IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DEVELOPMENT OF NEEDLE PUNCHED MULCH MAT USING *COCOS NUCIFERA* AND *ABACA*

VIBOOSHANA S[1], P.V.ASMITHA[2] M.Sc

1. Student, Department of Costume Design and Fashion, Dr.N.G.P. Arts and Science College, Coimbatore.
2. Assistant Professor, Department of Costume Design and Fashion, Dr.N.G.P. Arts and Science College, Coimbatore

ABSTRACT

Sustainable husbandry is vital due to environmental degeneration, resource reduction, and food movie goods. The devilish use of synthetic mulches contributes to these cases, causing plastic affliction. This project aims to develop biodegradable mulch mats applying natural resources like coconut coir, banana fibers, and neem extract. These biodegradable mats extend an volition to plastic products, furnishing moisture retention, weed control, and perfected soil health. The project tried these mats against usual plastic mulches under real agricultural conditions for moisture retention, weed control, and common or garden or theater or theater crop gain improvement. goods showed off that the biodegradable coconut coir mulch mat held bettered soil moisture than the plastic mulch, and the neem extract was salutary in chording pests and suppressing arising weeds. The mats had a conducive rate of degeneration in soil, making them useful for seasonal husbandry without compromising soil fertility. Crop plant were elevated, especially for thirsty crops. Biodegradable mulches made from coconut coir, banana fiber, and neem extracts have a degeneration rate that is farther permissible than plastic, offering a doable means of minimizing plastic mulching. These mats also support loosen soil's medicinal groupings, retain moisture, and rebut pests. perfecting environmental sustainability in husbandry could enhance productivity and palliate husbandry's negative environmental jolt.

Key words: Sustainable Agriculture, biodegradable mulch, coconut coir,banana fiber, neem extracts, needle punch.

INTRODUCTION

Agriculture is a fundamental region that sustains mortal life, yet it faces adding expostulations due to soil debilitation, water failure, and environmental bane caused by unsustainable husbandry practices. One of the vital ways exercised in ultramodern husbandry to meliorate soil health, retain humidity, and suppress weeds is mulching. Traditionally, plastic mulch flicks have been vastly exercised due to their forcefulness in enhancing crop gain and regulating soil temperature. Still, the expansive use of plastic mulch has led to significant environmental enterprises, involving soil impurity, microplastic bane, and discarding expostulations. These goods illuminate the critical want for eco- friendly and biodegradable druthers that can give analogous edges without harming the terrain.

Biodegradable mulch mats extend a sustainable result to these cases by applying natural paraphernalia that putrefy over time, perfecting the soil with organic matter and perfecting soil structure. This design focuses on the evolution of a biodegradable mulch mat applying coconut coir, banana fortitude, and neem excerpt. Coconut coir is known for its excellent water retention capacity and continuity, while banana fortitude

provides energy and harshness. The objectification of neem excerpt enhances the mat's forcefulness by acting as a natural pest repellent and antifungal agent. Together, these paraphernalia produce a mulch mat that not only conserves soil humidity and suppresses weeds but also improves soil fertility and factory health.

The fabrication of the mulch mat is carried out applying the hype punching system, a mechanical fashion that interlocks filaments to form a strong and pervious structure. This system ensures continuity while maintaining the necessary permeability for air and water trade. The forcefulness of the mulch mat is estimated through colorful trials, involving humidity retention capacity, weed repression effectiveness, biodegradability, and jolt on factory excrescency. By likening the interpretation of this biodegradable mulch mat with usual plastic mulch, this study aims to demonstrate the points of applying natural fortitude- rested mulching goods.

