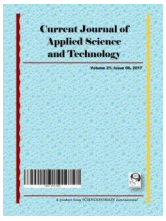

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Agave webert Agro-Mats for Water Conservation

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Authors' contributions

This work was carried out in collaboration between both authors. Author PA has designed and wrote the protocol of the study and author KSS performed the study, statistical analysis and wrote the first draft of the manuscript. Both authors managed the analyses of the study. Author KSS has managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Agriculture consumes water in major quantity to fulfill its needs. To conserve and save the water, its careful application with special attention is required, especially in farming. When farming was carried out with modern techniques, it may fulfill this requisite. Today agro-tech products are in good demand and supply, which includes mulch mat, bird net, shade net, sacks, packing, and winnowing, etc, If properly used these technical textiles will improve the quality of farm needs. Natural fibers have better insulation properties under moist condition than polypropylene/ polyethylene. Hence, in the present study, Sisal agro-mats were analyzed against black sheet and control sample to test the water conservation levels in soil with pH 7.1 of the Croton plant (*Codiaeum variegatum*). Agro-mats were prepared in three thicknesses (1, 2 and 3mm). Sisal 3mm agro-mats conserves soil moisture content to 40-50 percent compared to black sheet and control, which does give spaces to flow air, which dries out the soil. Being economically viable, agro-mats with 2 mm holds comparatively less moisture content are suitable to apply at nursery level where regular watering is needed.

Keywords: Sisal fiber; nonwoven sheets; agro-mats; moisture content; water conservation; watering intervals.

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1. INTRODUCTION

Farming is one of the major occupations in India, where consumption of water is vast. Also, it is said that globally irrigation consumes about two-thirds of the world's fresh water. According to State of Indian agriculture 2015-16, India has 4% of the world's renewable water resources, but the average availability is decreasing progressively [1]. Predictors are expecting over a period of time agriculture needs will be increased, but natural resources will remain limited, which draws attention to conserve natural sources and use it to its maximum extent. Now a day's 'water conservation' has become a foremost discussion topic, as farmers and gardeners are facing water restrictions. It is also expected that, due to the depletion of the Ozone layer from rising temperature with different pollutants, India will soon become a water-stressed nation. According to J. Clemmens et al. truly water can be saved through four ways, which includes reduction of unnecessary evaporation and transpiration, more effective use of rainfall, reduction of deep percolation water that becomes severely degraded in quality, and reduction of runoff from fields that are not reusable downstream [2].

For surface irrigation in India, the efficiency of canal water usage at field level is low (30-40%) as compared to groundwater (65-70%) and drip irrigation (90-95%) [1] and approximately 35-50 percent of the applied irrigation water is lost by evaporation and leaching. Water saving and water use efficiency estimates are to be adopted to better utilize the shrinking water resources for the increasing water productivity.

In agriculture, heavy subsidies are provided for electricity consumption which has encouraged extravagant usage of energy and water. According to State of Indian Agriculture 2015-16, the overuse of water in the country leads to low irrigation efficiency, of about 25 to 35 percent, wherein few cases with the efficiency of 40-45 percent were noticed. Land Use Statistics (2012-13), Ministry of Agriculture & Farmers Welfare have recorded various sources of irrigation during 2012-13, which showed the highest irrigation source is through tube wells as shown in Fig. 1.

In a view to managing the water deficiency, there is a need to approach appropriate technology to conserve the water in the soil contour and work towards its best possible utilization without affecting plant growth. Bhella; Bafna et al. Raina et al. Imtiyaz et al. have reported water saving in their respective articles. In this context 'mulching' has emerged in agriculture in order to reduce evaporations by creating a barrier between the soil surface and immediate environment, thus conserving the moisture content in the soil [3,4,5,6].

