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Morphological and Physiological Characterization of *Sesbania* genotypes

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ABSTRACT

Background: *Sesbania* species are widely used in different agricultural systems providing green manure, forage, firewood, pulp, food, landscape decoration, control of soil erosion and soil improvement. The biomass yield and yield contributing descriptors of *Sesbania* depend on different physiological traits.

Method: An experiment was conducted at Bangladesh Agricultural University to find out the morphological and physiological variability among four *Sesbania* genotypes. *Sesbania* species, *viz*. *S. bispinosa, S. cannabina*, *S. sesban* and *S. rostrata*, were used as experimental materials. Seeds were sown in 2.5 m × 2.0 m plots to maintain 200 plants m^{-2} following randomized complete block design with three replications. Seed length and width, 1000-seed weight, germination percentage, vigour index, seedling length and biomass yield parameters were recorded. Different growth data were recorded and physiological descriptors were calculated at every 10 days intervals up to 60 days after sowing (DAS).

Result: The results revealed that the highest value of plant height, number of leaflets pair $leaf^{-1}$, leaf length and biomass yield were found in *S. bispinosa* and the lowest in *S. sesban* at 60 DAS. *Sesbania sesban* produced higher biomass and studied growth descriptors up to 20 DAS and thereafter declined, however, other three species produced higher biomass and studied growth descriptors from 30 to 60 DAS.

Key words: CGR, Morphology, RGR, Root-shoot ratio, *Sesbania*, Shoot weight ratio.

INTRODUCTION

The genus *Sesbania* L., belongs to sub-family Papilionoideae, family Leguminosae, consists of *ca*. 60 species encompassing annuals, perennials, herbs, shrubs and trees (Evans, 1990). Being a member of legume crops, *Sesbania* capable to fix nitrogen in the soil through Legume-*Rhizobium* symbiosis, improves soil organic matter status and other uses for fodder, fuel, wood, firewood, mulch, ground cover and others in traditional agroforestry (Kalpana *et al*., 2002; Porpavai *et al*., 2005; Takawale *et al*., 2016; Chanda, 2019). In Bangladesh, five species of *Sesbania viz*. *S. sesban* (L.) Merr., *S. bispinosa* (Jacq.) W. Wight [former *S. aculeata* (Wild.) Poir], *S. cannabina* (Retz.) Poir., *S. grandiflora* (L.) Poir. and *S. javanica* Miq., are found. However, *S. sesban*, *S. bispinosa* and *S. cannabina* are commonly known as dhaincha in Bangladesh (Prain, 1903; Ahmed *et al*., 2009). Among these, *S. bispinosa* is the prominent one (Chanda *et al*., 2019). An exotic species *S. rostrata* Bremek. and Oberm., commonly known as African dhaincha, is also used as a green manure crop; although the germination percentage of seeds of this species is comparatively lower than that of indigenous dhaincha species. The establishment of a plant depends on ecological perception and increase of initial growth, relative growth rate and plant physiological processes. Quick initial growth is often associated with a shorter lifespan, or alternatively, genotypes that are characterized as slow starters usually have a longer lifespan. The first one may be suitable when anticipating shorter lifespan (Larcher, 1995). Growth parameters include plant height and girth as the most applicable parameters for determining the genotypes potential for suitable plant growth (Lamers *et al*., 2006). Assortment of improved genotypes possesses plant morphology, physiology and agronomic uniformity (Aguirre *et al*., 2003). Within a population has great variability in growth habit, color of leaf, flowers, pod and seed (Berrocal *et al*., 2002). The biomass yield and yield contributing parameters depend on some physiological traits. Morphological and physiological basis differentiate the yield among the genotypes of *Sesbania*.