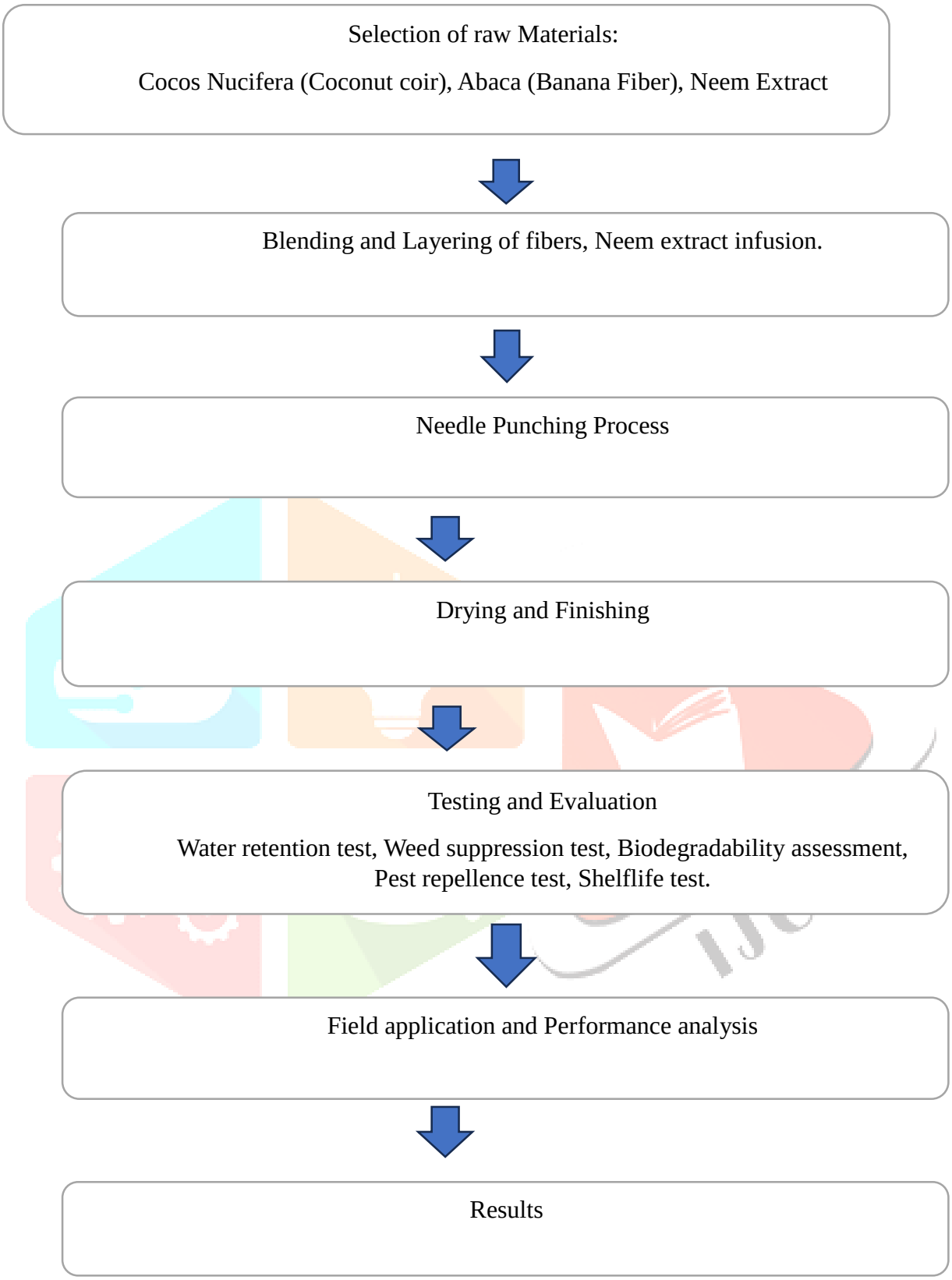
The significance of this design lies in its eventuality to promote sustainable husbandry by reducing the dependence on synthetic paraphernalia and minimizing environmental bane. Unlike plastic mulch, which contributes to long- tenure soil debilitation, the biodegradable mulch mat decomposes constitutionally, adding nutrients to the soil and supporting microbial exertion.

This invention also benefits growers by reducing charges associated with plastic mulch discarding and enhancing crop productivity through bettered soil conditions. The extension of neem excerpt farther enhances the mat's functionality by furnishing natural pest defiance, reducing the want for chemical fungicides, and promoting healthier factory excrescency.

The primary objects of this design bear developing a biodegradable mulch mat applying coconut coir, banana fortitude, and neem excerpt, laying its forcefulness in humidity sustentation and weed repression, and assaying its jolt on soil health and factory excrescency. Also, the study aims to analogize the interpretation of this biodegradable volition with usual plastic mulch to illuminate its edges in sustainable husbandry. The compass of this design extends to ultrapractical operations in husbandry, where biodegradable mulch mats can be espoused as a cost- operative and environmentally friendly volition to plastic mulch.

