International Journal of Agriculture Sciences
ISSN: 0975-3710&E-ISSN: 0975-9107, Volume 8, Issue 48, 2016, pp.-2004-2007.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

STUDIES ON PHYSICAL PROPERTIES OF SISAL (*Agave sisalana*) PLANT LEAVES

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Received: June 13, 2016; Revised: June 26, 2016; Accepted: July 01, 2016; Published: October 18, 2016

Abstract- Sisal plant produces hardest vegetable fibre from the mature leaves.In this study the physical properties of individual elements for sisal (*Agave sisalana)* plant and leaf were determined using basic measuring devices.A free falling device was fabricated and used to assess the energy required for cutting the sisal leaf at every 0.1 m distance along leaf length and measure the unitary energy. The unitary energy was quantified by the relationship between the leaf cutting energy and transverse sectional area of same cut positions. The unitary energy required for cutting of leaf was found to be 2.38 Jcm^{-2}. The relationship between cutting position, its sectional area andenergygoverns second order polynomial equation with correlation coefficient (R^2) near to 1.

Keywords- Energy, Fibre, Leaf, Sisal

Citation: Naik R.K., et al., (2016) Studies on Physical Properties of Sisal (*Agave sisalana*) Plant Leaves. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 8, Issue 48, pp.-2004-2007.

Academic Editor / Reviewer: Khadraji Ahmed, Jaybhaye R V

Introduction

Sisal plant which produces hard leaf-fibre is a monocotyledonous perennial evergreen xerophyte belongs to the genus *Agave.* It possesses over 200-300 species native to tropical and subtropical regions of North and South America [3, 9]. At present the leading or major sisal fibre producing countries in the world are Brazil followed by Mexico, Tanzania, Kenya and China etc.[2]. In India, sisal plantations are found in the arid and semi-arid regions of Odisha, Maharasthra and southern states [8].

The sisal plant looks like an over grown pineapple plant of height ranging from 1.2-1.5 m with a short bole. The crescent shaped leaves with a terminal spine having basal rosette are encircle around the meristem. Sisal plant forms a shallow but tufted, fibrous and spreading root system [4, 9]. In favourable soil conditions, the roots of plant having diameter between 2–4mm are spreads horizontally up to 5m from the stem base, but concentrated in the upper 30-40 cm of soil [5, 11]. Sisal can grow on poor soils in the regions with evenly distributed annual rainfall of 60–125 cm and temperature ranging from 16-35 ^{0}C. Being a xerophyte plant, it can withstand extreme drought condition [4]. After 11-12 years of life cycle, it produces a large flowering stalk/ pole of 8-12 m tall and plant dies [11].

Traditionally, sisal had been cultivated or grown for 'line-fibre', which is used in the manufacturing of marine and industrial ropes, twines, sacking and carpet making [1]. However, research studies showing feasibility of obtaining hecogenin, pectin, fat and wax from sisal leaf pulp [5]. Sisal biomass from non-irrigated marginal land is a good source for biofuel production [7, 11], paper making [7] and methane gas [10].

The information on physical and biometric characteristics of individual elements for sisal plant is useful in design of mechanical devices for efficient cutting, extraction and shredding. To mechanize leaf harvesting operation mechanical properties of leaf has been studied by Majaja and Chancellor (1997) [6]. Attempts have been made in the present study to investigate the relationship on physical properties of sisal leaf with unitary cutting energy.

Materials and Methods

Physical Properties of Plant

Physical properties of sisal plant (*Agave sisalana*) of 7-8 years old such as plant height, maximum diameter of the plant, root length, root weight, plant weight with and without root were measured with the help of measuring scale, steel tape and electronics balance. The physical properties of bole/stem were measured after removal of leaves. After removing poles/ flower stalks from the plants their physical properties were measured with same procedure.

Physical Properties of Leaves

The physical properties of leaves like leaf length, width, thickness and weight were measured with the help of measuring scale, steel tape and electronics balance. The leaf parameters were taken from 10 leaves randomly from five selected plants, giving a total of 50 leaves.

Estimation of energy per section cut

A device was designed and fabricated to assess energy required for cutting of sisal leaf [Fig-1]. The device was fabricated with two inverted 'U' frames welded to a metallic frame (2nd frame taller than 1st frame). A mild steel sheet of 0.6 cm thickness was welded on the base of the metallic frame to support the leaf and cutting knife. In both frames 6 cm length and 2.5 cm inner diameter G.I. pipe was welded in the middle to act as a guide for free movement of knife holder in first frame and weight holder in the second frame. A wooden base was put on the metallic plate to prevent the loss of knife sharpness. The aim of the device is to transform potential energy in to kinetic energy by free fall, with cutting of leaf by knife. The weight holder was prepared with weights of 2, 5, 10 and 12 kg in different combinations. Smaller and bigger weights were used at tip-end and butt-end portion of leaf, respectively due to varying in thickness.