Rajbir Singh, said that there were a complete elimination of weeds, effective water usage, and benefit-cost ratios in yield under black polyethylene mulch [7]. Ashworth and Harrison, Chakarborty and Sadhu, Singh, have also reported that weed can be controlled by the use of black polyethylene mulch in vegetable production and it also increases hydrothermal regimes of soil as reduces the nutrient losses [8,9,10]. Even though mulching

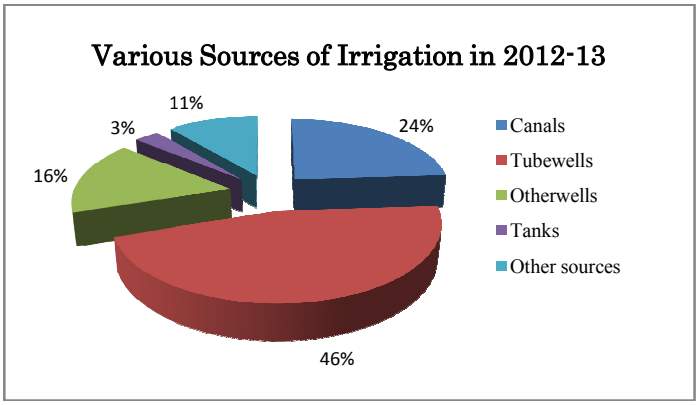

Fig. 1. Source: Land use statistics (2012-13), ministry of agriculture & farmers welfare, state of Indian agriculture 2015-16

Table 1. Sisal fiber compositional analysis and characteristics

Diameter (µm)	Density (g cm-3)	Cellulose (%)	Lignin (%)	l/d ratio*	Cell wall thickness (µm)	Micro fibrillar angle (deg)
100-300	1.450	70	12	100	12.5	20-25

Source: Mukherjee and Satyanarayana [17]

with black sheets have been showed benefits, they are unhealthy to the environments and are also non-biodegradable materials. This limitation has turned the scientists and researchers interests towards eco-friendly biodegradable mulch materials with natural sources.

Research on mulching has been proven to minimize temperature in the soil, in turn, conserving moisture and which leads to growth and yield improvement. For farmers, it is a benefit, where the limitation of moisture in the soil is the concern factor for cultivation [11,12]. Under practical field conditions, Jalota SK et al. developed a soil water evaporation model and evaluated its effect on soil texture, tillage and crop residue management. They said that crop residues have a beneficial effect by minimizing the soil water evaporation and also suggested that, balance in soil evaporation depends on the amount and mode of residue used and managed [13]. A two-year study conducted by Jalota SK et al. have quoted that straw mulch treatment stored more moisture content and has shown an increase in the soil moisture profile [14].

Many researchers (Kulkarni et al. Gram, Mukherjee and Satya Narayana, Mattoso et al.) have studied the structure and properties of the sisal fiber. The fiber structural understanding will help the finder to investigate new avenues. A study by Gram, the cell wall of Sisal fiber consists of several layers of fibrillar structure consisting of fibrillae, where primary wall of fibrillae has a reticulated structure, outer secondary wall, located inside the primary wall and the fibrillae are arranged in spirals with an angle of 40 degrees with respect to its longitudinal axis. The fibrillae in the inner secondary wall of sisal fiber have a sharper slope of 18 to 25 degrees. The thin innermost tertiary wall has a parallel fibrillar structure, encloses lumen. The fibrillae are built up a micro-fibrillae with a thickness of about 20 nm, which is composed of 0/7 nm thickness cellulose molecular chains with varying lengths in mm. In cross-section, sisal fiber is built up of about 100 fiber cells. Sisal fiber characteristics and characteristics were studied by Mukherjee and Satyanarayana, as shown in Table 1 [15,16, 17,18].

The new generation of organic mulch is to be designed with natural fiber needle punched non-woven textiles to save or conserve water and energy. Thus, there is a strong need to strengthen research non-woven textiles for potential application in agriculture, soil conservation, and small-scale industries. In a view to fulfilling the raised need, a study on non-woven Agro mat with Sisal fiber has been carried out in the present study.

2. METHODOLOGY

2.1 Selection of Fiber

The available varieties of sisal in Telangana namely *Agave webert, Agave cantala,* and *Agave Veracruz* were considered for the study. A pilot test was conducted in order to assess the strength of the sisal varieties by tensile strength tester in the department of Apparel and Textiles, College of Home Science, Saifabad, Hyderabad. Based on the observations of the tested fiber varieties for the strength *Agave webert* variety was selected. *Agave webert* fiber utilized for the study was extracted at one of the operational villages.

