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Effect of Processing Parameters of Mesta Sheet for Use as Eco-friendly Agrotextiles

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An attempt has been made to use woven and mechanically entangled sheet of mesta as soil cover of strawberry cultivation with an aim for weed control and moisture retention. It was observed that sheet from 500 g/m^2, 190 punches/cm^2 and 10 mm needle penetration produces the best quality mulching product with respect to growth characteristics, moisture retention, and increase in yield, weed suppression and reduction in soil temperature. The initial higher cost of raw material is justified by the higher return from cultivation using the suggested mesta nonwoven as the mulch.

Keywords: Mesta fabric, Mulching, Polythene, Properties, Weed suppression, Plant growth

Introduction

In agriculture and gardening, mulch is a protective cover placed over the soil. It is an age-old practice in certain crops. When synthetic material came into the market, it captured the major share of the mulching area due to very low cost. In spite of the higher cost, application of any organic material in the soil is better for social and environmental point of view[1]. For several decades, mesta is being used as packaging along with jute. At present, jute/mesta packaging is facing a stiff competition from synthetic products. Needle punched nonwoven manufacturing[2] is one of the promising unconventional systems, in one way very much suited to the mesta industry in view of its high productivity and low wage component; in other way possesses unique properties of excellent hydraulic, thermal insulation and impact resistance property with lower but sufficient strength[3]. In this study, an attempt has been made to use mesta entangled sheet and woven fabric as a mulch of strawberry to ascertain the effect of that mulch.

Material and methods

In the area of mulching, black polyethylene is conventionally used. Black synthetic (7 microns) is procured from local market and that has been compared with needle punched nonwoven (a) from TD6 quality (IS 271) mesta fibre and (b) from processing waste mesta fibre with scrim cloth reinforcement and (c) woven mesta cloth. The construction parameters of different cloths are shown in Table 1. Fabrics have been prepared in Dilo nonwoven plant comprising a card, a camelback cross-lapper and a needle loom (model number OD II/6). The processing parameters are same as the previous work[4]. The thickness of fabrics was measured by Prolific Thickness Tester following ASTM standard D 6242-98. Bulk density was measured multiplying area density by thickness. Shirley Air Permeability Tester was used for measuring the air permeability following ASTM Standard D 737-04. The thermal resistance of samples was measured using guarded two-plate thermal resistance instrument following BS 4745. The tensile properties of the fabrics were determined on an Instron Tensile Tester using ISO 9073-18: 2007. Single or stack of fabrics is made completely wet and extrinsic sorptive capacity (ESC), i.e. the volume of liquid absorbed per unit area and extrinsic rate of sorption (ERS), i.e. the volume of water absorbed by unit area in unit time was calculated considering the density of water as 0.997 g/mL at 25^o C[5]. The degradation of fabric in soil has been tested using ASTM D 638IV. The drape coefficient was calculated (ISO 9073-9:2008) in Paramount Drapemeter .

Agricultural practice

Field experiments were conducted in semi-arid zone suitable for strawberry cultivation. Experiments were set up in a randomized complete block design with three replications. The reported data is the

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Table 1 — Constructional details of mesta fabrics

Sample code	Mesta quality	Punch densitypunches/cm^2	Needle Penetration mm	Nominal Area Density g/m^2	Thickness mm
S1	TD_6	190	12	300	2.97
S2	TD_6	190	12	500	4.38
S3	TD_6	190	12	700	5.70
S4	TD_6	160	12	500	4.53
S5	TD_6	220	12	500	4.19
S6	TD_6	190	10	500	4.62
S7	TD_6	190	14	500	4.07
S8	Waste	220	14	500	4.88
S9	TD_6	Plain Woven Ends/cm,16; Picks/cm,9 End linear density, 210 tex Picks linear density, 210 tex		500	2.98

average of experiments conducted for three consecutive years i.e. 2011-14. The yield was taken from 44 plants in the middle row, while whole plants were randomly sampled from the outer rows.

