Enhanced Abutilon Indicum Fiber Needle Punched Mulch Mat for Sustainable Agriculture Growth

***Dr.G.MALARVIZHI**, Associate Professor, Department of Costume Design and Fashion, KPR College of Arts Science And Research, Coimbatore, India.

**** Dr. S. KARPAGAM CHINNAMMAL**, Associate Professor and Head, Department of Costume Design and Fashion, Chikkanna Government Arts College, Tirupur, India.

***** SAVITHA. V** MBA Student, Vivekananda Institute of Management, Coimbatore, India.

Corresponding author mail id: gmalar.vizhi18@gmail.com

ABSTRACT

Agriculture is India's backbone. Many textile materials have been integrated into agricultural fields in recent years. Eco friendly sustainable textile innovations are the new evolution in the textile industry. It has several and obvious advantages, such as being biodegradable. Needle punching method was used to create a natural and bio-degradable non-woven mulch mat. This mulch mat can be used on various types of plants and trees, including ornamental, medicinal, and aromatics. In this study, mulch mats were made using two fibers *Abutilon indicum* and low melt polyester. Because agricultural mulches made from plant waste can biodegrade and integrate into the soil, they represent an environmentally friendly alternative. This mulch mat has been successfully investigated and analysed for air permeability, tearing strength, water absorbency, and biodegradability. The impact of the mulch mat on edaphic and productive parameters, including plant height and weed control was assessed. Plants with the mulch mat led to increases in plant height and decrease in weeds.

Keywords: Mulch mat, *Abutilon indicum*, low melt polyester, weed control, water absorbency, biodegradable.

INTRODUCTION

The industrial advancements and technological progress of earlier decades have spurred the innovation and development of numerous new products in all fields. However, this industrial growth has also resulted in the generation of substantial volumes of waste, posing serious environmental hazards. The environmental threats posed by hazardous waste and carbon-rich gas emissions have driven researchers to focus on developing alternatives that reduce dependence on non-renewable resources and synthetic materials. (Sanjay et al., 2018; Vinod et al., 2020). At the same time, greener and eco-friendly materials derived from natural and renewable resources are being increasingly utilized across various industries, including automotive, construction, aerospace, and other commercial sectors. One notable example of such renewable materials is fibers sourced from nature, including plants, animals, and other biological resources. Plant-based fibers, in particular, are environmentally friendly, abundant, cost-effective, biodegradable, and serve as excellent materials for the sustainable production of innovative products (Ramachandran et al., 2022). In addition to traditional natural fibers such as jute, coir, hemp, bamboo, silk, banana, and kenaf, several emerging cellulosic fibers have been identified as suitable materials for various applications. Among these, *Abutilon indicum,* commonly known as Indian mallow or velvetleaf, is a plant native to tropical and subtropical regions. Fiber is derived from the stem of the 'Thuthi Plant,'. Previous researches has characterized this fiber and evaluated its potential for reinforcement in polymer composites (Arunramnath et al., 2023). Among the various plants found in the southern region of the Indian subcontinent, Thuthi plants and their leaves are primarily used for their medicinal properties. Based on earlier research studies on the physico-chemical properties of Abutilon Indicum Fibers, these fibers are identified as potential material in production of composites **(**Arunramnath et al., 2024)

Agrotextiles, valued at $9.05 billion globally in 2020 (Grand View Research, 2021), are specialized textiles utilized in agriculture, horticulture, fishing, landscaping, animal husbandry, aquaculture, gardening, forestry, and agro-engineering (Azam & Ahmad, 2020). A notable application of agrotextiles is mulch mats, commonly used in agriculture, horticulture, and floriculture. Mulch mats are a form of mulch designed to cover soil, offering various benefits such as: Weed suppression, soil hydration retention, preventing soil loss, temperature and frost regulation, soil stabilization and separation, reduced nutrient leaching, enhanced soil organic matter and nutrient levels, improved soil porosity, and support for plant germination and growth, Protecting plant roots from heat, cold, or evaporation. Additionally, they can modify insect and disease pressures (Manna, Kundu, Saha, & Ghosh, 2018; Restrepo-Osorio, Álvarez-López, Jaramillo-Quiceno, & Fernández-Morales, 2019).

