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FIBER YIELD, PHYSICAL AND BIOCHEMICAL PROPERTIES OF THREE SPECIES OF *Sesbania*

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Abstract

An experiment was conducted at Field Laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh to compare the fiber yield, physical and biochemical properties of three *Sesbania* species. A total of 38 accessions, 28 from *S. bispinosa*, 4 from *S. cannabina* and 5 from *S. sesban* were used as experimental materials. Seeds were sown @ 30 kg ha^{-1} on 23 April, 2016 following randomized complete block design with three replications. Each plot size was 4.0Ч2.5 m^2 maintaining at the spacing of 50 cm row to row and 15 cm plant to plant. Plants were harvested at 120 days after sowing and plant height, base diameter, plant fresh weight and dry fiber as well as dry stick weight were measured. The fiber yield was the highest in *S. bispinosa* (2.18 g $plant^{-1}$) and the lowest in *S. sesban* (1.40 g $plant^{-1}$). Fiber luster (%), strength (g tex^{-1}) and crude fiber (%) showed significant differences among these three species. Both fiber luster and strength showed the highest value in *S. cannabina* (53.50% and 51.20 g tex^{-1}, respectively) and the lowest in *S. sesban* (35.16% and 33.68 g tex^{-1}). Crude fiber (%) was also the maximum in *S. cannabina* (41.41%) and the minimum in *S. sesban* (25.57%). It may, therefore, be concluded that fiber quality of *S. cannabina* was superior to other species and could be possible to blend with other natural fiber for industrial purposes.

Introduction

Natural fibers have superiority upon artificial fibers in many aspects e.g. environment-friendly, biodegradable, renewable, health benefits, etc. To raise global awareness of the importance of natural fibers, the United Nations designated 2009 as the "International Year of Natural Fibers". Bast (/bark) fibers, one of the major sources of natural fibers, are developed in the phloem (inner bark) of dicotyledonous stems like, jute, hemp, flax, ramie, dhaincha, etc. This fiber development is simultaneous with the vegetative growth of the plant (Talukder and Chanda, 2001). Bark fiber yields are ranging between 26-49% of stems weight (Maiti, 1980) and fiber length is increased from 0.98 to 1.34 mm with the increase of harvesting age from 2-6 months. The fiber quality depends on its length and coarseness which increase with the increase of plant harvesting time. Short and thick fiber doesn't produce good surface contact and fiber to fiber bonding (Ogbonnaya *et al.*, 1997; Jahan *et al.*, 2009). Biomass and bark weight may be considered as better selection criteria for yield improvement of the fiber crop.

Three *Sesbania* species *viz.* *S. bispinosa* (Jacq.) W. Wight [former *S. aculeata* (Wild.) Poir.], *S. cannabina* (Retz.) Poir. and *S. sesban* (L.) Merr., are commonly known as "dhaincha" in Bangladesh (Prain, 1903; Sarwar *et al.*, 2015). Dhaincha is an ideal green manure crop; to lesser extents they are grown for animal feed and fodder, ground cover, providing wood, firewood and other uses in traditional agro-forestry systems. The dhaincha fibers are harsh, coarse and shiny in appearance but lack elasticity (Singh and Rani, 2014). Extracted fiber is suitable for nonwoven fabric and it is used for making fish net and rope, carpets, sackcloth, sailcloth and cordages, paper pulp (Jahan *et al.*, 2009; Orwa *et al.*, 2009; Singh and Rani, 2013). In *Sesbania bispinosa,* fiber yield was 9% of whole plant weight and fibers were poor quality and low yield compared to jute (*Corchorus* spp.), kenaf (*Hibiscus* spp.) and *Urena* spp. (Maiti, 1980; Duke, 1983). This present study, therefore, was undertaken to compare the fiber yield, physical and biochemical properties of three indigenous *Sesbania* species at the mature stage of harvest.

