J Bangladesh Agril Univ 18(3): 585–592, 2020 https://doi.org/10.5455/JBAU.116218

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Influence of Shoot Cutting on Growth Descriptors and Biomass Yield of Dhaincha Plant

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ARTICLE INFO

Article history
Received: 20 Jun 2020
Accepted: 23 Jul 2020
Published online: 01 Sep 2020

Keywords
Plant age,
Cutting height,
Morphological descriptors,
Reproductive descriptors,
Total dry mass

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ABSTRACT

Dhaincha (*Sesbania* spp.), a multipurpose quick-growing, succulent and easily decomposable herb, is an ideal green manure crop. Shoot cutting at a specific height or time might be one of the options for the biomass yield maximization. To evaluate the influence of shoot cutting on morphological and reproductive descriptors and biomass yield, an experiment was carried out with eight dhaincha accessions representing three *Sesbania* species, *viz. S. bispinosa* (Acc #5, 71, 77 and 103), *S. cannabina* (Acc #25, 28) and *S. sesban* (Acc #82 and 85), and three times of shoot cutting at 8, 9 and 10 weeks after sowing (WAS) keeping plant height 25 cm above the ground level. The experiment was laid out on a randomized complete block design with three replications. The results revealed that cutting time had a significant effect on biomass yield and other descriptors; and showed a decreasing trend with delay in cutting treatments. The biomass yield ascended to 37 per cent in cutting at 8 WAS than the uncut control plants. Among the species, *S. bispinosa* responded positively (increase in biomass yield and other descriptors) to the cutting treatments, however, *S.cannabina* and *S. sesban* responded negatively. Accession #77 produced the highest fresh weight (340 g 10^{-1} plants) and biomass yield (190 g 10^{-1} plants) in cutting at 8 WAS and accession #82 and #85 produced the lowest biomass yield in cutting at 10 WAS. The optimum cutting time would be 8 WAS to produce higher biomass of dhaincha. Among the accessions, #77 may be recommended to cultivate as a green manure crop due to its higher biomass yield.

Introduction

Soil organic matter (SOM) is a storehouse of all nutrients required by plants; it supplies a substantial quantity of some macro- and micronutrients for the growing crops (Bot and Benites, 2005). The loss of SOM with cultivation, erosion, or inappropriate soil management practices is a common phenomenon of a crop production system. Under these situations, soil degradation process starts and the soil is no more sustainable for profitable long term agriculture. The SOM is considered to be a key attribute of soil and environmental quality as well (Fageria, 2007); it is involved in and related to many soil physical, chemical, and biological properties. According to the soil related researchers, the presence of organic matter in Bangladesh soil is very low, avg. 1.0-1.5% against the optimum requirement of 5% (Khan, 2018). Green manuring is one of the most effective and environmentally sound methods of adding organic matter and sustaining soil productivity. It improves soil texture and structure, checking soil erosion and soil moisture-holding capacity as well (Heering, 1995a; Fageria, 2007).

The leguminous crop dhaincha (*Sesbania* spp.), being rapid growing, tender and easily decomposable, is one of the best options to grow as green manure crop to improve soil organic matter, productivity and fertility. It produces the maximum amount of organic matter, used to increase the soil health and productivity; it also improves soil texture and structure, checking soil erosion and soil moisture-holding capacity as well (Heering, 1995a; Bunma and Balslev, 2019). Dhaincha fixes atmospheric nitrogen in its root nodules (exception *S. rostrata* in its stem nodules also) through *Sesbania*-*Rhizobium* symbiosis and can be used as animal feed and fodder, ground cover, bio-fuel, raw materials of paper and pulp (Bunma and Balslev, 2019); it has medicinal value and other utilizations—fibre source, weed control, live support fencing, etc. Besides, *Sesbania* is tolerant to stress conditions *viz*. saline, waterlogging, high and low temperatures, and can, therefore, be grown in

Cite This Article
Sarwar, A.K.M.G., Islam, N., Tinne, F.J., Chanda, S.C., Hossain, M.A. 2020. Influence of Shoot Cutting on Growth Descriptors and Biomass Yield of Dhaincha Plant. *Journal of Bangladesh Agricultural University*, 18(3): 585–592. https://doi.org/10.5455/JBAU.116218

unproductive poor soils (Heering and Guttheridge, 1992; Parlawar *et al*., 2003; Bunma and Balslev, 2019). It has been copping ability to high resistance against pests and diseases and easily propagates to the sexual and asexual system (Chanda, 2019). Dhaincha is the most important green manure crop for *in situ* incorporation in rice-based cropping patterns, is known to add 80–100 kg N ha^{-1} per year in the form of green manure (Pandey *et al*., 2013). Decomposed dhaincha helps to mobilize phosphorus, potassium and other trace elements likely to be deficient in the crop root zone (Islam *et al*., 2013; Chanda *et al*., 2020a). Decomposed leaves of dhaincha release a large amount of organic acid which helps to neutralize the soil reaction and nutrients availability in soil. It brings up the nutrients from the deeper soil layer. Besides, it also reduces soil erosion or loss of nutrients leaching (Islam *et al*., 2013).