The average fruit was determined by compiling a season average of 25 marketable fruit from each harvest date. All other standard programs were followed according to recommended practice[6]. Whole plants were 4-5 weeks. At each whole plant harvest date, four whole plants from each treatment were harvested. Roots were washed over fine mesh sieve to separate soil from root tissue. Plants were then divided into roots, crowns, leaves, flowers and fruit. Leaf area of fresh leaves was determined using a leaf area meter. All plant parts were bagged separately, then placed in a drying oven at 158^{0}F (70^{0}C) for 10 d. Individual plant yield was calculated on each harvest date by dividing total yield (grams) per plot by the number of plants in each plot [7, 8].

Results and Discussion

Fabric properties

Test shows that samples S1, S4 and S6 are having lower tenacity (1.10-1.26 g/tex) and permeability (62-65 cm^3/s/cm); but higher elongation (38-41%), drape (73-78%), the rate of absorption (6-8mL/m^2/S), absorptive capacity (2326-2509 mL/m^2), thermal resistance (16 Km/W) and degradation rate (36-39%) mainly due to low area density and processing parameters. Whereas S3 and S7 show higher tenacity (1.6 g/tex) permeability95 cm^3 /s/cm)and drape 88%; but lower elongation 26%, , the rate of absorption 4 mL/m^2/S, absorptive capacity (1900 mL/m^2), thermal resistance (13.5 Km/W) and degradation rate (32%) mainly due to high bulk density (0.121 g/cm^3) and processing parameters. S8 produces low bulk density fabric resulting in higher permeability, the rate of absorption, absorptive capacity, thermal resistance and degradation rate due to waste and short fibres, but high strength and low elongation because of the presence of scrim cloth. Woven mesta fabric (S9) has high strength, low degradation, low drape, low wet ability compared to similar nonwoven due to its compact yarn structure.

Biomass and growth characteristics

Table 2 (part a) shows the data of plant weight, shoot weight, root weight, plant height, root length and leaf characteristics of strawberry cultivation on control (without mulching), synthetic sheet mulching, mesta nonwoven (of different parameters) mulching and woven mesta mulching. In comparison to control and synthetic sheet mulching, mesta nonwoven/ woven fabric shows better growth. Out of all types of mesta fabrics, waste mesta shows the best performance probably due to low bulk density, higher permeability, higher water absorbency and higher thermal resistance. The percent growth improvement using waste mesta nonwoven fabric over control and synthetic sheet mulching shows 12% on shoot dry weight, 9% on plant height, 9% leaf dry weight. Among mesta nonwovens without reinforcement (Samples S1 to S7), S6 shows the best results in all the biomass and growth characteristics.

Fruit characteristics

Table 2 (part b) shows the data of the number, average fresh weight, total fresh weight and length of fruit on control (without mulching), synthetic sheet mulching, mesta nonwoven (of different parameters) mulching and woven mesta mulching. In comparison to control and synthetic sheet mulching, mesta nonwoven/woven fabric shows better performance regarding fruit. Out of all types of mesta fabrics, waste mesta shows the best results as above. The percent fruit improvement of waste mesta nonwoven fabric over control and synthetic sheet mulching shows 25% in the number of fruits per plant and 14% of fruits total fresh weight per plant in strawberry. S4 shows the best fruit characteristics among mesta nonwovens without reinforcement (Samples S1 to S7).

Soil moisture and temperature

Table 2 (part c) show the soil moisture condition after 3, 7 and 14 days of irrigation and also average soil temperature in control (without mulching), synthetic sheet mulching, mesta nonwoven (of different structure) mulching and woven mesta mulching. In comparison to control and synthetic sheet mulching, mesta nonwoven/woven fabric shows better moisture retention and control in temperature of the soil. Out of all types of mesta fabrics, waste mesta shows the best results probably due to low bulk density, high water retention, and thermal insulation. The moisture evaporation after 14 days is 83% and 10% over control and synthetic sheet respectively. The soil temperature in waste mesta mulching is lower by about 21% over control and 28% over synthetic sheet mulching. Here, the main point to note is that synthetic sheet mulching increases the soil temperature which is detrimental to the plant. But as mesta fabric can control the soil temperature, it is useful in extreme temperatures (summer as well as winter). Out of the nonwoven fabrics without reinforcement, sample S6 shows the better performance than others in both cultivations.