Materials and Methods

An experiment was conducted at the field laboratory of Crop Botany Department, Bangladesh Agricultural University, Mymensingh. A randomized complete block design was followed with three replications. The 30 kg ha^{-1} seeds were sown on 23 April, 2016 on each plot (4.0 × 2.5 m^{2}) having 8 rows. Seeds of 38 accessions from three *Sesbania* species *viz.* *S. bispinosa* (28 accessions), *S. cannabina* (4 accessions) and *S. sesban* (5 accessions), were used as experimental materials. Standard management practices were followed. At 120 days age, dhaincha plants were harvested and plants were taken as a bundle weight around 10 kg. Randomly 10 plants were taken from each accession for measurement of plant height, base diameter, plant fresh weight and dry weight of fiber and stick. Harvested dhaincha plants were stacked of 3 days for defoliation of leaves. After defoliation of leaves, dhaincha bundles were retted by steeping in water for 15 days. Then barks (fiber) were separated from stick and thoroughly washed in water. Fibers were sundried on bamboo cross-bar for 5 days. Physical properties of fiber were tested at the Fiber Quality Laboratory of Bangladesh Jute Research Institute, Dhaka following standard procedure. Crude protein, crude fiber, biomass, ash and other major chemical properties were measured at the Laboratories of Department of Animal Science, Bangladesh Agricultural University, Mymensingh and Paper & Pulp Division, Bangladesh Council for Scientific and Industrial Research, Dhaka following standard procedure (Sarkar *et al.*, 2017; Kabir *et al.*, 2018).

Results and Discussion

The maximum plant height was observed in *S. bispinosa* (3.00 m) followed by *S. cannabina* (2.90 m) and the shortest in *S. sesban* (2.41 m) (Table 1). Base diameter was ranged from 0.80-1.14 cm in *S. bispinosa*, 0.74-1.05 cm in *S. cannabina* and 0.86-0.99 cm in *S. sesban*. It might be due to differences in the genetic makeup of *Sesbania* species (Sarwar *et al.*, 2015). The highest amount of green weight was produced in *S. bispinosa* (102.50 g plant^{-1}) followed by *S. cannabina* (98.21 g plant^{-1}) and *S. sesban* (67 g plant^{-1}). Fiber weight varied from 1.11-3.25 g plant^{-1} in *S. bispinosa* followed by 1.08-3.20 g plant^{-1} in *S. cannabina* and 0.80-2 g plant^{-1} in *S. sesban* (Table 1). These indicate that there is a positive correlation between fiber yield and plant height, base diameter and biomass yield of dhaincha species. Fiber yield might also be controlled by the genetic makeup of the species. Duke (1983) reported that fiber yield of *S. bispinosa* varied from 100-1,000 kg ha^{-1}. On contrary, Islam and Ali (2017) opined that dry fiber was 5.5% (4.8-6.8%) of whole plant of jute and allied fiber. The heaviest stick was recorded in *S. bispinosa* (24.83 g $plant^{-1}$) and the lightest in *S. sesban* (11.55 g $plant^{-1}$). Though fiber and stick weight together was the largest in *S. bispinosa* (27.00 ± 4.53 g $plant^{-1}$), the ratio of green weight to fiber and stick weight was highest in *S. sesban* (5.17). These indicate that *S. sesban* has the ability to produce more fiber and stick with relatively smaller amount of green biomass. Again the ratio of fiber weight to stick weight ranged from 9.37-17.31 in *S. bispinosa*, 7.68-12.69 in *S. cannabina* and 6.65-12.26 in *S. sesban* (Table 1). Islam and Ali (2017) reported that dry ribbon were 10.3% (9.5-11.7%) and dry stick was 15.15% (12.5-16.6%) of whole plant of jute and allied fiber.