2.2 Fiber Extraction

Sisal fiber traditionally extracted by retting, a biodegradation process involving microbial decomposition of sisal leaves, which separates the fiber from the pith. The fibers are washed and processed further. This process takes 15-21 days for a single cycle of extraction and degrades the quality of fiber. The retting process is water intensive, unhygienic and not eco-friendly. The other methods available for the extraction of fiber are chemical treatment and mechanical extraction. The mechanical extraction was done with the help of a Raspidor machine, developed by RRL (Regional Research Laboratory, Bhopal. It is a semi-automatic machine suitable for small-scale operations.

So, in this present research fiber used was extracted by Raspidor (decortications) machine. In this process, the machine removes green biomass surrounding the fibers. Thus, the time taken to separate fibers from leaves is only

around 10-12 seconds. After removing the thorns on the sides of leaves, they should be graded according to the length of leaves, bundled and then extract. If the leaf is very thick, slit the leaf longitudinally for better extraction by avoiding fiber breaking. When the leaves inserted in the machine, the knife rotating inside pulls the leaf quickly inside and removes the green matter from the fiber from scrapping. Care should be taken in pulling back the fibers so that no damage is done to the fibers. The time taken for this activity is about 8-10 seconds only. By using the Raspidar machine, 10-12 kilograms of fiber can be extracted per day, which states around 4000 leaves. The operator must stand at a recommended distance from machine since it drags speedily with heavy strength.

2.3 Processing of Extracted Fiber

The extracted wet green fibers should be washed in water. The washed fibers should be kept on wires specially arranged to remove the entire water then dried fibers are beaten against the poles till the small trace of greenery on fibers removed. Dried and cleaned fibers should be sun-dried for 2-3 hours. Necessary care should take so that, the fibers do not get entangles with each other.

Dried fibers should be spread on grassland till the pale green fiber turns to creamy white. Then beat this fiber against the poles so that dust and other foreign matter are removed from the fiber. Now, this fiber can be used for grading based on color and length and then balling according to sorted fibers.

Delignification: To soften the fiber, it was treated with 5% of NaOH.

2.4 Chopping of the Fiber

The chopping of the fiber was done with the fodder cutting machine with fiber measuring around 1/4 to 1/2 inch or 0.635 to 1.27 centimetres.

2.5 Non-Woven Making

Nonwoven mats were prepared by the random spreading of chopped fibers with sprayed natural gum. To optimize agro mat in different thickness, 16.5 g, 33 g, and 50 g chopped fiber was utilized to make a diameter of 32.5 cm/13.5", as shown in Fig. 2. The thicknesses of agro-mats were measured with 'fabric thickness tester'.

Fig. 2. Nonwoven sheet with Sisal fiber

3. AGRO MAT PROPERTIES

Thickness: Thickness and surface thickness of the non-woven fabric are useful indicators of any change or variation in the fabric handle and appearance (Booth) [19].

GSM: Fabric weight is mass per unit area (ASTM 2007). The weight of a known size of non-woven fabric specimen was measured using a sensitive balance as per IS No: 1964-1970.

Cutting of agro mats: Agro mats were cut according to the selected pot size from the prepared non-woven sheets according to the required diameter to place on top of the soil. For anchoring of the mat, slit the mat at the radius and cut out a small circle at center for insertion, as shown in Fig. 3.

3.1 Section of Croton Plants for Evaluation of Agro Mats

The study was conducted at Horti-College farm, PJTSAU, Rajendranagar, Hyderabad. Similar types of samples (Croton plant pots) were selected to evaluate the effective conservation of water and moisture regain in the soil.

3.2 Anchoring of Agro Mats in Nursery Pots

Prepared agro mats were placed in the pots as shown in given Fig. 4. The study was conducted at Horticulture Nursery, PJTSAU during February & March with an atmospheric temperature of 36-40°C.

a. cutting of Sisal sheet for agro mats **b. agro mat**

Fig. 3. Cutting of sisal agro mats

Fig. 4. Prepared sisal agro mat to be inserted on top of croton pot

3.3 Pot Soil Characterization

Soil characterization was analyzed at Soil Health Care Diagnostic Laboratory, College of Agricultural, Rajendra Nagar, Hyderabad.