Crop growth and development and pertinent variables are necessary to quantity for crop improvement. Variation in biomass accumulation in diverse genotypes is correlated to several factors *viz*. leaf area (LA), crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR) and root-shoot ratio (Malek *et al*., 2012). Crop growth,

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physiological descriptors *viz*. CGR, NAR, RGR and LA and yield varied among the varieties (Pandey *et al*., 1978). Canopy photosynthesis rate is determined through LAI, CGR and the optimum LAI and NAR afford higher biological yield (Mondal *et al*., 2007). The CGR and RGR measure the increase in biomass with a given amount of assimilatory material at a given point/period (Rajput *et al*., 2017). The capability of efficient biomass partitioning between the vegetative and reproductive parts produces high economic yield (Shiraiwa *et al*., 2004; Oh *et al*., 2007). A better understanding of crop development and biomass yield attributing characters and the partitioning of assimilates into biomass yield improvement of green manure crops. Very little work has been done in this regard in *Sesbania* in tropic areas. A detailed analysis of biomass partitioning with respect to morphology and physiology of four *Sesbania* genotypes was, therefore, undertaken.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at Field and Plant Systematics Laboratories of the Department of Crop Botany, Bangladesh Agricultural University during April to July, 2016 to find out the variability in morphology and physiological features of four *Sesbania* genotypes. Geographically it is located at 24° 75′ N latitude and 90° 50′ E longitudes at the elevation of 18 m above the sea level (UNDP and FAO, 1988). The initial soil of the Field was analyzed and had the following characters: pH 5.82, organic matter 1.53%, total nitrogen 0.09%, phosphorus 3.66 ppm, potassium 0.15 meq/100g, Sulfur 2.51 ppm.

Laboratory experiment and germination test

A total of four genotypes from four *Sesbania* species *viz*. *S. cannabina* (Accession #28), *S. bispinosa* (Accession #71), *S. sesban* (Accession #81) and *S. rostrata* (Accession #105), were used as experimental materials. The observations like seed length and width, 1000-seed weight, germination percentage, vigor index, seedling length and biomass yield were recorded. The experiment was laid out in a completely randomized design with four replications. From each genotype, 50 healthy seeds were spread uniformly on each Petri-dish using filter paper as medium of growth. Cumulative germination (CG) percentage of seeds was counted daily up to 10 days (Bewley and Black, 1994).

$$CG\% = \frac{\sum n}{N} \times 100$$

Where

n is the number of seeds germinated at each day and N is the total number of seeds sown.

Vigor index (VI) was calculated based on the percentage of seed germination and mean length of shoot and root (Sreelalitha *et al*., 2015).

VI= (Mean shoot length + Mean root length) × Germination percentage

Field experiment, design and crop establishment

The experiment was laid out in randomized complete block design with three replications. *Sesbania* seeds were sown in four lines of 2. 5 m × 2.0 m plots with a spacing of 50 cm (row-row) × 15 cm (plant-plant) to maintain 200 plants m^{-2}. Data on different morphological and physiological growth parameters were recorded at every 10-day intervals up to 60 days after sowing (DAS).

Data measurement on plant growth parameters

Plant morphological descriptors were collected from 60 days old plants. Morphological attributes were measured with a ruler and using a digital slide callipers with a precision of 0.1 to 150 mm. The morphological descriptors *viz*. length of shoot, root, base diameter, number of leaves $plant^{-1}$, internodes number $plant^{-1}$, inter-node length, leaf length and leaf width were measured.

Data collection on biomass production

Ten plants from each plot were carefully uprooted and roots were cleanly washed in water. The root and shoot portions were separated. The samples were air dried and subsequently oven dried at 72°±2°C for 72 hours to constant weight. Biomass accumulation study was carried out at 10 days interval from 10 DAS to 60 DAS. Following growth studies were made using the prescribed formulae:

The biomass accumulation of the crop per unit area per unit of time is referred to crop growth rate (CGR), expressed as g m^{-2} d^{-1}. The mean CGR values for the crop during the sampling intervals were computed using the formula of Brown (1984):

$$CGR = \frac{W_2 - W_1}{SA\,(t_2 - t_1)}\ g\ m^{-2}\ d^{-1}$$

Where,

W_1 = Total biomass of plant at time t_1

W_2 = Total biomass of plant at time t_2

SA = Ground area occupied by the plant at each sampling.