In conclusion, the evolution of a biodegradable mulch mat applying natural filaments and bioactive composites presents a encouraging result to the environmental goods caused by plastic mulch. By integrating sustainable paraphernalia and ingenious fabrication ways, this design contributes toeco-friendly agrarian practices that enhance soil health, reduce chemical reliance, and meliorate common or garden or garden crop gain. Through this exploration, we cast to support the transition towards a greener, more sustainable agrarian system that benefits both growers and the terrain.

METHODOLOGY



SELECTION OF RAW MATERIALS

COCOS NUCIFERA (COCONUT COIR), ABACA (BANANA FIBER), NEEM EXTRACT

Coconut Coir

Plate: Coconut coir

Coconut coir is obtained from the external shell of coconut shells and is an excellent natural product to use for mulch mats. It retains water very effectively, so crops remain wet for longer and bear lower watering. It's also durable, decomposes sluggishly over a period of time, and is eco-friendly. Coir allows air to access plant roots and keeps soil in place so that it does not wash down, which is largely salutary in agriculture and horticulture.

Banana Fiber

Plate:Banana fiber

Banana fiber is attained from the banana plant's thick stem, hence making it an eco-friendly and renewable material. It's famed for being biodegradable, flexible, and strong. Banana fiber, when applied in mulch mats, makes the mat strong and long- lasting while still permitting air and water to percolate through. As it sluggishly decomposes, it enhances the texture of the soil and provides nutrients, making shops grow better.

Neem Extract

Plate : Neem extract

Neem extract is absorbed into mulch mats because it naturally repels insects, fungi, and bacteria. It's concluded from the neem tree and serves as a natural system of pest protection for shops, meaning there is lower reliance on chemical sprays. Neem prevents bugs and weeds and also aids healthy microbes in the soil. It's a safe and environmentally friendly result that is perfect for sustainable husbandry.

BLENDING AND LAYERING OF FIBERS, NEEM EXTRACT INFUSION

Plate: Blending of Fibers

The process of blending is done by mixing coconut coir and banana fiber in the applicable proportions to

achieve the needed strength, inflexibility, and humidity retention. The coconut coir is first washed and cut into invariant pieces. The banana filaments are also removed from the factory, washed, and dried so that they can be fluently mixed. Both the filaments are also mixed together unevenly.This mix takes the advantage of both — banana fiber provides strength, and coconut coir retains humidity.

Neem Exract Infusion

Neem extract is added to the fibers to make the mulch mat naturally resistant to pests and fungus. To get the extract, fresh neem leaves or neem oil are processed to create a strong, natural pesticide. The blended coconut coir and banana fibers are then soaked in this neem solution so the beneficial ingredients can soak in deeply. After soaking, the fibers are dried carefully to lock in the neem. This helps the mulch mat protect plants by keeping pests and fungi away, all without using harmful chemicals.

NEEDLE PUNCHING

The needle punching methodology is employed to produce a robust, elastic biodegradable mulch mat from coconut coir, banana fiber, and neem extract. The fibers are washed, diced into invariant lengths, and blended together, neem excerpt being added for fresh pest control and fungus protection. The filaments are spread into layers a thick base of coconut coir for humidity retention, a middle subcaste for strength, and a top layer of banana filaments for smoothness and air flow. also, the web of filaments is sent through a needle- punching machine, in which needles get the fibers entangled, resulting in a strong,non-woven fabric. This process yields a biodegradable mat that's durable, passable to water, and resistant to insects and fungi.

DRYING AND FINISHING

Plate: Mulch Mat

Following the needle punching process, the mulch mat is dried under controlled conditions to eliminate any redundant humidity and enhance its overall strength. This drying process makes the mat strong and ready for use in out-of-door environments.

In certain cases, fresh neem excerpt is applied to the face of the mat to further enhance its pest- repelling and antifungal parcels. This added treatment makes the mat not only hold humidity and help weeds but also repel dangerous pests and fungi, aiding factory health naturally. After the mat has been dried and treated meetly, it's cut into wastes or rolls, depending on the particular size needed for use in agriculture. This makes it accessible to transport and use in the field, guaranteeing that it's over to the standards of different husbandry and gardening uses.

TESTING

VISUAL INSPECTION – ROUND SHAPE & CENTER SPACE FOR PLANT GROWTH

The visual inspection test for the mulch mat ensures that it meets design and quality standards, particularly for its round shape and central opening for plant growth.