The test was conducted on five selected leaves of equal length of 1.2 m. The leaves were marked at an interval of 0.1 m along their length starting from the butt-end to the tip-end with a total of 12 marks per leaf. A total of 60 cutting energies were measured from five leaves at 12 positions on each leaf. Cutting energy (E_{CS}) was calculated using the [Eq-1] given below.

$$E_{CS} = m_p gh, \text{ J} \quad \text{............ [1]}$$

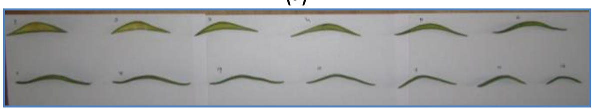
Where,
m_p = mass of weight holder + mass of weights, kg,
g = gravitational acceleration, m/ s^2 and
h = displacement of weight holder, m.

Fig-1 Leaf cutting device and cutting test at 0.1 m interval

Determination of transversal area of leaf section

To determine the transversal area at every 0.1 m of leaf, the selected and marked leaves were shredded at the corresponding marking positions using a sharp knife, thus obtaining a total of 12 parts per leaf [Fig-2]. From each part a sample of 2 mm thickness section were cut for measurement of area by graphical method. After obtaining the area values of each leaf, the mean and standard deviation were calculated. As unitary energy is the amount of energy required for cutting the leaf per unit transversal area, with mean area value and cutting energy value, the average unitary energy value as well as relationship of cutting energy with transversal area was determined.

(a)



(b)

Fig-2 Shredded sisal leaf and transversal sections

Results and Discussion

Physical Properties of Plant

The physical properties of individual elements for sisal (*Agave sisalana*) plant are given in [Table-1].

The height and diameter of sisal plant ranged from 1.3-1.65 m and 2.2-2.83 m, respectively. The average plant and root weight of full grown sisal plant was found out to be 127.75 kg and 29.98 kg, respectively. The mean length and weight of bole was found to be 0.57 m and 38.38 kg respectively, whereas mean weight of pole was found to be 21.4 kg.

Physical Properties of Leaves

The dimensions of length, width and thickness of leaf are presented in [Table-2]. The leaf weight ranges from 0.275- 0.725 kg with mean of 0.52 kg and standard deviation of 0.12 kg. The average length, width and thickness of leaf were found to be 1.04 m 0.079 m and 0.018 m, respectively. The average number of leaves per plant was found to be 128.

Table-1 *Physical properties of sisal (Agave sisalana) plant*

Parameter	Range	Mean	SD	CV, %
Plant height, m	1.30-1.65	1.50	0.11	7.8
Plant dia., m	2.20-2.83	2.58	0.24	9.48
Length of root, m	0.30-0.48	0.40	0.06	16.07
Dia. of root, m	0.43-0.48	0.44	0.02	4.75
Length of bole, m	0.37-0.82	0.57	0.19	33.53
Dia. of bole, m	0.50-0.85	0.71	0.10	15.27
Length of pole, m	6.8-14.3	10.0	3.31	33.24
Dia. of pole, m	0.12-0.30	0.21	0.08	38.57
Plant + root wt., kg	103.5-152.8	127.75	18.0	14.15
Plant weight, kg	85.5-117.4	97.77	12.3	12.6
Bole weight, kg	27-53	38.38	10.6	27.67
Root weight, kg	18.0-38.6	29.98	7.9	26.65
Pole weight, kg	9.7-27.6	21.4	6.9	32.43

Table-2 *Physical properties of sisal (Agave sisalana) leaves*

Particulars	Range	Mean	SD	CV, %
No.of leaves/ plant	112-153	128	11.94	9.32
Leaf weight, kg	0.275-0.725	0.520	0.12	24.61
Leaf length, m	0.54-1.62	1.04	0.35	34.49
Leaf width, m	0.04-0.12	0.079	0.02	27.04
Leaf thickness, m	0.01-0.04	0.018	0.007	40.55

Estimation of cut energy per section (position- energy)

The leaf cutting energy values for every 0.1 m leaf position from butt-end of leaf for all the five leaves are presented in [Table-3].

From the [Table-3] it is evident that leaf sections from 0.1 to 0.9 m, the energy values in function of leaf sectional position have a linear trend. It was observed that higher energy values were obtained at butt-end ofthe leaf, whereas smaller energy values were obtained towards tip-end at positions 1.0, 1.1 and 1.2 m due to lesser thickness.