Table 1. Fiber yield contributing descriptors of *Sesbania* species

Descriptor	*S. bispinosa*	*S. cannabina*	*S. sesban*
Plant Height (m)	3.00±0.48 (2.00-4.10)	2.90±0.70 (1.88-3.40)	2.41±0.42 (1.90-2.92)
Base Diameter (cm)	0.96±0.09 (0.80-1.14)	0.90±0.11 (0.74-1.05)	0.93±0.06 (0.86-0.99)
Green Weight (g $plant^{-1}$)	102.5±16.26 (70.0-135.0)	98.21±12.69 (65.00-131.0)	67.00±9.08 (50.00-84.0)
Fiber Weight (g $plant^{-1}$)	2.18±0.76 (1.11-3.25)	2.14±0.90 (1.08-3.20)	1.40±0.52 (0.80-2.00)
Stick Weight (g $plant^{-1}$)	24.83±4.19 (19.21-30.45)	19.14±5.63 (13.71-24.57)	11.55±2.87 (9.81-13.29)
Fiber & Stick Weight	27.01±4.53 (20.32-33.70)	21.28±4.13 (14.79-27.77)	12.95±3.24 (9.71-15.29)
Green Weight : Fiber & Stick Weight	3.80±0.75 (3.44-4.01)	4.62±1.02 (4.39-4.72)	5.17±1.21 (5.09-5.49)
Fiber Weight : Stick Weight	11.39±4.26 (9.37-17.31)	8.94±3.84 (7.68-12.69)	8.25±3.47 (6.65-12.26)

The physical properties of fibers are important characteristics to evaluate for industrial and domestic uses. The fiber luster was varied among *Sesbania* species, and fiber brightness of *S. cannabina* was better compare to that of *S. bispinosa* and *S, sesban* (Table 2). The numerical variation was 26.17-62.00% in *S. bispinosa*, 49.00-65.00% in *S. cannabina* and 23.80-49.80% in *S. sesban*. Singh and Rani (2013) reported that fiber fineness was 37.36% at 30 days after harvest in *S. aculeata*. Fiber diameter was relatively wider (24.61 ± 5.70 µm) in *S. sesban* and narrower (23.42 ± 2.96 µm) in *S. bispinosa* (Table 2). It may be happened due to the effect of fiber coarseness and thickness of *Sesbania* species. Coarse fibers adversely affect the bursting strength, tensile strength and Young's modulus (Munawar *et al.*, 2007; Kaur and Dutt, 2013). The fiber strength was highest in *S. cannabina* (51.20 ± 4.93 g tex^{-1}.) followed by *S. bispinosa* (48.56 ± 5.93 g tex^{-1}) and *S. sesban* (33.68 ± 7.13 g tex^{-1}). The highest strength of fiber may be due to the presence of higher amount of lignin, fat, wax, etc. which act as cementing materials and high tensile strength. The *Sesbania* fibers can be classified as very strong (https://www.cottoninc.com/cotton-production/quality/us-cotton-fiber-chart/ratings-of fiber-properties/). Linear density of the fiber was decreased due to the loss of hemi-celluloses and it made the cementing capacity of fiber as well as separate out from each other (Ray and Sarkar, 2000). Singh and Rani (2013) found that fiber bundle strength of *S. aculeata* was 15.28 g tex^{-1} at 30 DAS and dhaincha fiber was cylindrical in appearance with rough outlines and a canal (lumen) running though the center. However, the cross sectional microscopic view showed that rectangular or square shapes with the serrated edges.

Table 2. Physical properties of *Sesbania* fibers

Parameter	*S. bispinosa*	*S. cannabina*	*S. sesban*
Fiber Luster (%)	44.93±10.67	53.50±7.68	35.16±9.63
	(26.17-62.00)	(49.00-65.00)	(23.80-49.80)
Fiber Diameter (μm)	23.42±2.96	24.39±3.24	24.61±5.70
	(19.22-31.60)	(20.80-28.40)	(16.86-31.98)
Strength (g tex^{-1})	48.56±5.93	51.20±4.93	33.68±7.13
	(36.06-60.42)	(48.27-56.89)	(22.66-57.35)

Biochemical properties are also considerably different among the *Sesbania* species. The highest biomass (%) was produced in *S. bispinosa* (91.29 ± 2.39) followed by *S. cannabina* (90.67 ± 1.14) and *S. sesban* (90.36 ± 0.71) (Table 3). The mineral nutrients content of *S. sesban* was comparatively better than two other *Sesbania* species. The highest ash (%) was observed in *S. sesban* (9.03 ± 0.86) and the lowest in *S. cannabina* (8.00 ± 1.54). It may happen due to genetic variation among the species. Crude fiber includes indigestible cellulose, pentosans, lignin, and other components of this type present in the experimental materials. The highest crude fiber (%) found in *S. cannabina* (41.41 ± 8.06) followed by *S. bispinosa* (28.95 ± 2.46) and *S. sesban* (25.57 ± 1.68). A wide variation was observed in the crude protein content (10.72-20.64%) among the *S. bispinosa* accessions (Table 3); therefore, there is a possibility to select accessions/genotypes with high crude protein content as animal feed and fodder.