Three species of *Sesbania*, *viz*. *S. sesban* (L.) Merr., *S. bispinosa* (Jacq.) W. Wight [former *S. aculeata* (Wild.) Pers.] and *S. cannabina* (Retz.) Pers., are commonly known as dhaincha in Bangladesh (Ahmed *et al*., 2009); and these showed a large genetic variation (Sarwar *et al*., 2015; Chanda, 2019). In Bangladesh condition, the main constrain of dhaincha cultivation is the unavailability of lands due to intensive cropping pattern, and it produces only 1.5 t ha^{-1} biomass in a period on 90 days (Bokhtiar *et al*., 2003). Therefore, all sorts of possibilities /operations should be implied to exploit/maximize its biomass yield potential. Shoot cutting at a specific height or time might be one of the options for the biomass yield maximization (Heering, 1995b; Abdul-Baki *et al*., 2001). Dhaincha re-grows rapidly after cutting operation and cutting height also influences yield in dhaincha (El-Morsy, 2009). The plant produces many branches from the main stem below the cutting height. These multi-branched, soft-wooded quick-growing plants are useful for green manure. The cutting operation should be performed before dhaincha stem becomes woody to incorporate into the soil. Although some efforts were given to exploit the biomass yield potential of dhaincha accessions by different cultural practices (Chanda and Sarwar, 2017; Chanda *et al*., 2018, 2020b), hitherto shoot clipping operation had not been practiced in Bangladesh condition. The present research was, therefore, conducted to find out optimum cutting time at a specific height to maximize the biomass yield and to compare the effect of cutting on morphological and reproductive descriptors of dhaincha.

Methodology

Experimental site and soil

The experiment was conducted at the Field Laboratory of Department of Crop Botany, Bangladesh Agricultural University during the period from April to December, 2017. Geographically, the experiment field is located at 24°75″ N, 90°50″ E and an altitude of 18 m above the sea level. The experimental field is medium high land belonging under the agro-ecological zone of old Brahmaputra Flood Plain (AEZ-9) (UNDP and FAO, 1988). The soil was silt-loam, imperfectly to poor drained with slow permeability.

Experimental treatments

Eight dhaincha accessions representing all three *Sesbania* species, *viz. S. bispinosa* (Acc #5, 71, 77 and 103), *S. cannabina* (Acc #25, 28) and *S. sesban* (Acc #82 and 85), were used as experimental materials. Seeds of dhaincha accessions were collected from the Laboratory of Plant Systematics of the same Department. The shoot clipping treatments were implied at 25 cm height above the soil (El-Morsy, 2009) at 8, 9 and 10 weeks after sowing (WAS) with an uncut control.

Field experiment

The experiment was laid out as a randomized complete block design with three replications. The unit plot size was 2.5 m × 4 m. Seeds were sown at 2–3 cm depth in the rows 50 cm apart. The emergence of seedling commenced at 4–5 days after sowing (DAS). Seedlings were thinned to maintain 20 cm distance between two adjacent seedlings. Standard management practice was followed (Chanda, 2019).

Data collection

Final harvesting was done when 80% of pods became mature (at 220–240 DAS). Data were recorded on plant height, base diameter, number of branches, fresh weight and biomass (cutting + final harvest), number of inflorescences $plant^{-1}$, inflorescence length, number of flowers $inflorescences^{-1}$, number of pods $plant^{-1}$, pod length and diameter, and 1000-seed weight.