Table-3 *Energy measured at different position of leaf*

Distance from butt-end, m	Distance of fall, m	Weight, kg	Energy (J)						SD
			Leaves					Mean	
			1	2	3	4	5		
0.1	0.14	20	37.4	34.1	34.3	33.9	35.2	34.9	1.44
0.2	0.13	20	25.5	32.0	31.2	31.8	32.1	30.5	2.82
0.3	0.13	19	24.2	30.1	30.2	29.7	28.5	28.5	2.51
0.4	0.12	19	22.3	25.7	26.5	25.8	24.0	24.8	1.70
0.5	0.11	16	17.2	21.5	22.4	21.7	20.1	20.5	2.06
0.6	0.11	15	16.1	18.3	18.4	19.6	16.9	17.8	1.37
0.7	0.10	12	11.7	11.4	11.3	11.5	11.6	11.5	0.15
0.8	0.095	12	11.2	10.2	10.6	10.4	10.2	10.5	0.41
0.9	0.090	12	10.6	9.5	9.4	9.1	9.4	9.5	0.57
1.0	0.065	7	4.5	5.2	5.2	4.9	5.3	5.0	0.32
1.1	0.063	6	3.5	4.2	4.5	4.7	4.3	4.2	0.45
1.2	0.060	5.5	3.0	3.5	3.6	3.5	3.6	3.4	0.25

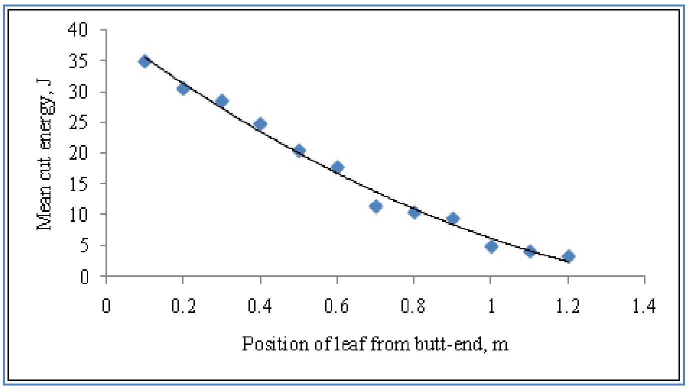


Fig-3 Relationship between leaf position and mean cut energy

The sectional position and mean cutting energy relationship is polynomial of level 2 as shown in [Fig-3]. At thicker positions of leaf section, higher cutting energy is required. Statistical regression model that had correlation coefficient near to 1 (R^2 = 0.989), was second order polynomial and given by the equation:

$$E = 12.48\,P^2 – 46.31\,P + 40.1 \quad .... [2]$$

Where, E = energy required for cut, J
P = position of leaf measured from butt-end, m

Determination of transversal area of leaf section [position-area, area-energy & unitary energy]

The transversal section areas obtained from each one of the twelve leaf sections along the leaf length for all five leaves are presented in [Table-4].

Table-4 *Transversal section area along leaf length*

Section from butt-end, m	Area, cm²						SD
	Leaves					Mean	
	1	2	3	4	5		
0.1	15.254	18.762	16.327	15.496	16.972	16.562	1.40
0.2	13.407	13.471	14.602	13.862	13.206	13.709	0.55
0.3	11.807	10.273	10.519	10.478	10.915	10.798	0.60
0.4	9.652	8.925	8.236	8.272	9.158	8.848	0.60
0.5	9.053	8.012	7.082	6.309	7.429	7.577	1.02
0.6	8.951	7.603	5.121	5.535	5.810	6.604	1.61
0.7	6.654	6.271	5.005	4.976	4.176	5.416	1.02
0.8	5.925	5.176	4.512	4.235	3.438	4.657	0.94
0.9	3.625	4.112	3.834	3.521	3.100	3.638	0.37
1.0	3.025	3.382	3.172	2.244	2.351	2.834	0.50
1.1	2.617	2.241	2.115	2.162	2.005	2.228	0.23
1.2	1.432	1.420	1.276	1.370	1.254	1.350	0.08

The data in the [Table-4] shows that standard deviation increases from position 0.5 m to 0.7 m of distance from the butt-end and then decreases for rest positions. The variation may be due to the variation of thickness of leaves in those positions. When position increases from the butt-end, transversal area also increases.