The relative growth rate at which a plant incorporates new material into its sink is measured by relative growth rate (RGR) of biomass accumulation and is expressed in g g^{-1} d^{-1}. The RGR was worked out by following the formula of Radford (1967):

$$RGR = \frac{\log W_2 - \log W_1}{t_2 - t_1}\ g\ g^{-1}\ d^{-1}$$

Where ,

W_1 and W_2 is initial and final biomass weight at the time t_1 and t_2, respectively, log refers to natural Logarithm.

Root-shoot ratio (RSR) is the ratio of root biomass and shoot biomass.

$$RSR = \frac{\text{Root biomass}}{\text{Root biomass}}$$

Shoot weight ratio (SWR) is the ratio of shoot biomass and total biomass.

$$SWR = \frac{\text{Shoot biomass}}{\text{Total biomass}}$$

Data analysis

The collected data were analyzed with Excel application to determine the arithmetic mean, standard deviation, coefficient of variance and range among the accessions (*de* Melo *et al*., 2016).

RESULTS AND DISCUSSION

Seed and seedling morpho-physiological characters

Variations in seed length and width, 1000-weight, seedling length, vigor index and biomass production were observed in different *Sesbania* genotypes (Table 1). The highest seed length was found in *S. bispinosa* (3.81 mm) and the lowest in *S. rostrata* (3.37 mm), however, the highest seed width was observed in *S. sesban* (2.93 mm) and the lowest in *S. bispinosa* (2.07 mm). Chanda *et al*. (2018) reported that cylindrical-shaped seed (*S. bispinosa* and *S. cannabina*) of *Sesbania* species showed the longest seed length and rectangular-shaped seed (*S. sesban* and *S. rostrata*) showed the shortest seed length. The maximum 1000-seed weight and germination (%) was found in *S. sesban* (21.5 g) and *S. bispinosa* (85%), respectively; however, the lowest value was in *S. cannabina* (13.6 g) and *S. rostrata* (26%), respectively (Table 1). Seed germination depends on the reserve food in seed, nutrients, environmental factors and genetic makeup (Gan *et al*., 1996; Marcos-Filho, 2005). The longest seedling length was produced in *S. sesban* (16.21 cm) and shortest in *S. rostrata* (8.06 cm) at 10 days after sowing (DAS). The results revealed that initial growth rate of *S. sesban* was higher than those of other three *Sesbania* species. The highest vigour index was found in *S cannabina* (1115) followed by *S. bispinosa* (1094), S. *sesban* (1054) and *S. rostrata* (210). Maximum biomass was produced in *S. sesban* (0.020 g plant^{-1}) and minimum in *S. rostrata* (0.007 g plant^{-1}) at 10 DAS (Table 1).