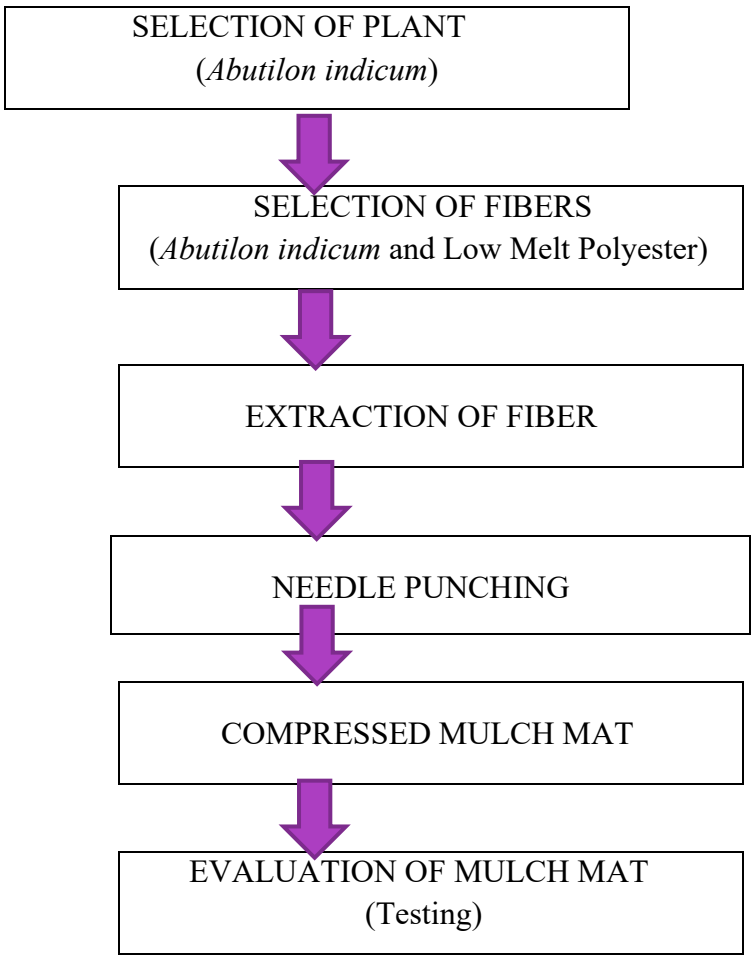
Mulch are made from a wide range of materials Natural and synthetic. Natural mulches, like straw and grass contribute to maintaining soil organic matter (Tindall et al., 1991). However, they are often limited in supply, vary in quality, and demand more labor for application. Additionally, they may not effectively suppress weeds, can introduce weed seeds, attract pests and often slow soil warming in spring, potentially delaying the growth and maturation of warm-season vegetables (Schultz, 1983). Synthetic mulches made from rubber, plastic, polypropylene are non -biodegradable and disposal is recognized as an environmental concern. Nonwoven mulch mats made from sustainable fibers offers an alternative to non-biodegradable mats, and are porous, breathable, and enhance soil quality and crop yields while preventing weed growth. The fibres experimented till date include; jute, coir, cotton waste, wool, palm leaves, bagasse, flax, sisal, banana Alfa, and Agave (Manna et al 2018). Additionally, in this study we are exploring the fiber Abutilon indicum for this purpose as it is abundantly available and seen as a weed in tropical areas, it is also inexpensive. The novelty lies in transforming this plant into a sustainable, functional material that addresses environmental concerns in horticulture and landscaping.

Objectives of the study are

- To develop an environmental friendly mulch mat
- To extract *Abutilon indicum* fiber
- To develop nonwoven fabric using needle punching method
- To convert the needle punched nonwoven fabric into mulch mat
- To analyse the produced mulch mat for its tearing strength, air permeability, absorbency bio degradability and plant growth

MATERIALS AND METHODS

FLOW CHART



Selection of Plant:

Abutilon indicum plant was selected, as it is an invasive plant found in abundance in many tropical areas.

Collection and Extraction of fiber:

Low melt polyester was procured commercially. *Abutilon indicum* plants were collected from Gobi Chettipalayam, TamilNadu, India. *Abutilon indicum* were extracted using fiber extractor equipment by scrapping method. Scraping was carried out in two stages called linear scrapping and rotational scrapping. The lengthy fibers extruded by scrapping were chopped to smaller size and transferred to next process. The quality and contamination free status of the selected fiber was determined using standard protocols.