Yield

The yield of strawberry under control and different types of mulching cloth has been shown in Table 2 (part d). It shows that waste mesta nonwoven produces the highest yield in both the plants due to better permeability, moisture retention and thermal

Table 2 — Effect of different mulching on cultivation of strawberry

	Control	Synthetic sheet	S1	S2	S3	S4	S5	S6	S7	S8	S9
(a) Biomass and growth characteristics											
Plant fresh weight (g)	146	169	161	170	165	178	169	180	167	185	164
Plant dry weight (g)	19.08	22.43	21.41	23.35	21.52	22.81	22.75	24.56	22.18	25.64	21.45
Shoot fresh weight (g)	106	123	117	122	120	132	123	133	122	138	120
Shoot dry weight (g)	8.21	10.32	11.46	11.16	9.22	11.83	11.49	11.27	9.25	11.40	10.08
Root fresh weight (g)	46.80	54.17	49.61	54.49	54.89	57.06	52.17	57.70	55.53	59.32	52.57
Root dry weight (g)	9.94	10.51	10.97	12.58	11.24	11.12	11.51	11.26	11.37	13.61	11.17
Plant height (cm)	20.99	24.30	22.15	24.44	24.72	25.59	23.30	25.88	25.01	26.60	23.58
Root depth (cm)	11.92	13.79	12.14	13.88	14.47	14.53	12.79	14.69	14.63	15.16	13.39
No. of leaves. plant^{-1}	6.94	8.04	7.46	7.59	7.85	8.97	8.04	8.06	7.94	9.03	7.80
Leaf area (cm^2)	117.5	136.2	128.5	136.8	133.8	143.2	135.0	144.8	135.4	148.9	132.0
Leaves dry weight. plant $^{-1}$ (g)	5.21	6.03	5.24	6.06	6.39	6.35	5.53	6.42	5.46	6.61	5.85
(b) Fruit characteristics											
Number of fruits. plant^{-1}	2.68	3.11	2.56	3.42	3.23	3.57	3.11	3.41	3.57	3.90	3.01
Average fruit fresh weight (g)	6.23	7.22	6.48	7.26	7.35	7.60	7.02	7.69	7.53	8.23	7.00
Fruits total fresh weight. plant^{-1}	18.78	21.74	20.71	22.87	21.23	21.90	21.74	24.16	21.48	24.81	21.10
Fruit length (cm)	3.08	3.56	3.09	3.58	3.68	3.75	3.36	3.79	3.52	3.95	3.46
(c) Soil moisture and temperature condition											
Initial moisture (%)	21.23	29.04	29.72	31.21	31.38	33.54	33.04	32.87	29.71	34.70	27.22
3 days after irrigation (%)	31.4	44.53	42.88	41.56	40.42	42.57	43.74	45.31	43.09	46.31	42.92
7 days after irrigation (%)	24.7	38.61	33.93	37.31	35.54	37.29	36.83	39.34	36.82	40.55	34.62
14 days after irrigation (%)	19.3	32.26	28.83	34.50	31.06	33.20	31.53	34.83	31.52	35.37	29.93
Soil temperature, ^{0}F	72	80	69	63	65	61	63	59	66	57	70
(d) Yield and weed suppression											
Yield (t/ha)	19.73	22.84	20.76	22.97	22.80	24.05	22.14	24.82	22.57	25.36	22.16
Weed suppression (%)	-	71.25	65.88	72.68	76.57	75.05	74.25	75.89	70.41	72.92	69.15
(e) Nutrient condition after strawberry cultivation											
Organic Matter (%)	0.57	0.56	0.63	0.66	0.64	0.69	0.66	0.70	0.65	0.72	0.64
Available N (kg/ha)	61.60	62.30	67.92	71.72	69.61	75.10	71.30	75.94	70.46	78.05	69.19
Available P (kg/ha)	23.04	22.67	25.41	26.83	26.04	28.10	26.67	28.41	26.36	29.20	25.89
Available K (kg/ha)	198.9	195.3	219.4	231.6	224.8	242.5	230.3	245.2	227.5	252.1	223.4