Morphological parameters

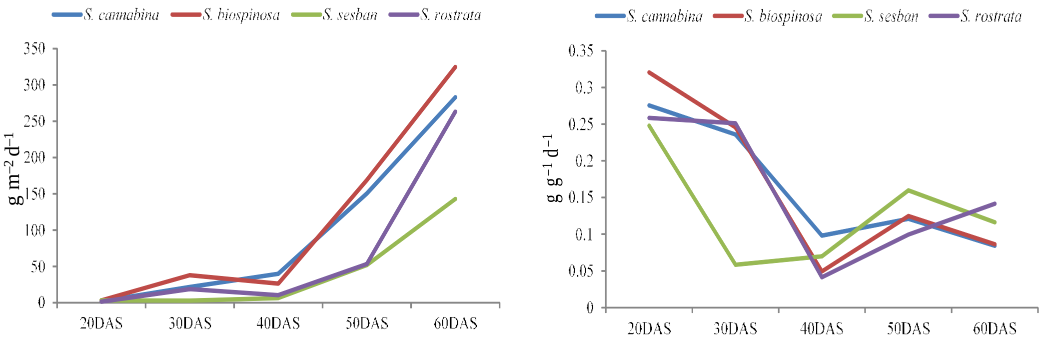
The tallest plant was attained in *S. bispinosa* (209 cm) and the shortest in *S. sesban* (120 cm) at 60 DAS (Table 2). The base diameter varied from 0.83 to 1.25 cm. The highest internode number plant^{-1} was found in *S. cannabina* (36) followed by *S. bispinosa* (34), *S. rostrata* (29) and *S. sesban* (20). The inter-node length was longest in *S. rostrata* (5.8 cm) and shortest in *S. cannabina* (3.8 cm). Plant height, base diameter, number of leaves plant^{-1}, inter-node number and length may be varied due to their genetic makeup of the genotypes. The maximum number of leaves plant^{-1} was recorded in *S. cannabina* followed by *S. bispinosa*, *S. rostrata* and *S. sesban* (Table 2). The highest number of leaflets pair leaf^{-1} was 44 in *S. bispinosa* and lowest was 25 in *S. sesban* at 60 DAS. The number of leaflets pair leaf^{-1} could be used as one of the most important vegetative descriptors for *Sesbania* species identification. Chanda *et al*. (2019) supported these results. The longest leaf was 39.2 cm and the shortest was 23.8 cm in *S. bispinosa* and *S. sesban*, respectively. The highest leaf width was *S. rostrata* (8.1 cm) and the lowest was *S. cannabina* (5.5 cm). The longest leaflet was 4.3 cm in *S. bispinosa* and the lowest was 2.08 cm in *S. cannabina* (Table 2). The broadest leaflet width was found in *S. rostrata* (0.68 cm) and thinnest was in *S. cannabina*. The leaflet pairs per leaf, length and width of leaf and leaflets length and width have emerged as

Table 1: Seed and seedling characteristics of four *Sesban*ia species.

Parameters	*S. cannabina*	*S. bispinosa*	*S. sesban*	*S. rostrata*
Seed length (mm)	3.79±0.19	3.81±0.16	3.64±0.18	3.37±0.24
Seed width (mm)	2.31±0.21	2.07±0.21	2.93±0.235	2.54±0.31
1000-wieght (g)	13.6±1.58	14.5±2.24	21.5±2.92	18.9±2.55
Germination (%)	82±2.92	85±3.81	65±4.12	26±1.91
Seedling length at 10 days (cm)	14.09±2.74	12.87±2.28	16.21±3.16	8.06±1.58
Vigor index	1155±72	1094±79	1054±81	210±22
Biomass at 10 days (g plant^{-1})	0.008±0.001	0.008±0.001	0.020±0.001	0.007±0.001

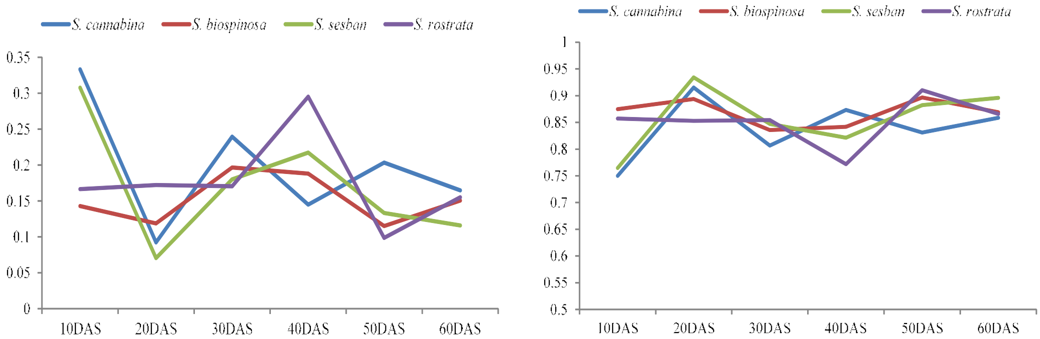
Table 2: Morphological descriptors (Mean ± SE) of four *Sesbania* genotypes at 60 days after sowing.