PLATE: 01 Low Melt Polyester

PLATE: 02 *Abutilon indicum*

Needle Punching:

The web structure in needle punched nonwoven fabrics were produced mechanically by orienting and interlocking of fibres. The needle punched nonwoven fabric was produced on a needle loom, M/s. Dilo Machine, Germany. The machine parameters of maximum working width 600 mm, width of needle boards: 200 mm, number of needles approximately: 4 x 45 / 1 cm working width, needle beam stroke: 60 mm, maximum stroke frequency: 1200 rpm and 250 stitch density were used in the production of nonwoven fabric. The layered web was passed into Dilo needle punching machine (Plate: 03) by means of web feeder. The feeder maintains the uniformity of layered web. Webs were fed into series of needle bed. The needle loom beam moves up and down, the blades of the needles penetrate on to the fiber batting. Barbs on the blade of the needle pick up the fibers on the downward movement and carry those fibers to the depth of the penetration. Here the entanglement of fibres was done. The draw roll pulls the batt through the needle loom as the needles reorient the fibers from a predominately horizontal to almost a vertical position. The more needles penetrate the web denser and stronger fabric are produced. Thus the required nonwoven fabrics were developed.

PLATE: 03 Needle Punching

Production of Mulch mat – Compression Method:

The developed needle punched nonwoven fabric was taken for mulch mat conversion. It was done in Ayyampalayam Palladam, Tirupur by compression method using hydraulic press machine. The needle punched *nonwoven* fabric of 1050 GSM was placed under the heat, pressure and then compressed into 300 GSM using hydraulic pressure. The produced mulch mat was cut in round shape with manual cutting machine.

PLATE: 04 Compressed mat

PLATE:05 Produced Mulch mat

PLATE: 06 Plant growth

Evaluation of produced Mulch mat:

Various testing has been done in order to check the capability of produced mulch mat. Air permeability, tearing strength, absorbency and biodegradability tests were performed.

Air Permeability Test: ASTM D737

Air permeability was tested in occurdance with ASTM D737. Testing were carried under standard temperature 21 (±) 2^0C RH 65 (±) 5%. A clamping ring is placed on the lower part of the instrument. The test specimen is positioned on the clamping ring. A gasket material is added on top of the specimen. A pressure differential of 125 Pa is applied across the test specimen. The volume of air passing through the specimen (in cm^3) is recorded over a specified time (in seconds) using the calibrated air permeability tester. The test was repeated five times using different specimens.

Tearing Strength: BSEN ISO 13937-2-2023

Testing were carried under standard temperature 20 (±) 2^0C RH 65 (±) 4% as per **ISO 139.** The test specimen was placed between the clamps of the tearing tester. An initial force was applied to initiate the tear. The force required to propagate the tear is measured through the specimen using the calibrated tearing tester. The test is continued until the tear extends a specified distance, and the maximum force applied during this extension is recorded.

Absorbency Test:

The measurement of static water absorption of produced mulch mat was carried out using Bureau Veritas Consumer Product services BV S1008 internal testing method. The samples were conditioned and cut in to 10 cm x 10 cm and their mass evaluated. The samples were kept in water for five minutes at room temperature. After that the samples were hanged for three minutes to remove excess water. Then, mass of the wet samples was measured. The amount of water absorbed by the samples were calculated by taking the difference between the wet and dry mass of the sample.

$$Sw = (m_{mw} - m_d)/m_d \times 100$$

Where: Sw = water absorbed, mw – Product wet mass, md – Product dry mass

Biodegradability Test: IHTM 98:2018

Biodegradability testing allows to evaluate whether a product can completely breakdown to a state to resemble the natural environment. This form of testing measures the ability of a product to degrade by microorganisms where a measure of CO_2 produced is used to assess the extent of biodegradation. This testing was done by soil burial test conducted under controlled conditions in laboratory and under real weather conditions.

Plant Growth Analysis

These plant growth analysis has been done with green gram. The comparison of green gram was done with both the produced mulch mat and without mulch mat. The growth of the plant was analysed, and the weed control property has been analysed, the moisture retention in the soil has been analysed.