Data analysis

The collected data were compiled and analyzed statistically following the analysis of variance (ANOVA) technique, using Statistix 10 software package (<https://www.statistix.com/>) to find out the statistical significance of the experiment results. The mean differences were evaluated by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results

Effect of shoot cutting on vegetative descriptors

Shoot cutting of dhaincha at 8, 9 and 10 WAS at 25 cm above the soil surface induced several major morphological changes in comparison to uncut (control) plants. Both shoot cutting and accessions and/or in combination significantly influenced all the vegetative descriptors studied (Table 1). The tallest plant (172.37 cm) and thickest base diameter (11.63 mm) were found in uncut control; the shortest plant (111.90 cm) and lowest base diameter (6.58 mm) was found in cutting at 10 WAS (Figs 1A, C). Among the accessions, the tallest plant (167.29 cm) and thickest base diameter (13.0 mm) were found in accession #77 (Figs 1B, D). On the contrary, the smallest plant (77.92 cm) and the lowest base diameter (6.25 mm) were found in accession #85 and #82, respectively. The plant height was highest in uncut accession #25, the shortest plant height in cutting at 10 WAS in accession #85 (Table 1). The base diameter was the greatest in accession #77 both in control and cutting at 8 WAS condition, and the lowest in accession #82 on cutting at 10 WAS (Table 1).

However, the number of branches plant^{-1}, fresh weight and biomass yield was larger in cut plants than the uncut (control) plants. The highest number of branches plant^{-1} (7.08), fresh weight (260 g 10^{-1} plants) and biomass (86.06 g 10^{-1} plants) were observed in cutting at 8 WAS (Figs 1E, 2A). The smallest number of branches plant^{-1}was found (4.58) in control plants; both the lowest fresh weight (222 g10^{-1}plants) and biomass (66.80 g 10^{-1} plants) in cutting at 10 WAS (data not shown here). The highest number of branches plant^{-1} (7.00), fresh weight (260 g 10^{-1} plants) and biomass (167.50 g 10^{-1} plants) were produced by accession #77 (Figs 1F, 2B). The lowest number of branches plant^{-1}(3.5) and fresh weight (196.25 g 10^{-1} plants) were produced by accession #82, but biomass (46.43 g 10^{-1} plants) in accession #85. The interaction effect of accession #77 and cutting at 8 WAS produced the maximum number of branches plant^{-1}, fresh weight and biomass; the minimum in accession #82 with control and cutting at 10 WAS, respectively (Table 1).

Effect of shoot cutting on reproductive descriptors

There was a significant difference in the number of inflorescences plant^{-1}, length of inflorescence, and the number of flowers inflorescence^{-1} between cut and uncut plants. The highest number of inflorescences plant^{-1} (9.38) and number of flowers inflorescence^{-1} (5.63) was found in plants cutting at 8 WAS and the lowest (6.00 and 4.25, respectively) in cutting at 10 WAS (Fig. 1E). The number of inflorescence plant^{-1} (9.00) and number of flowers inflorescence^{-1} (6.75) was the highest in accession #77 and the lowest (3.5 and 3.83, respectively) in accession #85 (Fig. 1F). The number of inflorescences plant^{-1} was greater in accession #77 for cutting at 8 WAS compared to uncut plants and lower in accession #85 for cutting at 9 WAS and 10 WAS (Table 2). However, the length of inflorescence was longer in uncut plants than the cut plants. The longest length (58.87 mm) of inflorescence was found in control and the shortest (35.75 mm) was found in cutting at 10 WAS (Fig. 1C). Length of inflorescence was the longest (60.25 mm) in accession #77 and the shortest (32.58 mm) in accession #85 (Fig. 1D). The interaction effect of accessions and treatments had also significant influence on the length of an inflorescence. Length of inflorescence was the highest in accession #77 for control compared to cut plants, and the lowest in accession #85 for cutting at 10 WAS (Table 2).

The significant difference was obtained in number of pods plant^{-1}, pod length and diameter, number of seeds pod^{-1} and 1000-seed weight between cut and uncut plants. Number of pods plant^{-1} was greater in cut plants than the uncut plants. The highest number of pods plant^{-1} (9.11), pod length (20.11 cm), pod diameter (2.64 mm), seeds pod^{-1} (31.23) and 1000-seed weight (19.67 g) was found in cutting at 8 WAS plants and all the lowest values were found in cutting at 10 WAS (Figs 1A, C, 2C). Among the accessions, #77 produced the maximum value of all parameters except 1000-seed weight that was the maximum in #85. Number of pods plant^{-1} was the highest (7.16) in #28 and the lowest (3.75) in accession #103 (Figs 1B, D, 2D). Among the interaction effect of accessions and treatments, number of pods plant^{-1}, pod length, pod diameter and number of seeds pod^{-1} were the greatest in accession #77 for cutting at 8 WAS plants compared to uncut plants; and the lowest in accession #85, #103 for cutting at 10 WAS plants compared to all treatments (Table 2). Although, the heaviest 1000-seed weight was obtained from accession #85 and cutting at 8 WAS compared to uncut plants and the lowest in accession #82 for cutting at 10 WAS plants compared to all treatments (Table 2).