Morphological traits	*S. cannabina*	*S. bispinosa*	*S. sesban*	*S. rostrata*
Plant height (cm)	170±7.27	209±8.85	120±2.53	165±6.01
Base diameter (cm)	1.18±0.05	1.24±0.05	0.83±0.05	1.25±0.05
Inter-node number plant^{-1}	36±1.17	34±1.12	20±0.50	29±0.74
Inter-node length (cm)	3.8±0.28	4.4±0.24	4.1±0.12	5.8±0.29
Number of leaves plant^{-1}	33±1.30	29±1.12	16±0.52	25±0.72
Number of leaflet pairs leaf^{-1}	33±0.15	44±0.44	25±0.61	27±0.55
Leaf length (cm)	25±0.44	39±1.04	24±1.12	32±0.97
Leaf width (cm)	5.5±0.07	7.9±0.08	6.9±0.18	8.1±0.32
Leaflet length (cm)	2.1±0.02	4.3±0.24	3.0±0.09	3.7±0.19
Leaflet width (cm)	0.20±0.01	0.51±0.03	0.48±0.02	0.68±0.03
Leaf angle with stem (0^{o})	59±1.38	54±2.06	68±1.02	72±1.72
Biomass (g plant^{-1})	27.63±1.43	31.19±1.67	11.55±0.51	19.30±1.13



(a) CGR　　(a) RGR

Fig 1: (a) Crop growth rate (CGR) and (b) Relative growth rate (RGR) of four *Sesbania* genotypes at different dates after sowing.



(a) Root-Shoot ratio　　(a) Shoot weight ratio

FIG 2: (a) Root-shoot ratio and (b) Shoot weight ratio of four *Sesbania* genotypes at different dates after sowing.

descriptors of taxonomic importance (Heering *et al*., 1996; Joshi-Saha and Gopalakrishna, 2007). The leaf angle with stem varied from 54-72° at 60 DAS.

The highest biomass (31.19 g plant^{-1}) was produced in *S. bispinosa* followed by *S. cannabina* (27.63 g plant^{-1}), *S. rostrata* (19.30 g plant^{-1}) and *S. sesban* (11.55 g plant^{-1}) at 60 DAS (Table 2). The biomass production might be depending on plant height, base diameter, number and length of inter-node of the genotype. It appeared that *S. bispinosa* was more efficient for biomass production compared to *S. cannabina*, *S. rostrata* and *S. sesban*. Chanda *et al*. (2017) reported that *S. bispinosa* produced the maximum plant height, number of branches plant^{-1}, inter-node number and length as well as biomass compared to *S. cannabina* and *S. sesban*.

Physiological parameters

Crop growth rate, relative growth rate, root-shoot ratio and shoot weight ratio were significantly varied among four *Sesbania* genotypes (Fig 1 and 2). Up to 20 DAS, all physiological parameters were higher in *S. sesban* and thereafter declined. Chanda *et al*. (2017) reported *S. sesban* produced higher biomass at the early growth stages (up to 20 DAS) comparatively that of the other two species. After 20 DAS, it produced lower biomass compared to *S. bispinosa* and *S. cannabina*. On the other hand, *S. bispinosa*, *S. cannabina* and *S. rostrata* showed initially growth rate was lower (up to 20 DAS) and it was increased up to 60 DAS compared to *S. sesban*. Chanda *et al*. (2017) further reported that *S. bispinosa* produced the highest biomass yield followed by *S. cannabina* and *S. sesban* at 30 to 60 DAS. Therefore, cultivation of *S. sesban* can be suggested in a very short rotation [*Boro* rice-(*dhaincha*)-Jute-T. *Aman* rice-Mustard and/or *Boro* rice-(*dhaincha*)-T. *Aus* rice-T. *Aman* rice-Mustard] and *S. bispinosa* for a longer period [*Boro* rice-(*dhaincha*)-T. *Aman* rice-Mustard/Winter vegetables] to add maximum organic matter to the soil.

CONCLUSION

Result from the experiment revealed that maximum morphological parameters showed higher value in *S. bispinosa* compared to *S. cannabina*, *S. rostrata* and *S. sesban*. However, *S. sesban* produced higher physiological growth parameters up to 20 DAS and thereafter it declined. On the other hand, *S. bispinosa*, *S. cannabina* and *S. rostrata* produced higher physiological growth parameters from 30 to 60 DAS.

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