RESULT AND DISCUSSION:

Air Permeability:

TABLE - I
Air Permeability of Produced Mulch mat

PARTICULARS	REPORT VALUE
TEST AREA:20 cm^2	36.1pa

The goal of air permeability test is to measure how easily air can pass through a material. The above Table - I value represents the pressure difference needed to force air through the material. A lower value would indicate that air flows easily through the mat, while a higher value means the material is denser and restricts airflow more. For this mulch mat, the final reported value is 36.1 Pascals (Pa). A 36.1 Pa reading suggests that the mulch mat allows for moderate air movement, balancing breathability with its primary function of retaining moisture and suppressing weeds. This ensures that air reaches the soil while still providing effective coverage for the plants.

Tearing Strength:

TABLE - II
Tearing Strength of Produced Mulch mat

PARTICULARS	REPORT VALUE
LENGTH	21.6N
WIDTH	17.8N

This mulch mat has tearing strengths of 21.6 N (in length) and 17.8 N (in width), which are within the 3N to 135N range for such materials. These values indicate moderate tear resistance, performing better than weaker mats but not as strong as the most robust ones. The produced mat is adequate for standard applications like weed control is shown in Table - II.

Absorbency:

With mw = 25.5 and md = 13.7, the absorbency is:

$$Sw= (25.5−13.7) / 13.7×100=86.13\%$$

The produced mulch mat material absorbed 86.13% of its dry mass in water. Its shows the ability to absorb moisture.

Biodegradability:

The test report for *Abutilon indicum* mulch mat meets biodegradable property and hence it is proved that it is a bio degradable material.

Plant Growth Analysis:

Initially, the stones and weeds were cleared in order to maintain better contact with soil and mulch mat was placed then green gram seeds were sowed.

(DAY: 1)

PLATE: 07 **PLATE: 08**

Plate: 07 displays the sowing of seeds with mulch mat. Plate: 08 Control- seeds sown without mulch mat

(DAY: 2)

PLATE: 09 **PLATE: 10**

Plate: 09 show higher germination of seeds and Plate: 10 displays very less germination of seeds. The mulch mat help in maintaining the soil moisture and seed germination.

(DAY: 3)

PLATE: 11 **PLATE: 12**

Checking out the plant growth development and also the initial stage of leaf growth. Plate: 11 show higher root germination and initial stage of leaf and Plate:12 exhibits minimum growth of plant.

(DAY: 4)

PLATE: 13 **PLATE: 14**

The growth rate of the plants was higher with use of mulch mat. Plate: 13 show the even growth of leafs and Plate: 14 display less leaf growth and uneven seed germination.

The growth of plant in mulch mat was larger than the plant grown without mulch mat. The length of the plant with mulch mat was 7 inch and the plant grown without mulch mat was 6.5 inch.

SUMMARY AND CONCLUSION

Natural resource has been exploited by mankind to extreme level; it has now become important to use alternatives to safeguard it for future generation. This is one such idea where natural fibres found in abundance were converted into mulch mat. Mulch mat not only makes agricultural labour easier but also helps limit environmental harm. It is stated that nonwoven mulch mats could become widely used for efficient weed control in many other plants and the attempt was made with green gram. Because the fiber is derived from invasive plant and reincorporated into the soil, soil erosion has been mitigated and sustainability is maintained. *Abutilon indicum* with low melt polyester nonwoven mulch mat efficiently suppress weeds in green gram throughout the plant growth cycle, while also increasing plant height and managing weeds. Mulch mat made from different bast fibers and invase plants can help to preserve a sustainable world. These nonwoven mulch mat are biodegradable. By using renewable resources, it reduces waste and minimizes environmental impact.

The results from the various tests and plant growth analysis demonstrate that the *Abutilon indicum* nonwoven mulch mat is a highly effective and environmentally friendly alternative to traditional mulching materials. Key findings include: air permeability allows for soil aeration and Mulch mats serve as a natural shield, blocking sunlight from reaching the soil and thereby suppressing weed growth. This also minimizes the reliance on herbicides for controlling weeds.