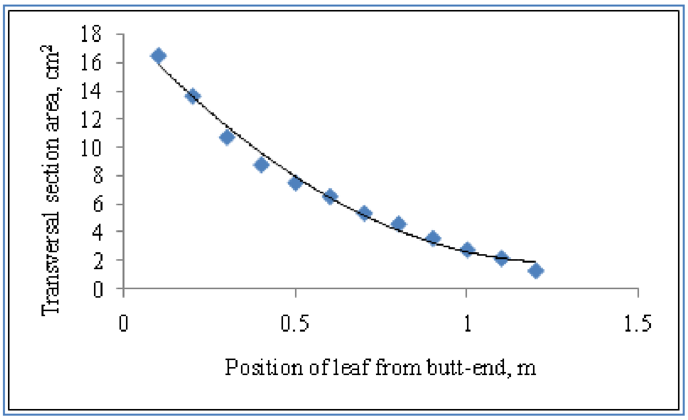


Fig-4 Relationship of position of leaf from butt-end and transversal section area

The relationship between position and transversal area is shown in [Fig-4] governs the second order polynomial behaviour with correlation coefficient, R^2 of 0.989. The equation that governs the transversal area behaviour in function of position in the leaf is given in [Eq-3] as follows:

$$A = 10.22\,P^2 – 25.96\,P + 18.35 \quad .... [3]$$

Where, A = transversal area of leaf, cm²
P = position of section along leaf, m

Using the average of mean values of transversal section area from [Table-4] and average of mean values of cutting energy from [Table-3]; the average value of unitary energy is found to be 2.38 Jcm^{-2}.

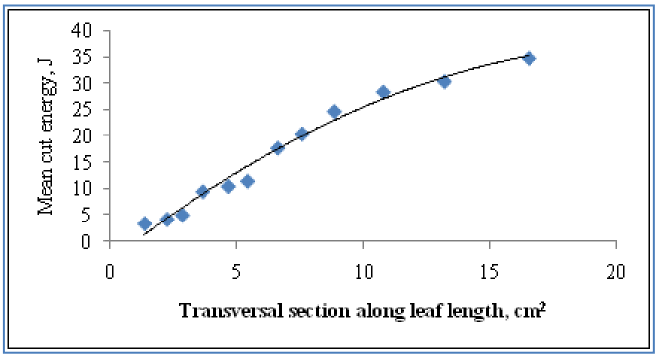


Fig-5 Relationship of transversal section area and mean cut energy

The relationship of area-energy shown in [Fig-5] governs the second order polynomial behaviour with R^2 = 0.982. As area in leaf position increases, cutting energy increases. The equation that governs mean energy behaviour in function of transversal sectional area is given by:

$$E = -0.086\,A^2 + 3.788\,A – 3.738 \quad .... [4]$$

Where; E = required energy for cut, J
A= transversal section area, cm²

Calculating with data from [Table-3] and [Table-4] the unitary cutting energy for a leaf section at 8 cm from butt-end gives the value of 1.81 Jcm^{-2}, which is comparable with the results obtained by Majaja and Chancellor (1997) [6] for cutting of sisal leaves at 7 cm from butt-end. It is evident that properties of species, geometry of cutting tools and cutting speeds affects the cutting energy value.

Conclusions

Dimensions and weights of individual elements for sisal (*Agave sisalana)* plant were determined and found some variability due to plant development factors for 7-8 years old plants. Sisal (*Agave*) leaf shredding machine for paper pulp production can be proposed using the leaf cutting energy results. There is a well defined relationship between sectional positions in a leaf and cutting energy due to the transversal area from the butt-end to tip-end of leaf according to second order polynomial function. The unitary leaf cutting energy value of 2.38 J is required to cut one square cm of agave leave.

Conflict of Interest: None declared

References

[1] Behera S., Sahu S., Patel S. and Mishra B.K. (2012) *Sisal fibre: A potential raw material for handmade paper. IPPTA,* 24(2), 37-43.

[2] FAO (2003) *Food and Agriculture Organization of the United Nations: Statistics Division. http://faostat.fao.org*

[3] Gibbon D. and Pain A. (1985) *Crops of the drier regions of the tropics.Longman Group Ltd., London*, 157.

[4] Kirby R.H. (1963) *Vegetable fibres- botany, cultivation and utilization. Leonard Hill, London, UK*, 148-300.

[5] Lock G. W. (1969) *Sisal: Thirty years sisal research in Tanzania. 2ndEdn., Logmans Green and Co. Ltd., London, UK*, 226.

[6] Majaja B. A. and Chancellor W. J. (1997) *Applied Eng. in Agric., ASAE,* 13(6), 703-708.

[7] Mclaughlin S. P. and Schuk S. M. (1991) *Eco. Botany,* 45(4), 480-486.

[8] Naik R.K., Pradhan S.C. and Dash R.C. (2015) *Ind. J. of Natural Fibres,* 2(1), 85-89.

[9] Nobel P. S. (2010) *Desert wisdom/agaves and cacti:* co_2*, water, climate change. Universe Inc., New York.*

[10] Purseglove J.W. (1972) *Tropical crops: monocotyledons. Longman Group Ltd., London*, 14-29.

[11] Valenzuela Z. A. G. (2011) *GCB Bionergy,* 3(1), 15–24.