Table 3. Biochemical properties of *Sesbania* species

Composition	*S. bispinosa*	*S. cannabina*	*S. sesban*
Biomass (%)	91.29±2.39	90.67±1.14	90.36±0.71
	(88.49-96.53)	(89.48-92.04)	(89.46-91.04)
Ash (%)	8.50±2.28	8.00±1.54	9.03±0.86
	(4.00-12.98)	(6.98-10.01)	(8.00-10.00)
Crude Fiber (%)	28.95±2.46	41.41±8.06	25.57±1.68
	(25.05-33.25)	(31.00-47.06)	(23.23-26.71)
Crude Protein (%)	16.38±2.46	16.31±1.77	18.22±0.94
	(10.72-20.64)	(14.01-17.78)	(17.10-19.40)
Klason-lignin (%)	23.10±1.73	23.05±0.20	21.97±0.10
	(20.91-26.87)	(22.91-23.19)	(21.87-22.07)
Holo-cellulose (%)	70.19±3.20	70.79±6.63	70.28±0.80
	(66.30-74.55)	(66.10-75.47)	(69.77-71.20)
α-Cellulose (%)	40.97±1.07	40.31±0.81	41.22±1.37
	(39.50-42.27)	(39.74-40.88)	(40.42-42.80)

A little difference was found in the Klason-lignin, Holo-cellulose and α-Cellulose content in the three *Sesbania* species studied (Table 3). Duke (1983) observed that 9.76% pentosan, 16.3% lignin, 85.2% holo-cellulose (63.6% α-cellulose) were present in *S. bispinosa*. Panzhi (1988) found that the lignin amount is 14.06%, pentosan 14.45% and holo-cellulose 73.61% in *Sesbania* species and also added that lignin and pentosan is lower in *Sesbania* than that of in reed and cellules are similar. Differences between holo-cellulose and α-cellulose represent hemicelluloses which are greatly responsible for giving overall strength of fiber

(Rahman *et al.*, 2016). The cellulose content of the fiber was increased while hemicelluloses and lignin content was decreased due to their removal from the fiber (Brindha *et al.*, 2012). Chemical composition of fiber varied due to a great extent between within the species which is affected growth condition and fiber processing method (Mohanty *et al.*, 2000).

The fibers have composite such as structure and consists of stiff crystalline cellulosic micro fibrils as reinforcement held together through lignin, hemicelluloses, waxes and some water soluble extractives (Fengel and Wegener, 1989). Rowell (2005) reported that wood and plant fiber of cellulose act as reinforcement, hemicelluloses and pectin as bonding, lignin for stiffness and wax for use as coating. The rich content of cellulose leads to improve the mechanical properties, however, the low hemi-cellulose content leads to reduce the moisture absorption capacity and in turn increase the thermal stability of the fiber (Raja *et al.*, 2016). The presence of lignin content acts as a bonding agent between the cell wall structures to improve the rigidity and strength of the fiber. Tanmoy *et al.* (2014) reported that jute plants hold three major categories of chemical compounds like cellulose (58-63%), hemi-cellulose (20-24%) and lignin (12-15%), and some other small quantities fats, pectin, aqueous extract, etc. Raja *et al.* (2016) reported that *S. rostrata* fibers showed cellulose content of 64.36%, hemicelluloses 11.25%, lignin 17.19% and ash 1.45%.

Conclusion

Yield contributing parameters like plant height, base diameter, green weight, fiber weight, stick weight significantly differ among the three *Sesbania* species. - Although the differences of physical and biochemical properties of three *Sesbania* species were very close , however, the properties of fiber luster (%), strength (g tex^{-1}) and crude fiber (%) had the highest differences among the three species. It may conclude that the fiber quality of *S. cannabina* was the superior compare to *S. bispinosa* and *S. sesban*. *Sesbania* fibers could be used, like as jute fiber, for blending with other natural fibers which can reduce the cost of an expensive fiber.

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