Moderate tearing strength ensures durability under typical agricultural conditions. High absorbency makes the mat an excellent tool for moisture retention, which would help keep the soil consistently moist and be especially helpful in dry climates, reducing irrigation needs. Biodegradability supports sustainability by ensuring the mat decomposes naturally, contributing to soil health. Improved plant growth and higher germination rates highlight the mat's effectiveness in maintaining optimal conditions for seedling development. This mulch mat, made from renewable resources like *Abutilon indicum* fiber, represents a sustainable solution to common agricultural challenges, including weed control, moisture retention, and soil health. It showcases the potential of biodegradable materials in reducing the environmental impact of agriculture while improving plant productivity. Additionally, using invasive plants like *Abutilon indicum* helps address environmental challenges while still providing all the benefits of traditional mulches, such as weed suppression, moisture retention, and soil temperature regulation and supports sustainable farming practices. The development of nonwoven mulch mats made from natural fibers holds promise for widespread use in both horticulture and landscaping.

REFERENCES:

Sanjay, M. R., Madhu, P., Jawaid, M., Senthamaraikannan, P., Senthil, S., Pradeep, S. “Characterization and properties of natural fiber polymer composites: A comprehensive review”, Journal of Cleaner Production, Volume 172, pp. 566 – 581, [2018]. https://doi.org/10.1016/j.jclepro.2017.10.101

Vinod, A., Sanjay, M. R., Suchart, S., Jyotishkumar, P. “Renewable and sustainable bio based materials: An assessment on biofibers, biofilms, biopolymers and bio composites”, Journal of Cleaner Production, Volume 258, 120978, [2020]. https://doi.org/10.1016/j.jclepro.2020.120978

Ramachandran, A., Mavinkere Rangappa, S., Kushvaha, V., Khan, A., Seingchin, S., & Dhakal, H. N, “Modification of Fibers and Matrices in Natural Fiber Reinforced Polymer Composites: A

Comprehensive Review. Macromolecular Rapid Communications", Volume 43(17), [2022]. https://doi.org/10.1002/marc.202100862

ArunRamnath, R., Murugan, S., Sanjay, M. R., Vinod, A., Indran, S., Elnaggar, A. Y.,Siengchin, S, "Characterization of novel natural cellulosic fibers from Abutilon Indicum for potential reinforcement in polymer composites", Polymer Composites, Volume 44(1), pp. 340–355, [2023]. https://doi.org/10.1002/pc.27100

R. Arun Ramnath, G. Rajeshkumar, N. Muthukumar et al, "An Investigation on Tribology Properties of Abutilon Indicum Fibre Reinforced Polymer Composites", PREPRINT (Version 1) available at Research Square, [2024] https://doi.org/10.21203/rs.3.rs-3887034/v1

Grand View Research, Agro textiles market size, share & trends analysis report by product (shade-nets, mulch-mats, fishing nets), by application (agriculture, aquaculture, horticulture & floriculture), by region, and segment forecasts, pp 2021-2028, [2021]. https://www.grandviewresearch.com/industry-analysis/agro-textiles market#:~:text=The%20global%20agro%20textiles%20market%20size%20was%20estimate d%20at%20USD, USD%209.37%20billion%20in%202021.

Azam, F., & Ahmad, S.. In S. Ahmad, A. Rasheed, & Y. Nawab (Eds), Fibers for Technical Textiles, Chapter 8. Fibers for Agro Textiles Springer publication, pp. 151-168, [2020].

Manna, K., Kundu, M. C., Saha, B., Ghosh, G. K. , "Effect of Nonwoven Jute Agrotextile Mulch on Soil Health and Productivity of Broccoli (Brassica oleracea L.) in lateritic soil, Environmental Monitoring and Assessment, Volume 190, P 82, [2018].

Restrepo-Osorio, A., Álvarez-López, C., Jaramillo-Quiceno, N., & Fernández-Morales, P., Agrotextiles and Crop Protection Textiles, In R. Paul Edition Chapter 10, High Performance Technical Textiles, John Wiley & Sons publication, pp. 279-318, [2019].

Mhamza, "Mulch mat"s, Textile magazine, Volume 3 issue (6) p.3 [2020]. https://textilevaluechain.in/

Tindall JA, Beverly RB, Radcliffe DE, "Mulch Effect on Soil Properties and Tomato Growth using Micro-Irrigation", Agron Journal Volume 83, pp 1028–1034, [1991].

Schultz, W, "Matching mulches", Organic Gardening, Volume 30 (6), pp 50-55. [1983].

Manna, Koushik & Kundu, Manik & Saha, Biplab & Ghosh, G, "Effect of nonwoven jute agrotextile mulch on soil health and productivity of broccoli (Brassica oleracea L.) in lateritic soil", Environmental Monitoring and Assessment, [2018].