Discussion

The morphological and biomass changes induced in dhaincha plants by shoot cutting at 25 cm above soil level are evaluated based on the utilization goal to add the fresh crop as green manure, and/or to compare the effect of cutting on growth and reproductive descriptors of dhaincha. Significant variations were observed in morphological and reproductive descriptors of dhaincha plants after imposing shoot cutting treatments (Tables 1 and 2; Figs 1 and 2). At the maturity stage, plant height, base diameter, inflorescence and pod descriptors, fresh weight and biomass yield were significantly different between uncut control and cut plants. The cutting treatment showed a positive impact on number of branches, inflorescence, flowers and pods plant^{-1} and seeds pod^{-1}; on the contrary, negative impact on plant height, base diameter and inflorescence length (Figs 1 and 2). Accession #77 out-yielded the other accessions throughout the study (Fig. 2B).

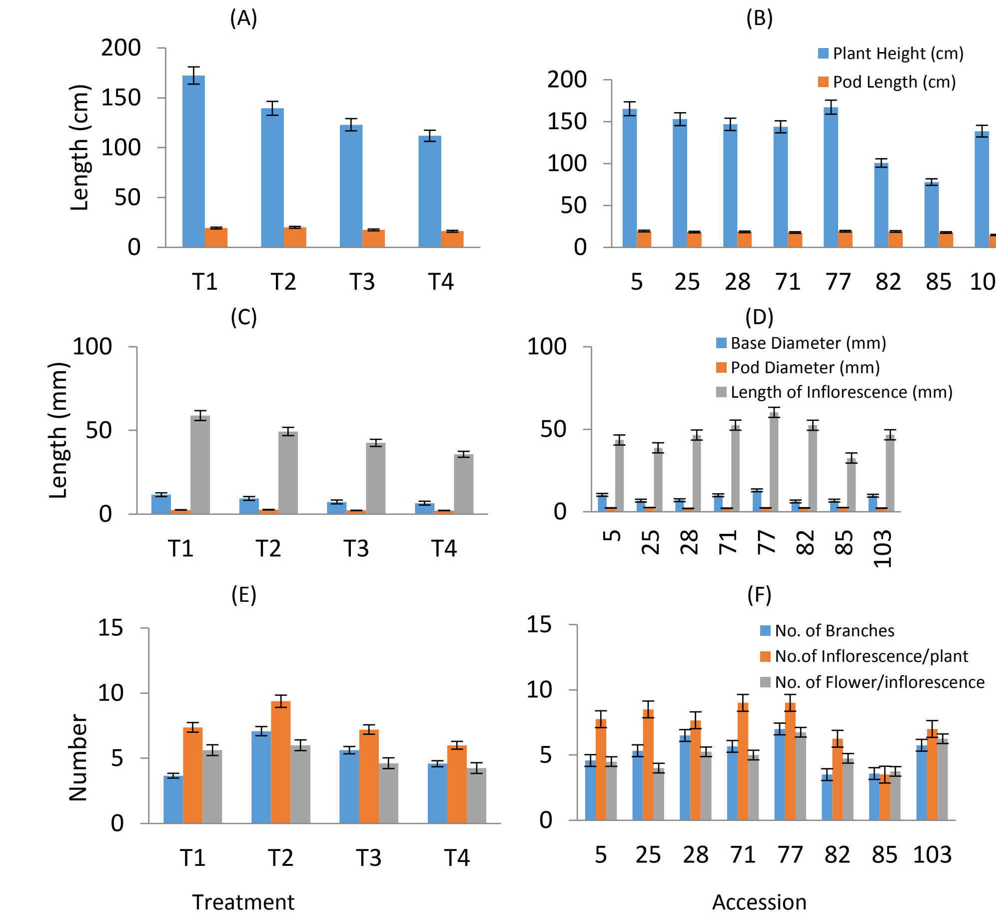

Fig. 1. Effect of shoot cutting on vegetative and reproductive descriptors. A–B. Plant height and Pod length; C–D. Base diameter, Pod diameter and Length of inflorescence; E–F. No. of branches plant^{-1}, No. of inflorescence plant^{-1} and No. of flowers inflorescence^{-1}. T1 Control, T2 Cutting at 8 weeks after sowing, T3 Cutting at 9 weeks after sowing, and T4 Cutting at 10 weeks after sowing. Vertical bar represents SEM (n=3).