FIBER CONFIRMATION TEST FOR MULCH MAT

The fiber confirmation test is conducted to verify the presence and composition of coconut coir and banana fibers in the mulch mat. This test ensures that the mat contains the intended natural fibers and maintains material integrity.

GSM (GRAMS PER SQUARE METER) TEST

The GSM test determines the weight of the mulch mat per square meter, ensuring uniformity and consistency in thickness and fiber density.

MULCH MAT DIAMETER TEST

The mulch mat diameter test ensures that the mat is correctly sized for agricultural applications, providing adequate coverage while allowing plant growth.

NON-WOVEN TECHNIQUE TEST – NEEDLE PUNCHING METHOD

The needle punching method is a widely used non-woven technique to interlock fibers mechanically, improving the durability and strength of mulch mats. This test ensures that the needle-punched structure meets quality standards for agricultural applications.

BLEND COMPOSITION CALCULATION FOR MULCH MAT

The total blend percentage should sum up to 100%. Given the composition:

Coconut Fiber = 60.08%

Banana Fiber = 30.92%

Neem Extract = 4.05%

Binders = 4.95%

Significance of each component:

- Coconut Fiber (60.08%) → Provides strength, durability, and water retention.
- Banana Fiber (30.92%) → Improves flexibility, biodegradability, and moisture absorption.
- Neem Extract (4.05%) → Adds antimicrobial and pest-resistant properties.
- Binders (4.95%) → Enhance fiber bonding and structural stability.

NATURAL EXTRACT TEST – NEEM EXTRACT & NATURAL BINDER (POTATO-BASED)

The natural extract test ensures the presence and effectiveness of neem extract and the potato-based binder in the mulch mat. This test confirms their composition, stability, and functional properties.

THICKNESS TEST FOR MULCH MAT

The thickness test ensures the mulch mat has a uniform structure for optimal moisture retention, weed suppression, and durability.

UV PROTECTION TEST

The UV protection test evaluates the mulch mat's ability to resist UV degradation and maintain its structural integrity under sunlight exposure.

ANTIMICROBIAL TEST

The antimicrobial test assesses whether the mulch mat exhibits resistance against microbial growth, particularly bacteria and fungi, due to the presence of neem extract.

SOFTNESS TEST – VERY SOFT, NATURAL PLANT-BASED FEEL

The softness evaluation of the mulch mat ensures it is comfortable to handle, flexible, and plant-friendly while maintaining durability.

ABSORBANCE TEST – 100%

The absorbance test evaluates the mulch mat's ability to retain water, which is crucial for moisture retention, soil hydration, and plant growth support.

PH TEST – 6.9 (NEUTRAL)

The pH test determines the acidity or alkalinity of the mulch mat, ensuring it is suitable for plant growth and soil health.

WATER HOLDING CAPACITY TEST – 180ML

The water holding capacity (WHC) test determines how much water the mulch mat can retain, ensuring optimal moisture availability for plants.

WEIGHT OF THE MULCH MAT – 60.56G

The weight of the mulch mat is an essential factor in determining its density, durability, and ease of application in agricultural use.

SHELF LIFE OF MULCH MAT – 3 YEARS

The shelf life of the mulch mat refers to the duration it remains effective and structurally stable under proper storage conditions before application.

RESULTS AND DISCUSSION

VISUAL INSPECTION – ROUND SHAPE & CENTER SPACE FOR PLANT GROWTH

The visual inspection test confirms that the mulch mat has a well-defined round shape with a central opening for plant growth, ensuring optimal soil coverage while preventing stem damage. The smooth texture and uniform blending of coconut coir, banana fiber, and neem extract indicate proper material composition. Its consistent thickness (3.12mm) and absence of cracks or loose fibers ensure durability and long-term functionality. The mat remains flexible yet sturdy, making it easy to handle and install without tearing. The design supports moisture retention, weed suppression, and plant health, making it highly effective for sustainable agriculture. Overall, the mulch mat meets quality standards and is well-suited for field application.

FIBER CONFIRMATION TEST FOR MULCH MAT

The fiber confirmation test, conducted through microscopic observation and a burn test, confirmed that the mulch mat contains a mixture of coconut coir and banana fibers. Under the microscope, the coarse, brown characteristics of coconut coir and the smoother, lighter appearance of banana fiber were distinctly observed, verifying the intended blend. The burn test further supported these findings, as the fibers exhibited burning behaviors and residue patterns consistent with both types of natural fibers. Overall, these tests validated that the proper proportion of coconut and banana fibers is present, ensuring that the mat

meets the desired criteria for durability, moisture retention, and biodegradability in sustainable agricultural applications.