3.4 Experimental Layout

Research work was planned with three variables, viz control, commercially available black sheet and sisal agro mat (three different thickness mats) were selected to study the efficacy of the ago mats in the pots for water usage/ conservation, as in Fig. 5.

3.5 Watering Intervals

Water requirement by the plant was monitored through three different watering intervals i.e., after 24 hours, 48 hrs and 96 hrs. The watering of pots in these intervals was quoted as I, III & V as they were watered on the first day, third day and fifth day. Each plant was poured 500 ml of water according to planned intervals.

3.6 Testing of Soil Moisture Content

Before starting of experiment soil wet & dry weight was recorded, by using following formula moisture content was calculated in percentage.

$$\text{Moisture Content} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100$$

a. Test pots with control **b. Test pots with a Black sheet** **c. Test pots with sisal agro mat**

Fig. 5. Croton plants (*Codiaeum variegatum*) with control, black sheet, and sisal agro mat

4. RESULTS AND DISCUSSION

A report was made on "Sisal fiber extraction and processing of fiber" by Padma A, highlighted the chemical analysis of sisal fiber. The main composition of sisal fiber consists of 66-72 percent cellulose, 12 percent hemicellulose, 10-14 percent lignin, pectin 1 percent and wax 0.3 percent. And the superior engineering properties are diameter 50-200 mm, microfibril angle 10-220, the ultimate tensile strength of 468-640 MPa; modulus of 9.40-15.80 GPa and elongation of 3-7 percent makes it as an excellent material for manufacturing high strength textile and reinforcement in composites for various applications [20].

Agro mat mulch is a layer of material applied to a surface of an area of soil. Organic mulches can mat down, forming a barrier that blocks water and airflow between the soil and atmospheric air.

3.1 Pot Soil Characterization

According to the Table 2, pH of the soil is neutral, which specifies there is acidic or alkalinity of the soil. Balanced EC was observed where organic carbon was low with the 1.17msm^{-1} need to be balanced with the mixing of organic fertilizers. Available phosphorous and potash was high, where nitrogen was low.

Table 2. Pot soil characteristics

Soil testing parameters	Results
pH	7.1
EC	1.17 msm^{-1} (0.117dsm^{-1})
Organic carbon (%)	0.24
Available nitrogen (k/h)	239.4
Available phosphorous (k/h)	25.3
Available potash (k/h)	541.125

3.2 Cost Estimation

3.2.1 Fiber cost Rs.50/kg

With one kilogram of fiber 60-65 agro mats can be prepared. To prepare each agro mat with a diameter of 32.5 cms/13 inches, it weighs around 16.5 grams which costs to Rs.1.00 ps, as given in Table 3.

Table 3. Cost estimation of the agro mats

Sisal agro mat with a diameter of 32.5 cms/13 inches	The weight of the mat	Cost (RS)
1 mm thickness	16.5	1.00
2 mm thickness	33	2.00
3 mm thickness	48.5	3.00

3.3 Agro Mat Properties

From the Table 4, it is clearly evident that the different thickness sisal agro mats showed GSM of 85 to 225 g/m^2, whereas commercially available black mulch was below 50 g/m^2.

Table 4. Agro mat properties

Parameters	Thickness (mm)	GSM (g/m^2)
Sisal agro mat	1	85
	2	170
	3.5	255
Black mulch sheet (poly propylene)	1	50

3.4 The Moisture Content of the Tested Soil Samples for Water Conservation

Before commencement of the experiment, soil moisture was recorded. For 10 grams of the test sample, after drying recorded 8.2 grams, which states there is 18 percent of moisture content in the soil. Moisture content after the experiment was recorded in the below-given Table 5.

Fig. 6 clearly depicts the presence of moisture content in the soil of pots spread with different thickness of sisal mat and black sheet along with control. The moisture content of selected soil sample for sisal agro mat and black sheet spread pots have retained up to 22-23 percent for every day watered plant, whereas soil from control pot has retained around 17 percent.

