving Absorption of Water

One of the mat's main ingredients, coco peat, has a high capacity to hold water.

It lowers the frequency of irrigation by absorbing and storing moisture, which is then progressively released into the soil as needed.

Reducing Water Runoff

The mulch mat stops water runoff during

irrigation or rainfall, increasing the amount of water that seeps into the soil.
This increases the efficiency of water use, particularly in regions that are prone to drought.
3. Controlling Soil Temperature to Protect Plants from Variations in Temperature
As a thermal insulator, the mulch mat controls the temperature of the soil throughout the year.
By reflecting extra heat, it keeps the soil cool in hotter climates and avoids overheating
It acts as insulation in cold climates, keeping soil temperatures from falling too low.
Establishing a Consistent Microclimate for Root Development
By preserving a steady subterranean environment, the mat shields plant roots from severe cold or heat.
This encourages healthier plant growth and more robust root development.
4. Soil enrichment and natural biodegradation
Slow Breakdown into Organic Substances
These mats are made to naturally biodegrade over time, in contrast to synthetic plastic mulch.
Soil microorganisms aid in the decomposition process by converting the mulch into organic matter.
Increasing Fertility in Soils
The mat releases nutrients that improve the soil as it breaks down.
Coco peat improves soil structure by increasing microbial activity and soil aeration.
Cellulose, which is produced by recycled paper waste, aids in the accumulation of soil organic matter.
Eco-Friendly Reduction of Waste
There is no need to dispose of plastic because the mulch mat completely breaks down.

This promotes sustainable farming methods and lessens the amount of plastic waste generated by agriculture.
5. Extra Advantages
Reduction of Disease and Pests
The mat serves as a physical barrier to keep insects and nematodes out of the soil.
Additionally, it lessens soil splash, which stops bacterial and fungal diseases from spreading.
Cost-Effectiveness and Usability
The mulch mat requires little work because it is lightweight and simple to apply.
It provides a cost-effective substitute for commercial mulching films because it is composed of recycled materials.

CONCLUSION:

An environmentally responsible and sustainable substitute for traditional plastic-based weed barriers is the creation of biodegradable mulch mats made from recycled paper waste and coco peat. By removing the environmental risks connected with synthetic mulches, this study effectively illustrates the potential of natural and recycled materials in weed suppression, soil moisture retention, temperature regulation, and soil enrichment. The results point to a number of significant benefits of these biodegradable mulch mats.
Effective Weed Suppression: The mats greatly lessen the need for chemical herbicides by obstructing sunlight and stopping the germination of weed seeds.
Enhanced Soil Moisture Retention: Coco peat's high water-holding capacity guarantees ideal soil hydration, lowering the need for irrigation and encouraging water conservation.
Better Soil Health and Fertility: As the mats break down over time, organic matter is added to the soil, promoting microbial activity and strengthening the soil's structure.
Eco-friendly and sustainable – These biodegradable mats naturally decompose, leaving no toxic residues, in contrast to plastic mulch films that contribute to long-term pollution and soil degradation.
Temperature Control and Root Protection: By protecting plant roots from intense heat and cold, the mats serve as thermal insulators, promoting healthier crop growth.
Field tests, mechanical strength testing, water retention analysis, and biodegradability analysis are all part of the experimental analysis that confirms how well these mulch mats support sustainable gardening and

agriculture practices.
Additional investigation can concentrate on:
maximizing the composition of materials to improve biodegradation rates and durability.
investigating different organic binders to increase the durability and strength of the mat.
carrying out extensive field tests in various soil types and climates.
evaluating the commercial viability and economic feasibility of broad adoption.
This study provides an economical, biodegradable, and ecologically friendly substitute for synthetic mulching products by utilizing agricultural waste and recycled materials, thereby supporting the global shift towards sustainable farming. Adopting such creative solutions will be essential to lowering the amount of plastic waste generated by agriculture, conserving resources, and promoting environmentally friendly farming methods.

REFERENCES:

Walsh, J., and Acharya, B. S. (2020). "A Review of the Assessment of Biodegradable Mulch Films for Sustainable Agriculture." Journal of Agronomy, 112(3), 2108-2123.

Iqbal, R., Anjum, M., and Mushtaq, S. (2019). "A Review of the Impact of Mulching on Soil Properties and Crop Yield." 2(1), Environmental Sustainability, 23-29.

Sanches, F., Bastos, R., and Ribeiro, C. (2021). "The Function of Organic Mulches in Plant Development and Soil Health." 21(5), 3140-3152, Journal of Soil Science and Plant Nutrition.

L. Chalker-Scott (2007). "Impact of Mulches on Landscape Plants and the Environment: A Review." Environmental Horticulture Journal, 25(4), 239–249.

Espi, E., García, Y., Fontecha, A., Salmerón, A., & Real, A. I. (2006). Journal of Plasticulture, 47(2), 33-44. "Plastic Films for Agricultural Applications."

Ghimire, S., Scheenstra, E., & Miles, C. A. (2020). "Biodegradable Mulches for Organic Specialty Crop Production." 55(1), Horticultural Science, 12–25.

Hayes, D. G., Miles, C., Wadsworth, L. C., Leonas, K. K., Dharmalingam, S., & Inglis, D. A. (2019). Journal of Applied Polymer Science, 136(27), 47738. "Biodegradable Agricultural Mulches: Environmental Impacts and Research Trends."

Ngouajio, M., and S. Kasirajan (2012). "A Review of Biodegradable Mulches and Polyethylene for Agricultural Uses." 30(4), 231-245; Agricultural Research.

Li, R., Shi, Y., & Wang, J. (2021). "The Impact of Organic Mulching on Crop Yield and the Soil Microbial Community." 145–158 in Journal of Soil Biology, 48(2).

Flury, M., and Sintim, H. Y. (2017). "Is Biodegradable Mulch the Answer to Agriculture's Plastic Waste Pollution?" 51(3), Environmental Science & Technology, 1068-1076.

Hu, H., Zhang, Y., and Sun, H. (2020). "A Meta-Analysis of the Impact of Mulching on Temperature and Soil Moisture." Journal of Soil Science, 65(4), 512-5.