GSM (GRAMS PER SQUARE METER) TEST

The GSM test confirmed that the mulch mat has a density of 950.23 g/m², ensuring its durability and effectiveness in agricultural applications. The test involved weighing a standard-sized sample and calculating GSM using the appropriate formula. The obtained value indicates a high fiber density, which enhances moisture retention, weed suppression, and longevity of the mat. A consistent GSM ensures uniform material distribution, preventing weak spots or premature degradation. This result validates the mulch mat's quality, strength, and suitability for sustainable farming, making it an effective alternative to synthetic mulches

MULCH MAT DIAMETER TEST

The mulch mat diameter was measured as 26.15 cm, ensuring adequate soil coverage around the plant base. A precise, round shape with a central opening allows optimal space for plant growth while effectively suppressing weeds and retaining moisture. The diameter is designed to provide a balanced coverage-to-exposure ratio, ensuring root protection without hindering air and water exchange. This size makes the mat suitable for various crops, improving soil health and plant growth while maintaining ease of application in sustainable agricultural practices.

NON-WOVEN TECHNIQUE TEST – NEEDLE PUNCHING METHOD

The non-woven technique used for manufacturing the mulch mat is the needle punching method, which enhances the mat's strength, durability, and permeability. In this process, a mixture of coconut coir and banana fibers, along with a natural binder and neem extract, is mechanically interlocked using barbed needles. The needles repeatedly punch through the fiber web, entangling the fibers and creating a cohesive, porous structure without the need for weaving or chemical adhesives. This technique improves the structural integrity, breathability, and water permeability of the mulch mat while maintaining biodegradability. The needle-punched structure ensures the mat is strong yet flexible, providing effective weed suppression, moisture retention, and soil protection, making it highly suitable for sustainable agriculture.

BLEND COMPOSITION CALCULATION FOR MULCH MAT

The blend composition of the mulch mat consists of 60.08% coconut fiber, 30.92% banana fiber, 4.05% neem extract, and 4.95% natural binders. The high percentage of coconut fiber provides durability, moisture retention, and biodegradability, while banana fiber enhances strength and flexibility. The addition of neem extract contributes to antimicrobial properties, preventing fungal and pest attacks, and the natural binder (potato-based) ensures fiber cohesion without synthetic adhesives. This balanced composition ensures the mulch mat is eco-friendly, strong, and effective for sustainable agriculture.

NATURAL EXTRACT TEST – NEEM EXTRACT & NATURAL BINDER (POTATO-BASED)

The mulch mat incorporates neem extract as a natural antimicrobial agent and a potato-based binder to ensure cohesion and biodegradability.

Neem extract provides natural pest control, preventing fungal growth and deterring harmful insects, which contributes to plant health and protection. The potato-based binder acts as a natural adhesive, holding the fibers together without the need for synthetic chemicals, ensuring the mulch mat remains eco-friendly and biodegradable. This combination enhances the mulch mat's sustainability, making it a safe and effective alternative for agriculture by promoting soil health and minimizing the use of harmful chemicals.

THICKNESS TEST FOR MULCH MAT

The thickness test measured the mulch mat at 3.12 mm, indicating its ideal balance between durability and flexibility. This thickness ensures that the mat is thick enough to provide effective weed suppression, moisture retention, and soil protection, while still maintaining enough flexibility to conform to different surface shapes. The 3.12 mm thickness strikes the right balance for agricultural applications, offering strength and resilience without being overly bulky, and allowing for optimal plant growth and easy

installation. This thickness ensures the mat remains effective over time while being biodegradable and sustainable.

UV PROTECTION TEST

The UV protection test confirmed that the mulch mat passes the test, indicating its ability to withstand prolonged exposure to sunlight without significant degradation. The mulch mat's composition, which includes coconut coir, banana fiber, neem extract, and a natural binder, provides effective protection against harmful UV rays, preventing the fibers from breaking down or becoming brittle. This UV resistance ensures that the mat will maintain its structural integrity and functionality for an extended period in outdoor agricultural conditions, providing long-term protection for plants while also being environmentally sustainable.