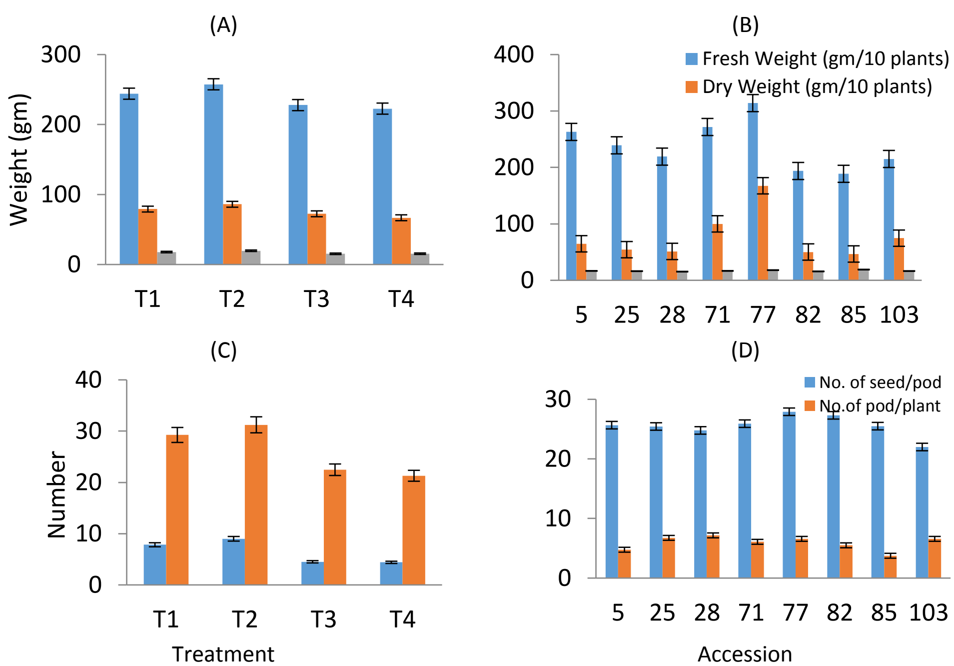

Fig. 2. Effect of shoot cutting on vegetative and reproductive descriptors. A–B. Fresh weight, Biomass and 1000-seed weight; C–D. No. of pods plant^{-1} and No. of seeds plant^{-1}. T1 Control, T2 Cutting at 8 weeks after sowing, T3 Cutting at 9 weeks after sowing, and T4 Cutting at 10 weeks after sowing. Vertical bar represents SEM (n=3).

Table 1. Effect of shoot cutting treatments on growth descriptors in 8 dhaincha accessions at maturity.

Shoot cutting treatment	Accession	Plant height (cm)	Base diameter (mm)	Number of branches plant^{-1}	Fresh weight (g 10^{-1} plants)	Biomass (g 10^{-1} plants)
Control (uncut)	Acc. #05	186.00 b	13.01 b	3.00 g	260.00 i	57.15 r
	Acc. #25	219.67 a	10.00 e	4.00 f	280.00 g	62.52 p
	Acc. #28	174.00 d	9.00 f	5.00 e	250.00 k	68.82 n
	Acc. #71	181.67 c	13.00 b	4.00 f	290.00 f	90.50 i
	Acc. #77	187.33 b	15.00 a	5.00 e	300.00 d	150.00 d
	Acc. #82	141.00 ij	10.00 e	2.00 h	245.00 l	71.50 l
	Acc. #85	108.01 p	11.00 d	2.33 h	220.00 o	62.50 p
	Acc. #103	181.33 c	12.00 c	4.00 f	235.00 n	70.50 m
At 8 weeks after sowing	Acc. #05	174.17 d	12.00 c	6.33 d	280.00 g	78.50 j
	Acc. #25	150.01 h	7.00 h	6.33 d	250.00 k	53.50 t
	Acc. #28	151.01 gh	7.00 h	8.00 b	240.00 m	55.50 s
	Acc. #71	152.67 g	12.00 c	8.00 b	295.00 e	116.50 e
	Acc. #77	183.00 c	15.00 a	10.00 a	340.00 a	190.00 a
	Acc. #82	92.01 q	6.00 i	5.00 e	195.00 s	59.00 w
	Acc. #85	75.67 t	6.00 i	5.00 e	205.00 q	50.00 v
	Acc. #103	137.01 k	10.00 e	8.00 b	255.00 j	95.00 h
At 9 weeks after sowing	Acc. #05	165.17 d	8.00 g	5.00 e	265.00 h	67.50 o
	Acc. #25	125.01 l	5.00 j	6.00 d	215.00 p	50.50 u
	Acc. #28	139.33 j	6.00 i	7.00 c	195.00 s	41.52 x
	Acc. #71	122.01 m	8.00 g	6.00 d	260.00 i	96.95 f
	Acc. #77	156.50 f	12.33 bc	7.00 c	312.33 b	170.00 b
	Acc. #82	89.67 r	5.00 j	4.00 f	185.00 u	41.00 y
	Acc. #85	67.01 u	5.00 j	4.00 f	200.00 r	39.00 z
	Acc. #103	119.33 n	9.00 f	6.00 d	190.00 t	73.00 k
At 10 weeks after sowing	Acc. #05	136.17 k	8.00 g	4.00 f	255.00 j	55.55 s
	Acc. #25	117.01 o	5.00 j	5.00 e	220.00 o	50.50 u
	Acc. #28	122.67 m	6.00 i	6.00 d	200.00 r	39.23 z
	Acc. #71	119.01 n	7.00 h	4.66 e	250.00 k	95.50 g
	Acc. #77	142.33 i	9.66 ef	6.00 d	307.00 c	160.00c
	Acc. #82	80.01 s	4.00 k	3.00 g	160.00 v	39.00z
	Acc. #85	61.00 v	5.00 j	3.00 g	200.00 r	41.23 x
	Acc. #103	117.00 o	8.00 g	5.00 e	190.00 t	60.00q
CV (%)		0.84	4.81	5.95	0.92	0.10