insulation property of the mulching material. The yield increases by 28% over control and 11% over synthetic sheet mulching. The best performance shows in case of sample S6 within nonwoven fabric mulch without reinforcement.

Weed suppression

Weed reduction under the synthetic sheet, different mesta nonwoven, waste mesta nonwoven and woven mesta over control has been shown in Table 2 (d & i). It shows S3 mesta nonwoven produces maximum control of weed which is around 76% due to compact structure (high bulk density) and the better cover of fabric which restricts penetration of sunlight and obstructs the growth of weed. In the contrary, waste mesta nonwoven and synthetic sheet mulching show 3% and 5% lower control of weed than S3 mulching. Sample S1 and S9 show the lowest weed suppression in comparison to other mulches under trial.

Nutrient enrichment

Before the start of this experiment, the soil nutrient condition has been studied in 15 different places separately for the strawberry field; and found that the differences were insignificant at 1% confidence level. After 6 months when the cultivation is over, the soil is well mixed with almost biodegraded mesta. After another 6 months, the soil samples have been collected for nutrient study. The results of this study have been shown in Table 2 (part e & j). In this table, organic matter, nitrogen, phosphorus and potassium available in the soil samples are shown. Mesta is a biodegradable natural fibre and hence, in presence of soil, water, and sunlight, it degrades and increases the plant needed nutrients around 26-33% which is a significant one. On the contrary, mulching by synthetic sheet cannot increase the soil nutrients. Mesta holds the loose soil particles in its place and resists the shifting of soil particles considerably during rain/thunderstorm/blowing of strong air/ watering. It also decreases the nutrient loss.

General observations

Nonwoven fabric loses strength after about two months but makes a solid coating over the surface which performs well up to four to five months depending on area density, structure and soil characteristics. Fabric decreases the soil erosion holding the loose surface soil particles during rain/thunderstorm/blowing of strong air/watering. There is no water accumulation on mesta fabric. It spreads evenly throughout the fabric due to good permeability and transmitivity. Plastic damages due to direct sunlight and change in temperature causing its removal difficult and labour intensive. Higher areal density and rough surface fabric restrict removal in action of a strong air current. Squirrel and rats are the main problems of using mesta nonwoven. If a diluted mixture of mud with water is poured over the nonwoven just after the laying this problem can be minimized. Mesta nonwoven is costlier proposition compared to other covering material. Hence, the initial cost is higher. But at the end, farmers earn more profit using waste mesta nonwoven soil cover which is 70% higher than without cover and 38% than plastic cover due to less requirement of pesticide, fertilizer, de-weeding cost etc; better yield and higher revenue from fruit when calculated on strawberry cultivation in Punjab soil in the basis of 2013 cost structure. Therefore, it is economically viable for high-valued crops.

Conclusion

Mesta needle punched nonwoven of 500 g/m^2 having 190 punches/cm^2 and 10 mm depth of needle penetration shows better produce than woven fabric or synthetic sheet as mulch. Nonwoven from waste fibre scrim cloth reinforcement and having 220 punches/cm^2 and 14 mm depth of needle penetration produces the best quality plant, fruit and yield. It also helps in better soil moisture retention, temperature control and weed suppression. Mesta nonwoven is more effective in the arid and semi-arid zone where water scarcity is a great problem for farming. As this fabric is costlier than other mulches, this is economically viable for high-valued crops. Indigenous, user-friendly and low-cost machines may encourage the small-scale sector also to produce mulching cloth. It will help to make a green environment.

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