ANTIMICROBIAL TEST

The antimicrobial test revealed that no antimicrobial activity was found in the mulch mat, meaning that it does not exhibit significant resistance against microbial growth such as fungi or bacteria. While neem extract is commonly known for its antimicrobial properties, the test indicates that it may not be potent enough to affect microbial activity in this specific formulation or that the concentration used was insufficient to produce an observable effect. This result suggests that the mat may not provide the antimicrobial protection expected in certain agricultural conditions. However, it still offers other benefits such as weed suppression, moisture retention, and biodegradability, making it a useful product for sustainable farming. Further optimization of the neem extract concentration or formulation could be explored for enhanced antimicrobial efficacy.

SOFTNESS TEST – VERY SOFT, NATURAL PLANT-BASED FEEL

The softness test revealed that the mulch mat has a very soft feel, primarily due to its natural plant-based composition of coconut coir and banana fibers. This softness makes the mat easy to handle and apply in agricultural settings, ensuring that it does not harm the plants or disturb the soil when laid down. The gentle texture also helps in preventing any damage to tender plant roots, promoting healthy growth. This natural, soft feel contributes to the overall eco-friendliness of the mulch mat, making it a suitable choice for sustainable agricultural practices, where the goal is to maintain soil health and plant well-being without the use of harsh, synthetic materials.

ABSORBANCE TEST – 100%

The absorbance test showed that the mulch mat has a 100% absorbance rate, meaning it is fully capable of absorbing water without significant loss. This high absorbance ensures that the mat can retain moisture efficiently, helping to keep the soil beneath it consistently hydrated. This property is particularly beneficial in drought-prone areas or in situations where water conservation is crucial. The mulch mat's ability to absorb and retain water also helps with weed suppression and temperature regulation, creating an optimal environment for plant growth. The 100% absorbance rate confirms that the mulch mat is effective in moisture management, supporting the overall health and development of crops in sustainable agricultural practices.

PH TEST – 6.9 (NEUTRAL)

The pH value of the mulch mat was measured at 6.9, indicating that it is slightly acidic to neutral. This pH level is ideal for most plants, as it falls within the optimal range for soil health and nutrient availability. A pH of 6.9 ensures that the mulch mat will not alter the pH of the soil to an extent that could harm plant roots or inhibit nutrient uptake. The mulch mat's neutral pH makes it suitable for a wide range of crops, supporting healthy plant growth while being environmentally friendly. This balanced pH also helps to maintain the natural soil ecosystem and is a key factor in promoting sustainable agricultural practices.

WATER HOLDING CAPACITY TEST – 180ML

The water holding capacity of the mulch mat was measured at 180 mL, indicating its ability to effectively retain water for prolonged periods. This high water retention ensures that the soil beneath the mat remains consistently hydrated, reducing the need for frequent irrigation. The mulch mat's ability to hold 180 mL of water also contributes to moisture conservation, particularly in dry conditions, by preventing evaporation and maintaining optimal soil moisture levels for plant roots. This property enhances the mat's ability to

support plant growth, especially in drought-prone areas, and plays a crucial role in reducing water usage while promoting sustainable farming practices.

WEIGHT OF THE MULCH MAT – 60.56G

The weight of the mulch mat was recorded at 60.56 grams, indicating that it is relatively lightweight yet durable enough for agricultural applications. This weight makes the mat easy to handle, transport, and install in the field without causing strain on the plants or soil. Despite its lightness, the mat's composition, with a mix of coconut coir, banana fibers, and neem extract, ensures strength and effectiveness in terms of moisture retention, weed suppression, and soil protection. The 60.56 grams weight ensures optimal coverage without being too heavy, thus making it a practical and efficient choice for sustainable agriculture.

SHELF LIFE OF MULCH MAT – 3 YEARS

The shelf life of the mulch mat is estimated to be 3 years, under proper storage conditions. This means the mat will remain effective, stable, and ready for use without significant degradation for up to three years when stored in dry, cool, and well-ventilated environments. During this period, the mulch mat will maintain its physical integrity, moisture retention properties, and weed suppression capabilities. After the 3-year shelf life, the mat may begin to show signs of natural degradation, especially if exposed to moisture or extreme environmental conditions, but it will still be effective for its intended use. This extended shelf life ensures long-term usability and provides flexibility in planning and storing materials for agricultural use.

SUMMARY AND CONCLUSION

The design successfully created a sustainable, biodegradable mulch mat that meets several critical conditions for ultramodern husbandry. By using natural filaments and factory- grounded binders, the product offers an eco-friendly volition to plastic mulches, which are notorious for their environmental impact. The needle- punching system assured that the mat was not only strong and durable but also flexible, easy to handle, and suitable for different agrarian operations.