Overall herbage yields were greater at 8 WAS compared to other cutting schedules (Fig. 2A). The variations in different descriptors might broadly be due to genetic make-up of the accessions and/or genera, growing condition, cutting time and height, etc. (Heering, 1995a, b; Veasey *et al.* 1999; Sarwar *et al*., 2015). The shoot cutting at 25 cm above the soil had a significant influence on plant height. Plant height was higher in uncut plants than the cut plants. Chanda *et al*. (2017) reported higher plant height and base diameter from *S. sesban* and the lowest both in *S. bispinosa* and *S. cannabina* at the early stages of growth (10 and 20 DAS). *Sesbania bispinosa* produced both the tallest plant and broadest stem diameter thereafter up to 60 DAS. In this experiment, the tallest plant and highest base diameter were recorded in accession #77 which belongs to the species *S. bispinosa* (Table 1). Veasey *et al.* (1999) found a similar result in *Sesbania* species and reported that the plant heights (mean value of 17 *Sesbania* species) were 8.95, 30.78, 60.55 and 86.07 cm at 17, 32, 47 and 62 DAS, respectively. Similarly in the present study among shoot cutting treatments, the highest plant height was found in the 8 WAS cutting plants. Chanda *et al*. (2017) reported that the highest (average) base diameter was 1.01 cm in *S. bispinosa* and the lowest was 0.85 cm in *S. sesban* when crop harvested at 60 DAS.

The highest shoot fresh weight was also produced by *S. bispinosa* followed by *S. cannabina* and *S. sesban* at 60 DAS (Chanda *et al*., 2017). Similarly, accession #77, belongs to *S. bispinosa*, showed the highest biomass accumulation (Table 1). However, the growth trend of shoot biomass was different in *S. cannabina* and *S. sesban.* Shoot biomass of *S. bispinosa* was doubled from 30 to 40 DAS, tripled from 40 to 60 DAS. In both *S. cannabina* and *S. sesban*, shoot dry weight was increased 3 times from 30 to 50 DAS; and two and a half times between 50 to 60 DAS (Chanda *et al*., 2017). Manh *et al*. (2003) reported that the initial growth of *Moringa oleifera* and some leguminous crops is slow and gradually increases over time. Cutting height can influence biomass yield in *dhaincha* (El-Morsy, 2009). The plant produces many branches from the main stem below cutting height (Table 1). Stem cutting is a very important cultural practice to increase biomass production (Costa *et al*., 1992). Fresh weight and biomass yield were higher in cut plants than the uncut plants and increased up to 37% compared to the control

Table 2. Effect of shoot cutting treatments on reproductive descriptors in 8 dhaincha accessions