Table 5. The moisture content of the soil samples in a black sheet and sisal agro mats

Sample	Control (%) without agro mat	Black sheet (%)	Sisal agro mat (%)		
			1 mm	2 mm	3 mm
Every day watered pot	17.08	22.028	22.725	22.9	23.76
Third day watered pot	16.1	19.45	20.285	19.33	21.2
Fifth day watered pot	8.28	18.4	13.89	15.89	19.47

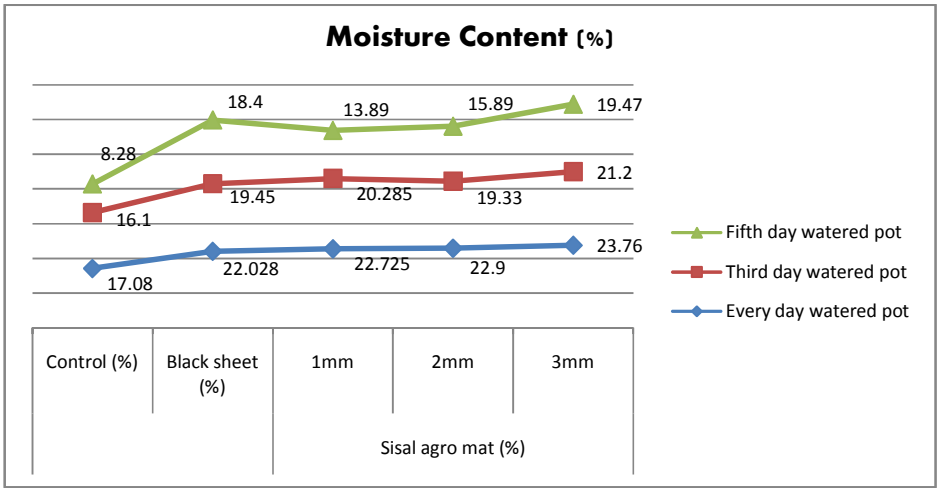

Fig. 6. Soil moisture content in test samples

Likewise for alternative watered and fifth day watered soil sample for control sample have shown the much lesser amount of moisture content than with different thickness of sisal agro mat and black sheet spread sample.

When critically analyzed black sheet spread pots holds more content of moisture than sisal agro mat even for the fifth-day watered pot, with around 2.5 to 4.5 percent difference for 2mm and 1mm thickness agro mat respectively, where 3mm thickness sisal agro mat have more moisture content with 1.07 percent difference. But the major drawback with the black sheet was, it does not biodegrade in soil and even can spoil the soil for further utilization, as it is made of polypropylene. Suzan et al. have analyzed biodegradation of polymer poly (hydroxybutyrate) (PHB) tubes and its composites with wood flour and sisal fiber having twenty percent fiber for 30, 60 and 90 days. Where the test results showed, biodegradable composite materials have a greater loss in its weight than the counterpart [21].

So, it was suggested the fourth day watering of the plants for 1mm thickness sisal mulch, as the presence of less than 13 percent moisture content dries the soil affecting the plant growth. In view of cost-effectiveness and moisture retention, 2mm thickness sisal agro mat was most suitable for nursery application with 40 to 50 percent water conservation.

4. CONCLUSION

Mulching minimizes the evaporation loss from the soil surface and thus utilizes the conserved moisture for higher transpiration and improves yield. Hence the study was taken up to develop innovatively and cost effective-fibrous structure organic sisal agro mats. From the current investigation, we have found that Sisal agro mats are environmentally friendly compared to the synthetic black sheet. Though black sheets hold more moisture content, they are also non-biodegradable material, which is harmful to the land, as debris are left while cleaning the field before sowing of next crop. It was also noticed that sisal agro mats hold good moisture content than control along with its aesthetic appeal and cost effectiveness due to its local availability in the raw material. Considering these suitability parameters, these agro mats can be applied at nursery level where regular watering is required. It not only conserves water but also minimizes labor work. As the agro-mat is of smaller dimension, it can only be used at nursery level. Further study/research can be conducted for mulches.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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