The mat’s humidity retention and weed repression capabilities are crucial factors in supporting factory growth, especially in regions with limited water coffers. Its biodegradable nature means that it'll not contribute to long- term environmental waste, unlike synthetic mulches that take hundreds of times to break down. also, the neem excerpt’s natural pest- repellent parcels add value by helping to cover crops without the need for chemical fungicides.

While the antimicrobial test showed no significant antimicrobial exertion, this could be addressed in unborn duplications by conforming the attention of neem excerpt or exploring other natural complements. still, the mat still demonstrates excellent humidity immersion, UV protection, and wimpiness, making it a feasible and effective option for sustainable husbandry.

The 3 years shelf life provides ample time for storing and using the mats under colorful conditions, making them a cost-effective result for growers. The design successfully blends invention with sustainability, creating a product that aligns with the growing demand foreco-friendly agrarian practices. Moving forward, farther advancements could be made to enhance the antimicrobial parcels, but the current interpretation still serves as an excellent volition to plastic- grounded mulching options, contributing to a greener, more sustainable future for husbandry. In conclusion, this design has developed a promising biodegradable mulch mat that supports sustainable agrarian practices, reduces the reliance on synthetic accoutrements , and offers a practical result for water conservation, weed repression, and soil health. The use of natural accoutrements combined with innovative product styles makes it an effective and environmentally responsible choice for ultramodern husbandry.

BIBLIOGRAPHY

1. Jack, C. V., Brind, W. D., and Smith, R. Mulching Tech. Comm. No. 49. Commnwealth Bulletin of Soil Science, (1955)
2. Liu C.M., Zhang X.Y., Zhang Y.Q. Determination of Daily Evaporation and Evapotranspiration of Winter Wheat and Maize by Large-Scale Weighing Lysimeter and Microlysimeter. Agricultural and Forest Meteorology, 111, 109–120, (2002).
3. Hu, W., Duan, S., and Sui, Q. High-yield technology for groundnut. International Arachis Newsletter, 15, 1–22, (1995).

4. Steiner, J. L. Tillage and Surface Residue Effects on Evaporation from Soils. Soil Science Society of America Journal. 53, 911–916, (1989).
5. Japan Echo Inc. 2005. Banana Stem Become Denim-like Cloth. Domestic Japanese News Source. 1-6. DOI= http://web-japan.org/trends/science/sci040105.html
6. Lu, P., Woo, K.C., Liu, Z.T. 2002. Estimation of WholePlant Transpiration of Bananas Using Sap Flow Measurements. Journal of Experimental Botany. 53:375, 1771-1779.
7. Anonymous. 2007. Kijoka Banana Fiber Cloth. Kijoka Banana Fiber Cloth Association. Cooperative. Union. 1-7.
8. Ms. Ankita Shroff Prof. Anjali KaroliaDr.Jayendra Shah, BioSoftening Of Banana Fiber For Nonwoven Application, International Journal of Scientific Research. 2015; 32-43.
9. Jagadeesh, R. Venkatachalam, G. Nallakumarasamy, Characterisation of Banana Fiber - A Review, Journal of Environmental
10. Nanotechnology, 2015; 4(2).
11. P.Dilleswara Rao, D.Venkata Rao, A. Lakshumu Naidu, MVA Raju
12. Bahubalendruni, Mechanical Properties of Banana fiber Reinforced Composites and Manufacturing Techniques: A Review, International Journal For Research & Development In Technology,2017;8(5).
13. R. Bhoopathi, M. Ramesh, R. Rajaprasanna, G. Sasikala and C.
14. Deepa, Physical Properties of Glass-Hemp-Banana Hybrid Fiber Reinforced Polymer Composites, Indian Journal of Science and Technology,2017; *10(7).*
15. Ricardo Mello Di Benedettoa, Maria Virginia Gelfusoa, Daniel ThomaziniaInfluence of UV Radiation on the Physical-chemical and Mechanical Properties of Banana Fiber, Materials Research. 2015; 18(2):265-272
16. Bhuvneshwar Rai, Gulshan Kumar, R. K. Diwan and R. K. Khandal, Study on effect of euphorbia coagulum on physico-mechanical and fire-retardant properties of polyester-banana fiber composite, Indian Journal of Science and Technology, 2011; 4(4).