Shoot cutting treatment	Accession	Length of inflorescence (cm)	No. of inflorescences plant^{-1}	No. of flowers inflores.$^{-1}$	Number of pods plant^{-1}	Pod length (cm)	Pod diameter (mm)	Number of seeds pod^{-1}	1000-Seed weight (g)
Control (uncut)	Acc. #05	63.00 d	9.00 d	5.67 cd	6.00 ef	21.00 b	2.43 e-h	30.00 cd	17.00 e
	Acc. #25	50.00 l	9.00 d	6.00c	8.33 b	20.67 c	2.63 b-d	26.67 gh	15.00 j
	Acc. #28	64.00 c	8.00 e	5.67 cd	9.00 b	20.00 d	2.33 f-i	30.00 cd	15.50 i
	Acc. #71	62.00 e	9.00 d	5.33 de	7.30 cd	18.00 f	2.4f g-i	27.67 fg	16.00 h
	Acc. #77	71.00 a	6.00 h	7.00 b	7.33 cd	20.00 d	2.67 bc	29.67 d	17.00 e
	Acc. #82	61.00 f	7.00 f	6.00 c	7.00 de	20.00 d	2.58 b-e	35.00 b	15.00 j
	Acc. #85	40.00 o	4.00 j	4.33 f	7.00 de	19.00 e	2.50 c-f	30.00 cd	26.00 a
	Acc. #103	60.00 g	7.00 f	5.33 de	9.33 ab	16.00 h	2.47 d-g	23.00 kl	15.00 j
At 8 weeks after sowing	Acc. #05	53.00 i	11.00 b	6.00 c	5.00 fg	21.00 b	2.4 f-i	31.00 c	18.00 d
	Acc. #25	40.00 o	10.00 c	4.00 f	6.00 ef	18.00 f	2.50 c-f	25.00 ij	13.50 m
	Acc. #28	45.00 n	10.00 c	6.00 c	7.00 de	20.00 d	2.10 j-l	29.00 de	16.00 h
	Acc. #71	55.00 h	11.00 b	5.00 e	7.00 de	19.00 e	2.20 i-k	28.00 ef	18.00 d
	Acc. #77	65.00 b	12.00 a	8.00 a	10.33 a	22.00 a	3.27 a	37.00 a	20.00 c
	Acc. #82	52.00 j	7.00 f	5.00 e	6.00 ef	20.00 d	2.50 c-f	29.00 de	15.00 j
	Acc. #85	35.00 q	4.00 j	4.00 f	4.00 g	19.00 e	2.00 b	22.00 lm	17.00 e
	Acc. #103	50.00 l	10.00 c	7.00 b	9.00 b	16.00 h	2.30 g-i	24.00 jk	17.00 e
At 9 weeks after sowing	Acc. #05	32.00 r	7.00 f	4.00 f	4.00 g	19.00 e	2.31 g-i	22.00 lm	16.00 h
	Acc. #25	35.00 q	8.00 e	3.00 g	5.00 fg	18.00 f	2.40 f-h	21.0 mn	15.00 j
	Acc. #28	45.00 n	6.67 g	5.00 e	6.00 ef	17.00 g	2.05 kl	20.00 no	15.00 j
	Acc. #71	53.00 i	8.00 e	5.00 e	5.00 fg	18.00 f	2.00 l	22.00 lm	16.60 f
	Acc. #77	55.00 h	10.00 c	6.00 c	5.00 fg	18.00 f	2.20 i-k	25.00 ij	18.00 d
	Acc. #82	50.67 k	6.00 h	4.00 f	5.00 fg	19.00 e	2.30 g-i	24.00 jk	14.00 l
	Acc. #85	30.00 s	3.00 k	4.00 f	2.00 h	17.00 g	2.26 h-j	25.00 ij	17.00 e
	Acc. #103	40.00 o	9.00 d	6.00 c	4.00 g	14.00 i	2.00 l	21.0 mn	17.00 e
At 10 weeks after sowing	Acc. #05	26.00 t	4.00 j	3.00 g	4.00 g	17.00 g	2.31 g-i	21.00mn	15.50 i
	Acc. #25	30.00 s	7.00 f	3.00 g	5.00 fg	16.00 h	2.40 f-h	19.00 o	14.40 k
	Acc. #28	32.00 r	6.00 h	4.00 f	6.00 ef	17.00 g	2.00 l	20.00 no	15.00 j
	Acc. #71	40.00 o	7.00 f	5.00 e	5.00 fg	16.00 h	2.00 l	26.00 hi	16.00 h
	Acc. #77	50.00 l	9.00 d	6.00 c	5.00 fg	17.00 g	2.10 j-l	22.00 lm	17.00 e
	Acc. #82	46.00 m	5.00 i	4.00 f	4.00 g	17.00 g	2.10 j-l	19.00 o	13.00 n
	Acc. #85	25.33 u	3.00 k	3.00 g	2.00 h	16.00 h	2.27 h-j	25.00 ij	16.00 h
	Acc. #103	36.67 p	7.00 f	6.00 c	4.00 h	13.00 j	2.00 l	19.00 o	16.50 g
CV (%)		0.54	1.36	6.01	10.00	0.56	2.30	2.90	0.19

In a column, figures bearing dissimilar letter differ significantly at 5% level of significance.

(calculation not shown here). Fresh weights of all eight accessions were higher in plants cut at 8 WAS than the other cutting treatments due to the influence of cutting time on growth stage. Cutting management has a very important consequence of the productivity of perennial *Sesbania* species (El-Morsy, 2009). For incorporation into the soil as green manure, the practices that produce highest yields of high-quality biomass i.e., low C/N ratio and decomposition within a reasonable period, are most desirable (Abdul-Baki *et al*., 2001). Dhaincha stem becomes woody at or after 60 DAS (Chanda, 2019); therefore, incorporation of dhaincha (shoot cutting) at the age of 8 WAS is also desirable for rapid decomposition. Cutting time had a significant effect on biomass yield. Biomass yield decreased as the cutting time increased from days after sowing. The highest biomass production was found in cutting at 8 WAS plants of accession #77 than the other cutting treatments. A similar result was found by Hare *et al*. (2013). Heering (1995b) observed the effect of cutting height of six *S. sesban* accessions and stated that most accessions reached their maximum production before or at the second re-growth and biomass yields decrease rapidly thereafter. Biomass production in many agroforestry species has been related to reserve carbohydrates which are major influential factors of biomass production in plants (Partey, 2011); although this experiment did not investigate the dynamism in reserve carbohydrates and soluble sugar with increasing pruning frequency, it might be a topic of future research.

Pod length, pod diameter, number of seeds pod^{-1} and 1000-seed weight were higher in cut plants than the uncut plants due to cutting allows plants growth rapidly (Nautiyal and Venhataraman, 1987). Similarly, in this experiment pod length, pod diameter, number of seeds pod^{-1}were recorded higher in cut plants which were given at 8 WAS in accession #77 than the other cutting treatments (control, cutting at 9 and 10 WAS) and accessions (Figs 1 and 2). The 1000-seed weight was also significantly higher in accession #77 followed by other cutting treatments and accessions. Accession #77 performed better in cutting at 8 WAS might be due to higher re-growth capability at the earlier stages which positively influenced the number of branches and seed yield as well. A similar increase in biomass yield was reported for other legumes (Hossain *et al*., 2006; Jahan *et al*., 2012) and forage grasses (Bhatt *et al*., 2009; Hadi *et al*., 2012). However, no clear trend was noted in the effects of cutting on reproductive morphological descriptors (Table 2). These reproductive descriptors might principally be governed by the genetic make-up of the accessions.

Among the species, *S. bispinosa* (4 accessions) responded positively (increase in biomass yield and other descriptors) to the cutting treatments, however, *S. cannabina* (2 accessions) and *S. sesban* (2 accessions) responded negatively (Tables 1 and 2). The results contradict with the previous results of Veasey *et al.* (1999), who reported an increase in biomass yield along with other morphological descriptors among all the studied *Sesbania* species including *S. sesban*. One of the major causes could be that they had cultivated *S. sesban* as a perennial crop and the cutting interval was 4 months. On the other hand, we cultivated *S. sesban* as an annual crop; the cutting treatment followed by flowering and plants did not receive any recovery period. Other causes might be the genetic variations among the accessions (Brazil vs. Bangladesh), taxonomic position (i.e., different sub-species), environmental factors, etc.

Conclusion

We conclude that accessions belong to the species *S. bispinosa* responded positively to shoot cutting treatments, other accessions (of two other species) performed negatively. Shoot cutting at 25 cm above soil surface when plants are 8 weeks days, produces a high yield of quality biomass with a large amount of foliage and tender branches for incorporation as green manure. Further studies based on different cutting heights and plant ages might be helpful for a clear understanding of biomass yield potential of these accessions. Shoot cutting induces more primary and secondary branches and subsequently yields the largest number of flowers plant^{-1} and seed yield as well. Among the accessions, #77 may be recommended to cultivate due to higher biomass yield. Possible variation(s) in the nutritional quality, both as green manure and animal fodder, of additional biomass due to shoot cutting might be a topic of future research.

Acknowledgements

We are thankful to Ministry of Science and Technology, Government of the People's Republic of Bangladesh for “National Science and Technology Fellowship” (to N.I., F.J.T. & S.C.C.) and a research grant (No-49.119.113.12.11.168.3126-3127/933/BS-233) during the period of this study.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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